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The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: RCT design, feasibility, and acceptability testing

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The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: RCT design, feasibility, and acceptability testing

By

Nesibe Cakmak

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At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without the prior agreement of the Doctoral College Quality Sub-Committee.

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Abstract

Nesibe Cakmak

The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: RCT design, feasibility, and acceptability testing

Background: Dual-task training (DTT), utilized in motor-motor (M-DTT) and/or cognitive-motor (C-DTT) forms, has been identified as an effective and safe approach to improve balance in people with Parkinson's disease (pwPD). Studies which investigate the superiority of the effectiveness of M-DTT and C-DTT interventions, however, are lacking. To determine superiority there is a need to design a randomized control trial (RCT). This PhD study, therefore, had two aims. Firstly, to design home-based M-DTT and C-DTT interventions for improving upright balance in people with mild to moderate PD. Secondly to test the feasibility and acceptability of the interventions, outcome measures, and the design of an anticipated future RCT to investigate the superiority of the effectiveness of these DTT interventions on balance.

Methods: Three linked work packages (WP) were implemented:

WP1- Scoping review to inform the proposed feasibility RCT in terms of the content and combination of DTT interventions and outcome measures used to treat balance impairments in pwPD.

WP2- A pre-trial stage qualitative study was held using semi-structured individual interviews and focus groups with six pwPD, two supporters of pwPD, and two physiotherapists to inform intervention design and balance assessment methods of the feasibility RCT. Transcribed data were analysed using the framework analysis method.

WP3- A feasibility RCT of six people with mild to moderate PD tested the acceptability and the feasibility of the home-based, non-supervised M-DTT and C-DTT interventions and the trial design. Interventions were delivered as 30-minute-sessions, three times/week over 6 weeks. Qualitative research (semi-structured interviews post-intervention) was embedded into the feasibility trial. Feasibility outcomes were attendance and adherence to the intervention and safety (by recording of adverse events and number of falls/near falls).

Acceptability of interventions were assessed with twice-weekly 5-point Likert scale, self-scored enjoyment and difficulty, and interviews. Acceptability of overall trial design was assessed with interviews. Signals of effectiveness of each intervention on balance function were assessed using the MiniBESTest and body sway data.

Results: WP1 – The scoping review showed that the delivery form of DTT, task combinations and task types within DTT, training characteristics and the balance assessment methods used for evaluation varied. Only one qualitative study explored participants' perceptions regarding DTT interventions, confirming the need for further qualitative studies. One study, which had methodological limitations, explored the superiority of M- DTT and C-DTT in improving balance in pwPD. Therefore, there is a clear need for further studies to determine any difference between M-DTT and C-DTT with regard to balance outcomes in these individuals.

WP2 – The qualitative findings showed that the acceptability of DTT is influenced by factors such as enjoyment and level of task challenge. Home setting was considered acceptable if the right number of sessions and session durations were provided. Despite the inconvenience of travel, pwPD found face-to-face assessments in a research clinic acceptable.

WP3 – The feasibility study results indicate that both M-DTT and C-DTT are safe. Attendance and adherence rates were high. Both interventions were acceptable, although improvements are required in the content and technical aspects of the training programs/session movies. The assessments were generally well-received and acceptable. No statistical analysis for balance-related data was conducted due to the small sample size and imbalance between groups. On an individual level, both M-DTT and C-DTT demonstrated promising effects on the MiniBESTest and standing balance. While M-DTT led to improved MiniBESTest scores, neither group exhibited a clinically meaningful change in MiniBESTest outcomes.

Conclusions: The findings from each work-package provide important information to inform a future powered RCT investigating superiority of two DTT interventions.

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Abbreviations

ACh: Acetylcholine

AP: Anteroposterior direction

APA: Anticipatory Postural Adjustment

BBS: Berg Balance Scale

BoS: Base of Support

C-DTT: Cognitive-motor dual-task training

CoG: Centre of Gravity

CoM: Centre of Mass

DBS: Deep Brain Stimulation

DTT: Dual-task training

GP: External globus pallidus

GPi: Internal globus pallidus

H&Y: Hoehn and Yahr Scale

JBI SUMARI: Joanna Briggs Institute System for the Unified Management of the Assessment and Review of Information software

MDS-UPDRS: Movement Disorder Society Unified Parkinson Disease Rating Scale

M-DTT: Motor-motor dual-task training

MiniBESTest: Mini Balance Evaluation System Test

ML: Mediolateral direction

MMSE: Mini Mental State Examination

MRC: The UK Medical Research Council

PD: Parkinson's disease

PwPD: People with Parkinson's disease

RCT: Randomised control trial

SC: Superior colliculus

SNc: Substantia nigra pars compacta

SNr: Substantia nigra pars reticulata

STN: Subthalamic nucleus

STN-DBS: Application of deep brain stimulation on subthalamic nucleus

STT: Single task training

TUG: Timed Up and Go Test

WP: Work package of PhD

Chapter 1- Introduction

1.1 Overview

Parkinson's disease (PD) is the fastest-growing neurological condition worldwide (Okunoye et al., 2022). The incidence of PD in a large UK primary care database was found stable according to the broadest case definition of PD (PD diagnosis OR symptom OR at least one prescription of antiparkinsonian medication) between 2006 and 2016 (Okunoye et al., 2022). Although this study suggested that there is no increase in incidence of PD in UK, the number of PD cases projected to double from approximately 7 million in 2015 to about 13 million in 2040 in worldwide (Collaborators., 2018). This future estimate underscores the substantial burden that PD may impose on society (Jankovic and Tan, 2020).

People with PD (pwPD) can manifest symptoms at various stages and experience diverse impacts. The diagnosis is typically delayed due to an initial asymptomatic phase (Vaartio-Rajalin et al., 2019), resulting in different limitations in daily activities and reduced quality of life upon diagnosis (Hariz and Forsgren, 2011). Postural instability and balance problems represent two of the most disabling motor features of PD, playing a pivotal role in the progressive deterioration of their independence (Carpinella et al., 2017).

This introduction chapter focuses on:

(i) Features of PD and disease pathophysiology: Exploring the distinctive characteristics of PD and understanding its underlying pathophysiological mechanisms.

(ii) Balance dysfunction and its management in PD: Investigating the challenges associated with balance in PD and examining strategies for effectively managing balance problems in individuals with Parkinson's disease.

(iii) Dual-Task Training (DTT) for balance rehabilitation in PD: Exploring the concept of dual-task training as a method for enhancing balance in pwPD.

(iv) Study Aim and Structure: Clearly outlining the objectives of the study and providing an overview of the organizational structure of the research.

1.2 What is Parkinson's disease?

PD is a chronic neurodegenerative condition marked by the degeneration of dopaminergic neurons in the substantia nigra. This degeneration results in diminished dopamine levels in the striatum, leading to disruptions in motor control (Elbaz et al., 2016). James Parkinson, the pioneer in identifying PD, initially referred to the disease as "Shaking Palsy" and described it as "involuntary tremulous motion with lessened muscular power, in parts not in action even when supported, with a propensity to bend the trunk forward and to pass from a walking to a running pace" in 1817 (Parkinson, 2002). Since this initial characterization, the understanding of the pathology and clinical spectrum of PD has significantly progressed (Bartels and Leenders, 2009). Although PD is primarily recognized as a dopaminergic deficit, it is believed to be a multicentric neurodegenerative disease. Epidemiological studies have demonstrated that both genetic and environmental factors can contribute to its onset (Bartels and Leenders, 2009).

PD manifests with a diverse range of clinical features broadly categorized as motor and non-motor symptoms (Table 1). Key motor symptoms include resting tremor, hypokinesia, rigidity, reduced movement amplitude, and postural instability (Varalta et al., 2015). Additionally, PD may present with other symptoms such as dystonia (continuous muscle contraction often accompanied by abnormal movements or postures), and oral motor disorders like speech disturbances (Sveinbjornsdottir, 2016). Approximately 25% of newly diagnosed PD patients exhibit cognitive deficits affecting visuospatial and executive functions, memory, and attention (Varalta et al., 2015). Non-motor symptoms encompass fatigue, sleep disturbances, mood alterations, pain, and autonomic disorders (Martinez-Martin et al., 2015).

Symptoms/ signs	**Definitions/key features**
Motor Symptoms/signs	

Rest tremor*	Tremor in a completely resting limb, which temporarily disappears when the limb is held outstretched and then reappears (reemergent tremor) and is not present during movement
Bradykinesia*	Slowness and progressively smaller movements (hypokinesia) occur as a person repeats a task (e.g., tapping index finger and thumb, opening and closing fist) multiple times in a row
Rigidity*	Involuntary, velocity-independent resistance to passive movement of a joint (e.g., wrist, elbow) by an examiner, with or without a cogwheel phenomenon
Postural instability	Typically observed as a late sign of the disease. Balance impairment affecting a person's ability to maintain or change postures such as standing or walking
Non-motor Symptoms/signs	
Cognitive impairment	Mild cognitive impairment (often initially affecting executive and visuospatial function and attention) or dementia
Psychiatric disturbances	Depression, anxiety, apathy, psychosis
Olfactory loss	Decreased or absent sense of smell (hyposmia)
Sleep dysfunction	Sleep-maintenance insomnia, symptoms of rapid eye movement sleep behaviour disorder, daytime sleepiness
Autonomic dysfunction,	Constipation, orthostatic hypotension, blood pressure variability, delayed gastric emptying, urinary urgency and frequency, erectile dysfunction
Other	Fatigue, trouble swallowing, hypophonia (softening of the voice), sialorrhea

Table 1: *Motor and non-motor symptoms of Parkinson's disease*

(adapted from Armstrong and Okun, 2020)

Standardised scales can be used to describe and evaluate aspects related to clinical disease progression, such as disability and impairment. In PD, the Hoehn and Yahr (H&Y) scale, widely employed globally, was created as a descriptive staging system. Its purpose is to offer a broad assessment of clinical function in PD by combining functional deficits (disability) and objective signs (impairment) (Goetz et al., 2004). This approach entails categorising patients into stages by considering the presence of unilateral or bilateral motor symptoms, disability level, and the presence or absence of balance impairments, using 1.0-point increments across five stages (Cardoso et al., 2023). The progression of motor impairment can be tracked as follows: starting from unilateral symptoms (Stage 1) and advancing to bilateral disease (Stage 2) without balance challenges. Subsequently, it evolves to include postural instability (Stage 3), resulting in the loss of physical independence (Stage 4), and ultimately leading to a state of being wheelchair- or bed-bound (Stage 5) (Goetz et al., 2004).

Another widely used scale in PD is the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS). This comprehensive scale was designed to assess disease severity across various aspects through its sub-scales: I) Non-motor Experiences of Daily Living, II) Motor Experiences of Daily Living, III) Motor Examination, and IV) Motor Complications. The evaluation involves the completion of twenty questions by the patient or caregiver (Goetz et al., 2008).

Both scales serve as widely employed tools in clinical settings and clinical trials within the area of PD (Goetz et al., 2004). By incorporating these scales into clinical assessments, healthcare professionals gain valuable insights into the dynamic nature of the disease, allowing for more precise tracking of motor and non-motor symptoms over time. Moreover, these scales play a pivotal role in research settings, enabling the standardized evaluation of treatment effectiveness and the comparison of outcomes across different studies.

1.2.1 Etiopathogenesis of PD

Most cases of PD are sporadic and among the six genes linked to heritable PD, mutations in SNCA (PARK1 = 4) and LRRK2 (PARK8) are responsible for autosomal-dominant PD forms, whereas Parkin (PARK2), PINK1 (PARK6), DJ-1 (PARK7), and ATP13A2 (PARK9) contribute to PD with an autosomal recessive (AR) mode of inheritance (Klein and Westenberger, 2012). However, these mutations in the six genes only account for a limited number (3-5%) of sporadic occurrences. This suggests that the etiology of PD is multifactorial, likely resulting from the interplay of various genes and environmental exposures. This multifactorial nature is the most common hypothesis regarding the mechanism of PD pathogenesis (Bartels and Leenders, 2009, Klein and Westenberger, 2012). According to this hypothesis, the interaction between genetic and environmental factors induces mitochondrial respiratory failure and oxidative stress in nigral neurons, leading to cell death (Moon and Paek, 2015).

One environmental factor is toxins; some epidemiological studies have indicated that certain pesticides and environmental toxins may impair mitochondrial complex-I of the respiratory chain, resulting in reduced ATP synthesis and potentially leading to the degeneration of neurons in PD (Moon and Ha Paek, 2015).

Neuroinflammation is another process that contributes to ongoing neurodegeneration in PD (Bartels and Leenders, 2007). As part of an inflammatory reaction in activated brain regions, activated microglia produce excessive superoxide anions and other potential neurotoxins, which may contribute to dopaminergic cell death by attacking them (McGeer and McGeer, 2004).

Age is the single most important risk factor, with a median onset age of 60 years for PD (Jankovic and Tan, 2020). The significant increase in its prevalence at later ages, peaking between 85 and 89 years, points to a potential role for aging in its pathogenesis (Van Den Eeden et al., 2003, Armstrong and Okun, 2020). PD may result from a lack of normal cellular compensatory mechanisms in sensitive brain regions, a condition exacerbated by age (Moon and Ha Paek, 2015).

There appears to be a higher incidence of PD in men than women (with a ratio ranging from 1.3 to 2.0); however, this may be influenced by differences in characteristics such as caffeine intake, cigarette smoking behaviour, and postmenopausal hormone usage (Ascherio and Schwarzschild, 2016). Increased risk of PD has been associated with factors such as dairy product consumption, a history of melanoma, and traumatic brain injury, while reduced risk has been linked to greater levels of physical activity, higher serum urate concentrations, higher caffeine consumption, higher tobacco consumption, and higher use of ibuprofen (Ascherio and Schwarzschild, 2016).

1.2.2 Pathophysiology of Motor Dysfunction

The neurodegenerative process targets different neuron groups distributed throughout the neuroaxis, including regions of the cortex, brainstem, midbrain, thalamus, spinal cord, and sympathetic and parasympathetic ganglia (Alexander, 2004). Various neurotransmitters and neuromodulators represent the losses of these extranigral neurons (Fig 1), mainly: acetylcholine (ACh), serotonin (5-hydroxytryptamine [5-HT]), noradrenaline (NA), and glutamate. Despite the apparent complexity, the neuropathology seems to be consistent across all affected regions, suggesting a unified pathogenic pathway.

These intricately interconnected neuronal networks, comprised of multiple layers and loops, are adversely affected by the depletion of dopaminergic neurons (Alexander, 2004). Since each loop originates from a specific set of anatomically and functionally related cortical fields (sensorimotor, prefrontal, limbic, oculomotor), PD manifests with different clinical symptoms (rigidity, bradykinesia, tremor, impaired motor sequencing, visuospatial deficits, impaired cognitive function, etc.) as a result of this neurodegenerative process (Alexander, 2004). The Figure 1 showed the clinical manifestations of affected regions (Alexander, 2004, p. 261).

Region	Cell group	Neuromodulator	Clinical manifestations
• **Central nervous system**			
Retina	Amacrine cells of inner nuclear layer	DA	Dyschromatopsia, reduced contrast sensitivity
Pons	Locus ceruleus	NA	Hypokinesia? Depression? RBD?
Pons	Dorsal raphe nucleus	5-HT	Depression? RBD?
Pons	Nucleus pedunculopontinus pars compacta	ACh	Akinesia, RBD?
Midbrain	Substantia nigra pars compacta	DA	Bradykinesia, rigidity, tremor
Hypothalamus	Supraoptic nucleus, paraventricular nucleus	Oxytocin, VP	Hypotension?
Thalamus	Centromedian nucleus, parafascicular nucleus	Glu	Bradykinesia, rigidity, tremor
Basal forebrain	Nucleus basalis	ACh	Cognitive impairment
Basal forebrain	Anterior olfactory nucleus	ACh, CRF	Hyposmia
Amygdala	Cortical nucleus	CCK, glu	Hyposmia
Amygdala	Basolateral nucleus	Glu	Visual hallucinations
Cerebral cortex	Parahippocampal gyrus	Glu	Minimal cognitive impairment
Cerebral cortex	Insular cortex	Glu	Postural instability?
Cerebral cortex	Presupplementary motor area	Glu	Bradykinesia, hypokinesia
• **Sympathetic autonomic nervous system**			
Preganglionic	Intermediolateral nucleus of spinal cord	ACh	Orthostatic hypotension
Postganglionic	Sympathetic chain	NA	Cardiac sympathetic denervation
• **Parasympathetic autonomic nervous system**			
Preganglionic	Dorsal glossopharyngeus-vagus complex	ACh	Dysphagia, esophageal and gastric dysmotility
Postganglionic	Myenteric plexus	ACh	Esophageal, gastric, and colonic dysmotility

Figure 1: *Clinical correlates of neuron loss in PD.*

Legend *- DA, dopamine; NA, noradrenaline; 5-HT, 5-hydroxytryptamine (serotonin); VP, vasopressin; Glu, glutamate; ACh, acetylcholine; CRF, corticotrophin-releasing factor; CCK, cholecystokinin; RBD, rapid eye movement (REM) sleep behaviour disorder (Alexander, 2004, p.261, with permission)*

The primary known pathophysiological feature in PD is the loss of dopamine (Bartels and Leenders, 2009). Dopamine is an amine group of transmitters produced by neurons in the substantia nigra and ventral tegmental area of the midbrain. Its action area includes the frontal lobe and basal ganglia (caudate head and putamen), playing a crucial role in motor control, goal-directed behaviours, and cognitive activity (Lundy-Ekman, 2013). The deficiency of dopamine, leading to dysfunction in the striatum, results in decreased activity in the direct pathway from GABAergic striatal neurons to the internal segment of the globus pallidus and substantia nigra pars reticulate (subcortical nuclei in basal ganglia) (Hamani and Lozano, 2003). Simultaneously, there is an increased drive via the indirect pathway to the external segment of the globus pallidus. Consequently, this disruption of activity occurs in the output structures of the basal ganglia, further impacting the activity in brainstem motor areas (Hamani and Lozano, 2003). This disruption contributes to difficulties in initiating movements and poor motion, which are characteristic features of PD

(Hamani and Lozano, 2003). Figure 2 shows the direct and indirect pathways in normal and PD neuronal networks (Pretegiani and Optican, 2017).

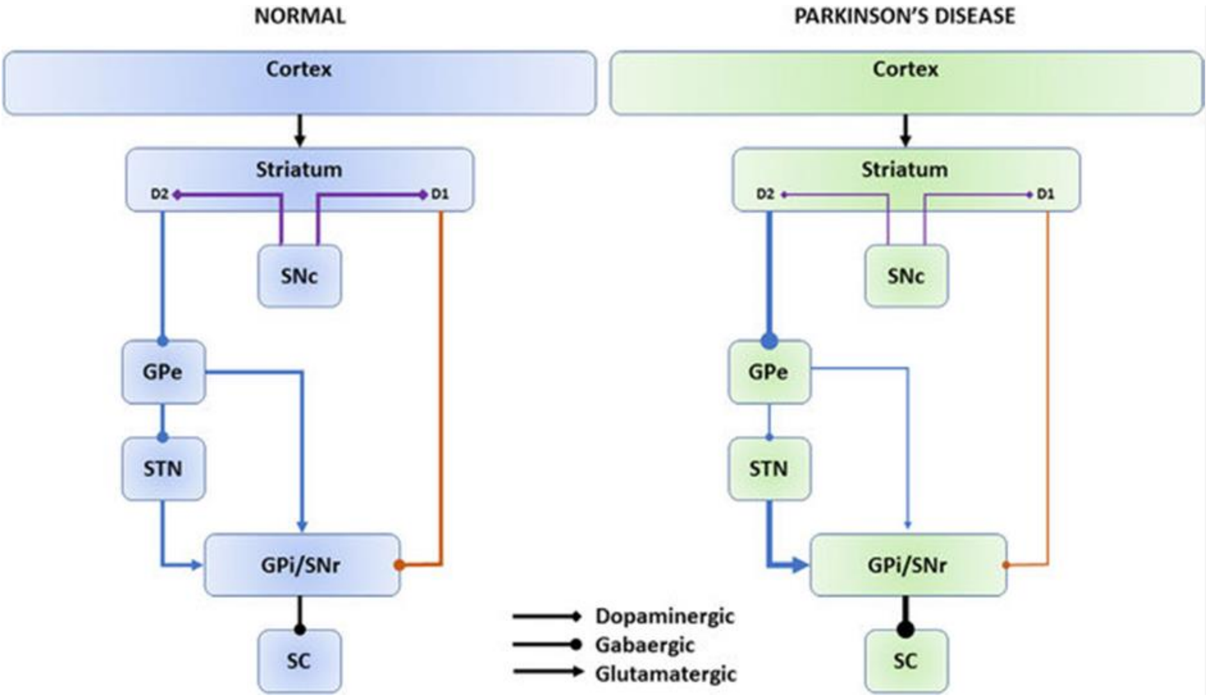

Figure 2*: Direct and indirect basal ganglia pathways.*

Legend*-The cerebral cortex sends input to the striatum. Dopaminergic projections from the SNc (violet connectors) target striatal neurons expressing D1 or D2 receptors. Direct pathway (orange connectors): D1 neurons send direct inhibitory projections to the SNr/GPi. Indirect pathway (blue connectors): D2 neurons connect indirectly to the GPi/SNr through the GPe and STN. The SNr inhibits the SC. In Parkinson's disease, dopaminergic depletion leads to reduced inhibitory direct pathway output (thin lines) and increased excitatory indirect pathway output (thick lines) onto the GPi/SNr and, consequently, increased SNr inhibition onto the SC as net effect. SNc, substantia nigra pars compacta; GPe, external globus pallidus; STN, subthalamic nucleus; GPi, internal globus pallidus; SNr, substantia nigra pars reticulata; SC, superior colliculus. (Pretegiani & Optican, 2017; p. 3, with permission).*

1.3 Balance control and its clinical implications in PD

Balance control refers to the ability to manage the position of the centre of mass (CoM) within the base of support (BoS); the CoM is the central point of the total body mass, determined by calculating the weighted average of each body segment, and it can be referred to as the centre of gravity (CoG) in the vertical line. The BoS represents the area of the body in contact with the support surface (Shumway-Cook, 2017). Balance involves the interaction of individual systems, environmental constraints, and task constraints (Shumway-Cook & Woollacott, 2017).

To maintain balance control amidst changing environmental constraints, such as alterations in the supporting surface, cognitive demands, or sensory context, various strategies may come into play (Shumway-Cook and Woollacott, 2017). These strategies encompass both anticipatory postural adjustments for expected changes and reactive postural adjustments for unexpected changes (Pollock et al., 2000). Responses to these disturbances involve the use of different individual systems, including muscle activation, sensory organization, movement initiation within the BoS, or adjustments to the BoS itself (Visser and Bloem, 2005, Pollock et al., 2000). Posturography studies have demonstrated the relevance of these responses to circuits in basal ganglia structures (Visser and Bloem, 2005).

Different studies have indicated increased activation in the frontal lobe, prefrontal cortex, and sensorimotor areas when introducing cognitive challenges (e.g., subtracting from seven, working memory tasks, visual feedback, Stroop task) during quiet or dynamic standing conditions in healthy individuals (Mirelman et al., 2014, Huang et al., 2014). Other research has shown similar changes in the occipital lobe, temporal and parietal areas of the brain when sensory challenges, such as standing with eyes closed or providing varying degrees of visual input, are introduced (Wittenberg et al., 2017). These findings suggest that different balance disturbances can impact various structures in the brain in pwPD, and alterations in motor circuits within these structures may explain the balance problems observed in this population.

1.3.1 Clinical implications of Impaired Balance Control in PD

Balance dysfunction can manifest in various ways, including (i) quiet stance, (ii) anticipatory postural adjustments, (iii) reactive postural adjustments, and (iv) dynamic balance (Schoneburg et al., 2013).

In quiet stance, postural alignment is crucial, involving the control of the stability of each body segment in relation to gravity within the BoS. In pwPD, a flexed posture is commonly observed due to hypertonia in the flexor muscles of the hip and knees. This can result in a posture misaligned with gravity, contributing to a common deficit in balance control during quiet stance (Horak et al., 1997). Rigidity, a form of muscle hypertonia and a cardinal sign of PD, leads to diminished body rotation and impaired head-trunk intersegmental coordination (Vaugoyeau et al., 2006). This condition affects dynamic balance, particularly during activities such as walking or turning when hypertonia is present in the hip and neck muscles (Franzén et al., 2009, Rinalduzzi et al., 2015).

Postural sway is the continuous subtle movement of the CoM, maintaining balance within the BoS during quiet stance and it involves complex sensorimotor loops (Schoneburg et al., 2015). In upright stance, the central nervous system integrates information from the vestibular, visual, and proprioceptive systems. Each sensory system detects sway in different body segments from a reference position. The central nervous system combines these signals, generating an appropriate corrective motor response to changes in the sensory environment, a process known as sensory reweighting (Rinalduzzi et al., 2015). This sensory reweighting is impaired in PD; for instance, individuals with severe PD struggle to stand on an unstable surface with closed eyes (Frenklach et al., 2009). Proprioceptive deficit is also evident in PD, as impairments in basal ganglia neurons, which house many proprioceptive receptors, lead to reduced perception from the trunk and surface in a stance position, resulting in reduced adaptation to changes in BoS (Chong et al., 2000). These sensory integration deficits collectively contribute to balance problems in pwPD. An increase in sway indicates balance dysfunction, with pwPD exhibiting higher sway velocity, frequency, and a larger sway area compared to age-matched healthy controls (Schoneburg et al., 2013). PwPD who do not complain of balance dysfunction exhibit higher postural sway in the ML direction than in the AP direction (Ferrazzoli et al., 2015). ML balance control requires active control with the hip, while AP direction relies on passive control with ankle strategies. This may be explained by disrupted basal ganglia function, influencing muscle tone and leading to stiffness in ankle muscles in PD.

Anticipatory postural adjustments (APAs) are automatic responses primarily involving the initiation of voluntary movements, such as raising an arm or taking a step, in response to internally generated perturbations. The initiation of movement in pwPD is primarily affected by deficits in the basal ganglia circuit (Hamani and Lozano, 2003). In the early stages of PD, smaller lateral APAs are observed, specifically impacting the loading and unloading of the legs; however, these are not seen in the backward direction. This suggests that the initial phases of PD may selectively influence leg dynamics. This observation aligns with the abnormal ML sway, as opposed to AP sway, seen in individuals with PD during quiet standing (Mancini et al., 2009). As the disease progresses, both lateral and backward APAs exhibit a bradykinetic response in PD.

Reactive postural adjustments to external perturbations can involve using an ankle or hip strategy or taking a step to place the leg under the falling CoM. An ankle strategy is effective for recovering balance from small perturbations, while the hip strategy is commonly employed with arm movements in the elderly, especially in situations involving an unstable surface (Schoneburg et al., 2013). PwPD exhibit abnormal generation of motor patterns, characterized by delayed muscle activation onset, improper amplitude, and a reversal of the typical activation sequence when subjected to perturbations (Rinalduzzi et al., 2015). These postural responses reflect a bradykinetic posture, resulting in less effective response to destabilisation and an increased risk of falling (Schoneburg et al., 2013).

Stepping responses in pwPD are characterized by being both small and slow, often necessitating the taking of more than one step to regain the CoM following forward or backward perturbations. A study revealed that this phenomenon may be linked to excessive postural preparation; pwPD employ APAs before stepping, leading to delayed and shortened compensatory steps, resulting in reduced effectiveness and the need for multiple steps (King et al., 2010). Another study found a difference between pwPD and healthy age-matched controls in the number of steps, pwPD required more steps in both forward and backward directions (Lu et al., 2021).

There may be differences in the number of steps between directions due to distinct neural circuits or responses to various stimuli. Nonnekes et al. (2013) found that in healthy adults, backward reactive responses are initiated with auditory stimuli, whereas individuals with PD exhibit a lack of reflexes to sensory stimuli, potentially explaining the suboptimal postural responses in the backward direction (Nonnekes et al., 2013). Lu and colleagues showed that there is a significant group difference in the number of steps by direction, meaning that the difference between pwPD and controls is greater in the forward than in the backward direction (Lu et al., 2021). These findings may be attributed to different neural circuits responsible for backward and forward reactive responses. Although these findings may suggest that stepping responses in a certain direction can be considered an indicator of balance impairment in pwPD, it may not be possible to specify which direction can be considered as an indicator, as various variables can affect the overall stepping response, such as the pace and magnitude of steps. There is no clear evidence for these variables in different directions. Nevertheless, these findings show that impaired anticipatory postural adjustments (APAs) may play a role in stepping responses and affect balance control in pwPD.

Walking requires *dynamic balance*. Maintaining balance during walking poses a significant challenge, requiring precise foot positioning and effective control of both lateral and forward stability to manage the continual movement of the CoM (Schoneburg et al., 2013). This process likely involves higher-level processing in various cortical areas. Recent research has highlighted the crucial role of the cerebellum in the balance and dynamic postural control of pwPD. This role may be attributed to the anatomical connections between the cerebellum and basal ganglia, and impairments in these areas in PD may contribute to dynamic balance deficits (Erdeniz et al., 2019).

Studies have demonstrated that pwPD exhibit a decrease in gait speed, step length, and an increase in double-support time, indicative of compromised balance control and bradykinesia (Schoneburg et al., 2013). Dynamic balance issues during walking are further evidenced by deficits in turning ability, characterized by slower turns with more steps, as well as reduced arm swing and trunk rotation, even in the early stages of the disease (Zampieri et al., 2010).

As a summary, the impaired interplay of complex multisensory integration systems and the altered regulation of background muscle tone may underlie balance dysfunction in PD. Individuals with PD tend to rely more on visual cues, encountering difficulties in maintaining balance control when visual information is absent, unreliable, or contradicts input from the vestibular and proprioceptive systems. Dysfunction in one sensory channel can be exacerbated by issues in another, such as the visual and vestibular systems. Abnormalities in the vestibular system can reduce the efficacy of proprioceptive and visual systems in providing feedback for balance control (Rinalduzzi et al., 2015).

The Role of Cognitive Function and Dual-tasking in Balance Control in PD

Another factor influencing balance control in PD is cognitive function (Christofoletti et al., 2016), with numerous studies suggesting that cognitive resources, including working memory and set shifting, that is the ability to change response to situations when they are changed (Monchi et al., 2004), play a crucial role in achieving postural stability (Erdeniz et al., 2019). It is well-established that increasing the difficulty of a postural task by temporarily impairing one of the sensory inputs necessary for balance requires heightened cognitive resources (Teasdale and Simoneau, 2001). In PD, the early and preferential loss of dopamine in the dorsal basal ganglia contributes to a reduction in automatic movements and an increase in cognitive control in PD. Consequently, individuals with PD must manage a larger cognitive load to execute both motor and cognitive tasks (Petzinger et al., 2013).

This challenge becomes particularly evident during dual-task performance, where individuals attempt to carry out two different tasks simultaneously. For instance, individuals with PD commonly report that walking while engaging in another task poses a significant challenge in daily mobility (Kelly et al., 2012). Under dual-task conditions, pwPD are more likely to experience a decrease in walking speed, stride length, and an increase in freezing of gait episodes compared to performing single tasks (Barbosa et al., 2016). During dual-task conditions, the frontal lobes allocate resources to the secondary task, while impaired basal ganglia predominantly control gait, leading to negative interference in gait performance (Vieira-Yano et al., 2021).

The phenomenon of dual-task interference can be elucidated through various theories, including the bottleneck theory, working memory theory, and the resource-sharing model. The working memory system relies on executive functions to coordinate the allocation of attention between concurrent tasks, drawing from multiple sources of information. Both attention and executive function impairments are evident in early PD and are associated with dual-task interference. In PD, greater attention to walking and/or cognitive impairments may lead to disproportionately greater interference due to reduced working memory capacity, deficits in dual-task coordination within working memory, or an inability to prioritize tasks effectively (Rochester et al., 2014).The bottleneck theory posits that when performing two different tasks simultaneously, both tasks require the same neural networks, resulting in a delay in one task until these neural networks can be recruited again

(Ruthruff et al., 2003). Another theory, the resource-sharing model, suggests that while performing simultaneous tasks, neural resources must be divided among them. When the capacity of these attentional resources is exceeded, it hinders performance on one or both tasks, leading to interference in dual-task performance (Wu and Hallett, 2008).

Although some pwPD who are in early stages of the disease indicated a feeling of instability in balance clinically, evaluation scores of balance tests were always normal in the early stages (Gan et al., 2023). The onset of postural instability or balance impairments was viewed as the shift from Hoehn and Yahr stage 2 to stage 3, denoting mild to moderate severity and representing a significant milestone in PD (Gan et al., 2023, Hoehn and Yahr, 1967). Balance dysfunction is strongly linked to falls in people with PD (Contreras and Grandas, 2012), contributing to falls for 68% of individuals who experience at least one fall each year (Menant et al., 2011). Most of the studies of balance disorders in PD population focused on the moderate to advance stages of the disease and fallers (Gan et al., 2023). Most reported falls are attributed to impaired balance control during everyday activities (Latt et al., 2009). These challenges with balance control and resultant falls significantly impact the quality of life, mortality, and morbidity in pwPD (Park et al., 2015). Therefore, improving balance control is crucial for pwPD in the mild to moderate stage to optimize their functional independence and overall quality of life. This PhD study focusses on pw mild to moderate stages of PD for this reason.

1.3.2 The management of balance dysfunction in PD

PD treatments have frequently focused on addressing dopaminergic deficits through pharmacological interventions (Smith et al., 2012). Initial treatments often involve Levodopa preparations, dopamine agonists, and monoamine oxidase-B (MAO-B) inhibitors, which are considered effective (Armstrong and Okun, 2020). According to findings by the PD MED Collaborative Group (2014), commencing treatment with levodopa yields a small but persistent effect on mobility, and individuals exhibit better performance in activities of daily living compared to those who initiate treatment with dopamine agonists or MAO-B inhibitors, even seven years later. However, pwPD who commence treatment with levodopa are more likely to develop dyskinesia. This suggests a compromise in balance function and an independent contribution to postural instability, particularly in advanced stages of the disease (Armand et al., 2009).

Dopamine replacement agents have demonstrated efficacy in addressing bradykinesia, tremor, and rigidity (Sparrow et al., 2016). However, their effectiveness in improving functional balance is limited (Smulders et al., 2016). For instance, Curtze et al. (2016) observed that levodopa increased mediolateral and anteroposterior sway velocities, along with directional variability of postural sway, essentially amplifying instability. This heightened instability may contribute to an increased risk of falls among pwPD (Curtze et al., 2015).

One contributing factor to this phenomenon is that dopaminergic medication only partially corrects early and late automatic postural responses, which are integral to balance control (Rinalduzzi et al., 2015). Levodopa, in particular, may not effectively impact performance for APAs and compensatory postural responses. A study revealed that pwPD on levodopa medication exhibited abnormal muscle activity in response to anticipated perturbations. This included early contractions in antagonistic muscles against perturbations from forward, right, and left directions, as well as heightened muscle activity with antagonistic co-contraction in compensatory postural responses (Heß et al., 2023). This complexity suggests that non-dopaminergic circuits, such as cholinergic systems, also influence postural responses (Di Giulio et al., 2016).

When medications are ineffective to address different abnormal motor symptoms, surgically implementing bilateral high-frequency deep brain stimulation (DBS) on the subthalamic nucleus (STN) may be a beneficial option, as it affects both dopaminergic and non-dopaminergic circuits (Colnat-Coulbois et al., 2005). Despite not yet being fully understood, the mechanisms of DBS involve a reduction in the excitability of neurons within the STN, leading to the normalization of network interactions among the basal ganglia, thalamus, and cortex (Heß et al., 2023).

Some studies have indicated that STN-DBS shows promise in enhancing the preparatory phase preceding voluntary and compensatory stepping after perturbations. This intervention has been found to enhance the vertical alignment of the trunk and shank, normalize postural sway displacement, and mitigate abnormal muscle activity (Heß, Oehlwein & Milani, 2023). A study discovered that, pwPD at mild-to-moderate stage, STN-DBS resulted in an immediate improvement in limits of stability post-operation. Additionally, balance performance at 6 and 12 months showed significant enhancement with STN-DBS, whereas levodopa did not show a significant effect on these parameters (Li et al., 2020a).

Studies have shown that, while both STN-DBS and levodopa exhibit comparable individual efficacy, their combined impact on motor severity can have an additive affect, lasting 5-years and beyond (Muthuraman et al., 2018). The bilateral stimulation of STN-DBS, combined with levodopa, has shown to enhance standing balance, even in conditions where eyes are closed, or sensory challenges are present. This improvement may be attributed to the enhancement of central information processing (Colnat-Coulbois et al., 2015). Thus, the combination of both therapeutic approaches may be optimal for enhancing motor symptoms and balance control in pwPD. Caution should be undertaken, however, when interpreting these findings, the studies report a variety of outcomes (Heß et al., 2023).

While pharmaceutical and DBS therapies play a significant role in the management of PD, additional targeted therapies are essential to optimize balance control. Physiotherapy and rehabilitative strategies, for instance, have proven effective in enhancing balance (Capato et al., 2015, Sparrow et al., 2016). A comprehensive meta-analysis of studies in PD provides evidence that exercise and motor training approaches result in notable improvements in various balance-related activities encompassing walking velocity, moving from sitting to standing, and maintaining standing balance (Allen et al., 2011).

More recently, a systematic review-meta-analysis (Radder et al., 2020) investigated the effects of diverse physiotherapy approaches encompassing conventional physiotherapy, resistance training, treadmill training, aerobic exercise, balance and gait training, martial arts, dance, Nordic walking, hydrotherapy, strategy training, dual-task training, and exergaming on motor symptoms, gait, and balance in pwPD. The results of the meta-analysis demonstrated that dance, Nordic walking, balance and gait training, martial arts, exergaming, and hydrotherapy resulted in improvements across various balance outcomes, as measured by instruments such as the Berg Balance Scale, Mini Balance Evaluation Systems Test, Activities

Specific Balance Confidence Scale, Timed Up and Go Test, Falls Efficacy Scale-International, and Functional Reach Test. Based on their findings, Radder et al. (2020) suggested that therapists and patients can choose from this array of physiotherapy approaches, tailoring interventions to specific symptoms and patient preferences. This understanding of effective physiotherapy strategies provides valuable guidance for optimizing balance outcomes in pwPD.

1.3.3 Dual-task Training in the management of balance dysfunction in PD

DTT is one intervention employed by physiotherapists from an array of management strategies. DTT involves the execution of two attention-demanding tasks with distinct objectives (Strouwen et al., 2014). Typically, a primary motor task such as walking or standing is coupled with a secondary motor or cognitive task, such as carrying an object or engaging in conversation.

Several studies provide evidence that dual-task training is effective in improving gait in parameters such as gait velocity and stride length in pwPD (Brauer and Morris, 2010, Yogev-Seligmann et al., 2012b, Fok et al., 2010, Fok et al., 2012, Strouwen et al., 2017). However, some physiotherapy guidelines suggest that DTT is better avoided or approached cautiously (Strouwen et al., 2017) on the basis that dual-tasking may result in negative interference with gait and balance. Various theories seek to explain this interference, with one notable explanation being the "bottleneck theory." According to this theory, when two tasks are performed simultaneously, both tasks require the same neural networks (Ruthruff et al., 2003). There is a specific point in information processing that allows only one task to be performed at a time, leading to a delay in the performance of one of the tasks until those information processes are recruited again (Ruthruff et al., 2003, Hofheinz et al., 2016). As described earlier, balance control relies on information processing within motor, sensory, and cognitive system networks. PD can negatively impact all these processes, consequently resulting in impaired balance and an increased risk of falls, especially under dual-task conditions.

Another theory explaining dual-task interference involves the prioritization of one task over the other due to environmental demands (Yogev-Seligmann et al., 2012a). Research has demonstrated that both healthy young and older adults tend to prioritize gait performance while walking at the same time as undertaking a cognitive task (Yogev-Seligmann et al., 2012a). This may stem from the desire to avoid prioritizing the less critical task to minimize potential danger. The act of prioritizing the primary task over the secondary one is referred to as the "posture-first" strategy, which serves to minimize the risk of balance loss and protect individuals from potential hazards (Yogev-Seligmann et al., 2012a).

However, pwPD have been observed to lean towards a "posture-second" strategy, prioritizing the secondary task over the primary one under dual-task conditions, leading to an increased risk of falls (Bloem et al., 2006). Varalta et al*.* (2015) found a significant association between balance skills and executive functions, particularly evident under dual-task conditions (Varalta et al., 2015). In situations where pwPD focus on performing a motor task, they can execute normal movement patterns by bypassing the affected basal ganglia circuit and activating the uninjured premotor cortex (Fernandes et al., 2017). However, under dual-task conditions, reduced movement automaticity resulting from basal ganglia dysfunction may increase reliance on cognitive resources, limiting their availability for the performance of secondary motor or cognitive tasks. Consequently, this inability to direct cognitive resources for dual tasks may increase the risk of falls (Kelly et al., 2012). While these and other theories attempt to explain dual-task interference, the precise mechanisms in PD remain unclear (Rochester et al., 2014).

Although evidence suggests that performing dual-tasks can increase the risk of falling due to interference, Ruthruff and colleagues (2006) found that the practice of a task pair promotes the automatization of individual tasks by minimising the bottleneck effect or by leaving the bottleneck active but shortened in terms of the duration of neural network recruitment (Ruthruff et al., 2006). These two mechanisms provide a theoretical explanation as to how DTT might work to improve the performance of an individual task.

Tedla and colleagues (2017) report that repeated training can contribute to schema changes in the brain (Tedla et al., 2017). In PD patients, cognitive prefrontal areas are highly activated to compensate for reduced automaticity during the performance of complex tasks, such as dual-tasking, leading to an increased risk of falls

(Vandenbossche et al., 2013, Mirelman et al., 2014). Exercise may impact prefrontal cortex activation by enhancing the efficiency of neural control and/or expanding the capacity, which is the maximal ability to activate the prefrontal cortex as task difficulty increases (Habeck et al., 2003).

Another theoretical explanation cited in literature is the theory of executive function. This theory assumes that DTT improves the executive function which is related to balance by enhancing the cognitive resources by engaging inhibiting, updating working memory and task shifting sets (Khan et al., 2022, Xiao et al., 2023). Motor-cognitive DTT intensifies the load for inhibiting primary motor tasks, updates the load on the working memory, and facilitates the switching between motor and cognitive tasks; together they improve executive function and so balance (Khan et al, 2022).

A study found that motor-cognitive DTT interventions comprising resistance training plus cognitive tasks such as counting, spelling names, remembering shapes/images, mental arithmetic, etc. improved both balance and working memory in older people (Norouzi et al., 2019). This study found that motor-motor DTT also improved both working memory and balance.

Motor-motor DTT can also improve balance by contributing to potential brain plasticity with executive function. Motor-motor DTT may resulted in engagement with higher centres in central nervous system like cognitive prefrontal areas as mentioned earlier in this section and consequently this improves the executive function and balance (Varalta et al., 2015, Mirelman et al., 2014). Another potential mechanism behind the effectiveness of motor-motor DTT can be sequential neurobiological processes elucidated by motor tasks like insulin-like growth factor-1 (IGF-1) and the schema changes in brain regions (Norouzi et al., 2019).

Another study found that in pwPD who trained with treadmill training only, prefrontal activation increased during dual-task walking, whereas in treadmill training with virtual reality arm, activation reduced (Maidan et al., 2018). Therefore, combined training, including cognitive tasks, can modify the effects of training. This condition can translate to motor skill learning, which is a hallmark of motor skill learning (Rochester et al., 2010). Using a similar task, a decrease in activation in the prefrontal cortex during the first hour of acquisition of motor learning sequence was reported (Lehéricy et al., 2005). However, automaticity and retention are also hallmarks of motor skill learning. During the early stage, attention is required to perform complex tasks, and with repeated practice, dual-task or complex tasks can be performed automatically with relatively little attention (Rochester et al., 2010). In the context of balance-related tasks, the repetitive practice of DTT may contribute to the management of balance impairments in pwPD.

Several systematic reviews have been undertaken evaluating the effectiveness of DTT training. One systematic review synthesised the results from 14 studies investigating the effects of motor-cognitive DTT on gait and balance across various neurological conditions, including PD (Fritz et al., 2015). The authors suggested that motor-cognitive DTT may have a modest effect on balance in PD.

Another, focused specifically on pwPD and published three years later, indicated that DTT is safe and can be integrated into physiotherapy programs for individuals with mild to moderate PD (De Freitas et al., 2018). The review concluded that DTT is effective in improving specific balance features, such as mediolateral and anteroposterior balance in closed-eyes tests, compared with single-task training and no intervention. In contrast, a recent systematic review-meta-analysis, which explored the effects of various physiotherapy approaches, reported that DTT does not significantly enhance balance outcomes in pwPD (Radder et al., 2020). It is essential to note that the analysis of this latest review relied on Timed Up and Go Test (TUG) scores. Although TUG exhibits high test-retest reliability and inter-rater reliability in PD (Pourkhani et al., 2019), it primarily assesses mobility and does not cover different aspects of balance control and function. Furthermore, the data were consolidated from only three studies, prompting caution in concluding that DTT is not an effective intervention for improving balance in PD. This caution is emphasized by another recent systematic review-meta-analysis conducted by Li et al*.* (2020), which revealed a moderate positive effect of DTT on balance function (Mini Balance Evaluation System Test-MiniBESTest) in individuals with mild to moderate PD (Li et al., 2020b).

Finally, a very recent systematic review and meta-analysis concluded that DTT is a safe and effective approach to enhance functional and dynamic balance (assessed through MiniBESTest, Berg Balance Scale, and Timed Up and Go Test) in people with PD (with the predominant participant group falling within H&Y stages 2 and 3) (García-López et al., 2023). Overall, therefore, DTT emerges as an effective method to enhance balance in pwPD.

Evident when looking across these reviews is the heterogeneity that exists concerning outcome measurements, the combination of tasks (motor-motor or motor-cognitive), and the types of tasks incorporated within DTT. While the primary task typically involves a motor aspect, such as walking backward or tandem standing, the secondary task can be either motor-oriented, like carrying a tray with glasses or transferring an object, or cognitive, involving activities such as repeating days of the week or counting backwards (Hofheinz et al., 2016).

Despite the most prevalent task combination in DTT being cognitive-motor, the reviews show that there is considerable heterogeneity in implementation of the training approach, ranging from being integrated into complex balance training to incorporating elements of dance or virtual reality environments (Li et al., 2020b; Garcia-Lopez et al., 2023). Moreover, the duration and frequency of the sessions, as well as the overall duration of DTT programs, display considerable variability (Garcia-Lopez et al., 2023).

While these studies contribute valuable insights into the design of specific DTT types (M-DTT and C-DTT), it is noteworthy that their focus has primarily been on gait parameters. While these proof-of-principle studies have significantly advanced the field, there is currently a lack of evidence regarding which type of dual-task training can yield greater improvements in balance for pwPD.

In summary heterogeneity exists in both content and structure within the realm of DTT. Several uncertainties persist regarding task types (motor or cognitive), task combinations, frequency, duration, and the appropriate methods for measuring DTT effectiveness. Moreover, there is a recognized need to establish a standardized approach for integrating DTT into existing programs, with a call for more research to discern the most effective DTT interventions (De Freitas et al., 2018; Fritz, Cheek and Nichols-Larsen, 2015).

In the context of this PhD research, the focus is on balance function in pwPD at mild to moderate stages. The research specifically considers DTT intervention designs featuring discrete secondary tasks, namely motor-motor DTT (M-DTT) and cognitive-motor DTT (C-DTT).

1.4 Study Aim and Structure

1.4.1 Overarching Aim of the Research

The primary aim of this study was initially to investigate the superior effectiveness of M-DTT and C-DTT on balance in individuals with mild to moderate PD. An initial literature review revealed a dearth of evidence regarding the existence of discrete M-DTT and C-DTT programs specifically developed for balance rehabilitation in pwPD. This underscored the imperative need to create separate M-DTT and C-DTT interventions.

The Covid-19 pandemic brought to light the potential benefits of a home-setting for delivering DTT interventions to a vulnerable population. Consequently, the study's focus shifted towards developing and assessing the feasibility and acceptability of a randomized control trial designed to investigate the superior effectiveness of home-based M-DTT and C-DTT interventions. The specific focus is on improving balance in pwPD at mild to moderate stage.

1.4.2 Structure of PhD Study

To accomplish this aim, a sequential approach was adopted, involving research to inform intervention development, the actual development of the interventions, and the subsequent testing of the acceptability and feasibility of interventions and trial design. Three interconnected work packages (WP) were implemented to address the stages of "intervention development," incorporating information from a scoping review, patient and public involvement and engagement (PPIE) activities, and a qualitative study, as well as "testing the acceptability and feasibility of the randomized clinical trial". Figure 3 illustrates these work packages briefly with their individual aims.

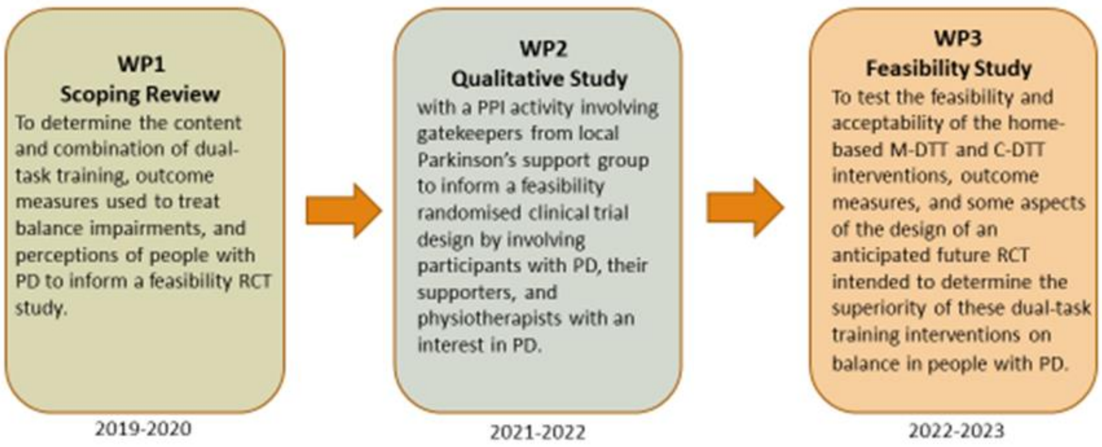

Figure 3*: An overview of the PhD study structure.*

This sequential approach allowed for a logical progression through the research process so that each stage builds upon the previous one, creating a cohesive and structured workflow. This approach helped to improve the quality of each stage by focusing on them individually. It also provided flexibility and adaptability throughout the research process, enabling refinement of the proposed methods and strategies with the findings of a previous work package and making adjustments when necessary.

WP1: Dual-task training interventions and outcome measurements for balance rehabilitation in people with mild to moderate Parkinson's disease: A scoping review of the literature.

The initial phase, WP1, involved a meticulous examination of existing literature and relevant studies to identify key insights and gaps in knowledge. This scoping review was an essential starting point of this PhD study. It was important to understand the need and in what way it could be met. Therefore, it comprehensively mapped the literature in terms of the use of dual-task training in balance rehabilitation for people with mild to moderate PD. It showed that there is a lack of evidence in superiority of the dual-task training types. Also, during the literature review, there was the era of the global pandemic because of the Covid-19. So, a possible need for a home-based training programme, and the lack of evidence in terms of the use of dual-task training in a home setting, guided this PhD study to a feasibility and acceptability testing of two different home-based dual-task training.

This scoping review comprehensively mapped the use of dual-task training in terms of task types, task combinations, delivery of the training; balance-related outcome measures, and the experiences and perspectives of people with PD regarding dual-task interventions. It indicated a dearth of evidence regarding the perspectives of individuals with PD concerning dual-task training interventions, both prior to undertaking them and following the experience. This led this PhD study to integrate a qualitative component in both the pre- and post-trial stage. In those ways, this comprehensive scoping review helped to decide the study design of WP2 and WP3.

The scoping review findings also helped to create a frame for the interviews and the data analysis process of WP2, the development of dual-task training interventions, and deciding the relevant outcome measures of WP3 feasibility study. The details of the scoping review are presented in Chapter 3.

WP2: The key features of a feasible and engaging randomized clinical trial design investigating the effects of dual-task training on balance outcomes in people with Parkinson’s disease: A qualitative study.

Subsequent to the scoping review phase, the focus transitioned to the actual development of interventions. WP2 entailed bringing the gathered information to pwPD, their supporters, and physiotherapists, and discussing them so that they could be a part of the development of DTT and research design. The emphasis here was on creating interventions that not only aligned with theoretical knowledge but also demonstrated a nuanced understanding of the target population and context. This approach allowed the researcher to bring existing knowledge into practical and effective strategies, tailored to address the identified needs and challenges for the development stage.

This qualitative study informed the overall shape of the dual-task training interventions in terms of task types, frequency, and duration of the sessions and home-setting of WP3 feasibility study. Also, those findings helped to choose outcome measures for testing of both acceptability and balance. The details of WP2 are presented in Chapter 4.

WP3: The potential effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: a feasibility study of a randomised clinical trial.

Following the intervention development, WP3 commenced, entailing a comprehensive examination of both the acceptability and feasibility of the interventions and trial design. This last phase of the PhD aimed to ensure the practicality and relevance of the interventions in the intended setting, while also validating the robustness of the research methodology to evaluate their effectiveness. The testing process encompassed various elements, including session attendance and adherence, acceptability, and safety of the M-DTT and C-DTT interventions. This evaluation utilized a questionnaire for outcome measures, analysis of training movie streaming data, and follow-up interviews with participants with PD. Additionally, this study examined the potential impact of these two home-based DTT interventions on balance. The details of WP3 are elucidated in Chapter 5.

It is anticipated that this feasibility study will inform a future randomized control trial which is designed to explore the superior effectiveness of M-DTT and C-DTT on balance in people with mild to moderate PD.

Chapter 2: Methodology

2.1 Introduction

Across the spectrum of existing studies, there is a substantial contribution to the field of DTT. However, there exists heterogeneity concerning the types of tasks employed within DTT, and there is a lack of evidence regarding which specific type of dual-task training is more effective in enhancing balance in PD. The insight gained from the initial literature review provided a foundation for designing DTT interventions that incorporate discrete task combinations, with the aim of exploring their superior effectiveness in enhancing balance function. The UK Medical Research Council (MRC) has proposed a framework for developing and evaluating complex interventions like DTT, emphasizing the importance of intervention development or identification, as well as the assessment of feasibility and acceptability of intervention and research design (Skivington et al., 2021).

Understanding the development, implementation, and evaluation of complex interventions and appropriately interpreting trial results is crucial. This chapter aims to provide a framework for the methods incorporated in the PhD by introducing the following key elements:

(i) The Concept of a Complex Intervention: Exploring the multifaceted nature of interventions and understanding the intricacies involved in their development, implementation, and assessment emphasizing how this concept was adapted for the PhD study.

(ii) Considerations of Study Designs: Discussing the choices made in design of the studies at each stage and their implications.

(iii) Philosophical Underpinnings of the Study: Discussing the foundational philosophical principles that guide the research, shaping the overall approach and perspective.

By addressing these elements, this chapter sets the stage for a comprehensive exploration of dual-task training in PD, laying the groundwork for an understanding of the complexities associated with intervention development and evaluation.

2.2 MRC Framework

Complex interventions are commonly used in health care services (Craig et al., 2008). A complex intervention may have different features such as different target behaviours, different groups and settings, different skills and expertise required by deliverers and receivers (Skivington et al., 2021).

In recognition of this the Medical Research Council developed a framework for researchers and research organizations to support them in terms of the use of appropriate methods to develop and evaluate complex interventions. The Framework highlights different phases in this process Figure 4 shows the phases and the key elements of MRC Framework (Skivington et al., 2021).

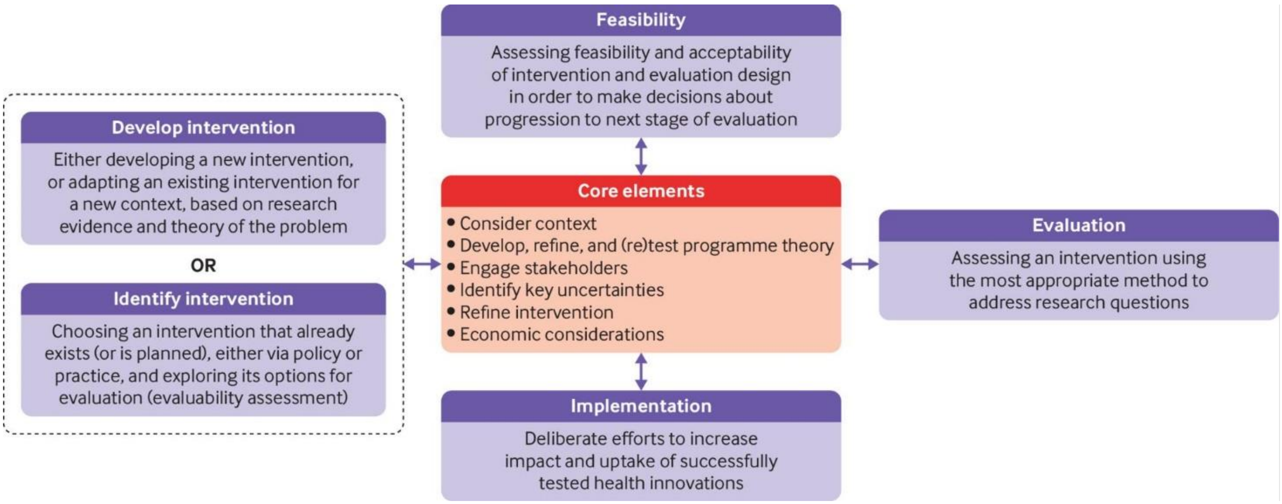

Figure 4: *Framework for developing and evaluating complex interventions.*

(Skivington et al., 2021, p.4, with permission)

The intervention which forms the focus of this thesis is DTT. DTT has different components within a training package. Also, its use in a population with neurological conditions requires expertise from service providers who deliver the training. Its use in PD populations requires different considerations such as assessing the individual's capacity and skills in terms of motor and cognitive functions to undertake it, training setting, safety, time, duration, etc. (Fritz et al., 2015). Together, these issues highlight why the MRC Framework was chosen as an appropriate framework to guide the development and evaluation of this intervention.

The MRC Framework (Skivington et al., 2021) and its stages were adapted with the sequential work package (WP) approach into this PhD study. These adapted phases of the framework presented in Figure 5.

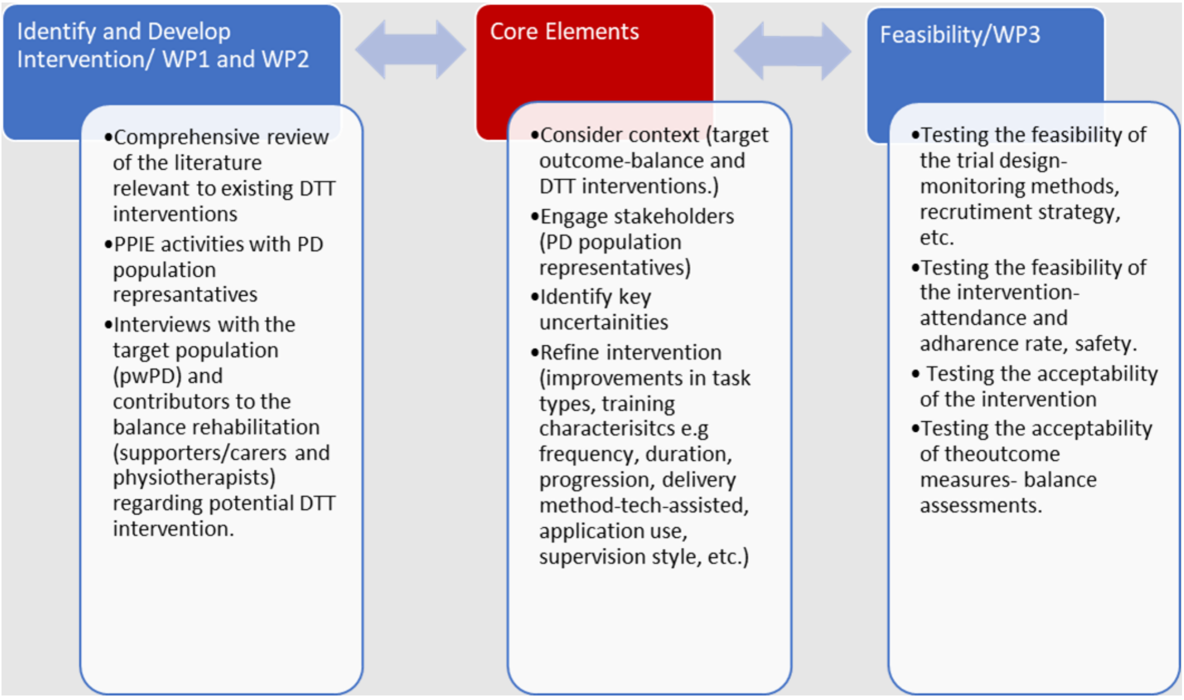

Figure 5*: Adapted MRC Framework*

Identifying and Developing Intervention

Developing a complex intervention does not always begin with a new intervention, it may also involve adaption of an existing intervention (Skivington, et al., 2021). A recent systematic review showed the use of DTT in the literature (Garcia-Lopez et al., 2023), but heterogeneity of the training types (Li et al., 2020b) showed the necessity of developing discrete M-DTT and C-DTT interventions. This is important since the overarching aim of this PhD is to explore the superiority of them on balance in pwPD. The lack of evidence exploring the feasibility and acceptability of DTT use in balance rehabilitation for pwPD (Li et al., 2020b) showed the necessity of assessing the feasibility of the use of DTT programmes and the acceptability of them by pwPD.

It may be achieved by introducing current evidence (typically based on a systematic review of literature), and sometimes with introducing an appropriate theory

(Shahsavari et al., 2020). The scoping review (Chapter 3) and further qualitative work which captured the perspectives of pwPD, their supporters (caregivers) and physiotherapists working with pwPD (introduced in Chapter 4) elucidated the development of two new dual-task training interventions.

Feasibility

The feasibility phase includes testing the acceptance of the procedures, intervention, and attrition and participation rate in research, likelihood of cost effectiveness, and calculation of sample size (Shahsavari et al., 2020, Skivington et al., 2021). Whilst it is important to evaluate all aspects of feasibility, such as sample size estimation or likelihood of cost effectiveness, this was not possible because of the limited timeline of this PhD. The objectives and explored aspects of feasibility were chosen for this feasibility study as the acceptability of the intervention, outcome measures, and trial procedures from perspectives of pwPD, and the attendance and adherence to the intervention, and safety. The details of the feasibility study are explained in Chapter 5.

In summary, the MRC framework (Skivington et al., 2021) was an important conceptual basis for deciding upon the study designs for work packages of this PhD. These study design considerations are explained in the following section.

2.3 Study design

Study designs are plans for research which shape the decision from assumptions to strategies and detailed methods of data collection and analysis (Creswell, 2009). The decision about which study design is most appropriate to use is based on the research question or the topic being addressed (Creswell, 2009). The following sections will provide the underpinning rationale for the approach adopted within each discrete work-package.

2.3.1 WP1- Scoping Review

A scoping review is one of the approaches used to review existing health research evidence (Levac et al., 2010). Although there is no universal definition of a scoping review, it commonly refers to mapping, which is a process of summarizing a range of evidence to convey the depth and breadth of a field (Levac et al., 2010).

Scoping reviews serve various purposes, including examining the nature, variety, and extent of evidence on a particular field or question. They are employed to determine the feasibility of conducting a systematic review, summarize findings from diverse methods or disciplines, and identify gaps in the literature to aid in planning future research (Tricco et al., 2018).

In contrast to systematic reviews, scoping reviews prioritize breadth and comprehensiveness over depth (Arksey and O'Malley, 2005). The objective of this review was to explore the structure of DTT, such as task types or combinations, and outcome measurements used in research, rather than delving into the mechanism of training effects on balance. Acquiring extensive knowledge in these areas would contribute to informing the development phase of the DTT interventions.

Another objective of scoping reviews is to identify research gaps in existing literature (Tricco et al., 2018). The initial literature review revealed that distinct task combinations for DTT interventions were primarily applied to enhance gait in pwPD. While there is evidence that can inform the designs of M-DTT and C-DTT, a scoping review has the potential to elucidate what is known and unknown regarding their delivery types and individual tasks within them, especially those that can potentially serve as balance tasks. This exploration aimed to contribute to the development of contemporary M-DTT and C-DTT interventions for specifically improving balance function in pwPD.

The findings from a scoping review may enable the researcher to identify gaps and guide the adjustment of existing aspects of interventions for the specific target of balance function. Overall, a scoping review was considered well-suited to serve as the developmental phase of the adapted MRC framework and as a foundation for the overarching PhD study.

2.3.2 WP2- Qualitative study

Qualitative research is a means of exploring and understanding the meaning individuals or groups ascribed to a social or human problem (Creswell, 2009, p. 5). This type of research is employed when the goal is to gather detailed and comprehensive insights regarding a phenomenon and to investigate a complex subject that cannot be adequately explored using quantitative measures (Curry et al., 2009). The qualitative approach is recognized as an inductive method that enables the generation of hypotheses about how things are happening, utilizing open-ended questions in its analysis (Tariq and Woodman, 2013).

Qualitative research is undertaken to address specific issues or problems that require exploration and understanding. These problems could take different forms, such as the need to identify relevant variables that should be measured or the exploration of a "silenced voice," as mentioned by Creswell (2007). Identifying relevant variables involves exploring the nuances and complexities of a given phenomenon, helping researchers to discern the key factors that should be considered. The notion of "silenced voice" refers to perspectives, experiences, or voices that may be overlooked or underrepresented in relevant to the specific issue and qualitative research (Creswell, 2007). In this case, it can become a tool to give voice to those experiences or perspectives that might not have been adequately acknowledged or understood.

A qualitative approach can provide an opportunity to patients and their carers to share their experiences regarding treatments they have engaged in (de Wit et al., 2019, Gibson et al., 2004). It can provide important information about such diverse areas as the relevance of outcomes to patients, compliance with an intervention, and participant involvement in trial procedures (Gibson et al., 2004). Not only can qualitative studies be used at all stages of clinical trials, but also in providing pre-trial qualitative studies in order to optimise aspects of trial design, from recruitment to trial delivery and methods of dissemination (Francis-Auton et al., 2020).

In the context of this PhD study, a qualitative approach was chosen to better understand the acceptability of a home-based DTT and the trial process for the target PD population. Specifically, in the development of this complex DTT intervention, the qualitative component (WP2) at the pre-trial stage aimed to inform the design of the feasibility randomized clinical trial by incorporating perspectives from people with PD, their supporters, and physiotherapists. The methods of this qualitative study are elaborated in Chapter 4.

2.3.3 WP3- Feasibility Trial

Feasibility studies are conducted before a main study to estimate important parameters of the main study (Arain et al., 2010). These parameters may be (a) recruitment capability, (b) acceptability of the intervention, (c) refinement of outcome measures, (d) preliminary results of the outcomes of intervention (Orsmond and Cohn, 2015). Feasibility is an umbrella term covering many areas (Eldridge et al., 2016). For this feasibility study the focus for evaluation has been selected as determining: the acceptability of the interventions; the potential efficacy of the interventions on balance; adherence and attendance to the intervention; safety, utility and acceptability of the outcome measures; and acceptability of online progress assessment from the perspective of participants with PD.

WP3 aimed to test the feasibility and acceptability of undertaking an anticipated RCT designed to evaluate the relative effectiveness of two home-based DTT interventions for improving balance in pwPD. When investigating the feasibility of a complex intervention, it is important to understand how acceptable and how feasible the intervention and the study procedures are from the participants' perspectives.

A deductive approach is used to test an a priori hypothesis and can potentially yield generalizable findings if based on a large enough sample (Tariq and Woodman, 2013). In the context of quantitative research aimed at hypothesis testing, this method is referred to as a deductive approach. Thus, this approach strengthens quantitative research by controlling bias and providing findings that are both generalizable and replicable. However, it is important to note that quantitative research may have limitations in addressing 'how' or 'why' questions (Tariq and Woodman, 2013).

While quantitative data obtained from surveys, questionnaires, or scales can offer replicable and measurable findings relevant to the initial effectiveness of interventions, they may not capture the full complexity of the trial's feasibility. In this context, qualitative research becomes crucial as it excels at capturing nuances and complexities that quantitative measures might overlook. Moreover, qualitative research can unveil unexpected or unanticipated findings that quantitative methods may fail to disclose. It provides a platform for participants to express their thoughts, concerns, and suggestions, thus contributing to a more comprehensive understanding of the intervention's implementation and impact. Despite the richness of data that high-quality qualitative research can offer, its ability to generate generalizable findings is constrained by its typically small sample size (Tariq and Woodman, 2013).

In such scenarios, a mixed-methods approach can be beneficial in achieving the objectives of a feasibility study. Mixed-methods research involves the collection, analysis, and integration of both qualitative and quantitative data within a single study (Tariq and Woodman, 2013). However, it is important to note that this approach goes beyond mere data mixing; it also incorporates the philosophical assumptions and approaches underlying both qualitative and quantitative methods (Creswell, 2009, Almalki, 2016).

It can activate the strengths of both research designs while mitigating their respective weaknesses, proving beneficial in tackling complex issues (Tariq and Woodman, 2013) such as the acceptability and feasibility of interventions and overall research procedures. Mixed-method research encompasses various design categories—parallel, embedded (nested), explanatory, and exploratory (Shorten and Smith, 2017). The embedded design involves integrating qualitative and quantitative elements into one study to achieve the overall study aim by enhancing the design (Schoonenboom and Johnson, 2017). Hence, this feasibility study incorporates a mixed-method design embedded with qualitative work so that the enhanced data can contribute to optimizing the design of an anticipated RCT, evaluating comparable effectiveness of DTT interventions in line with the subsequent phase (Evaluation) of the MRC Framework (Skivington et al., 2021).

2.4 Underlying philosophical perspective of the PhD study

Philosophical ideas influence the practice of research and need to be discerned because they aid in understanding and explaining the selection of research design and the context for interpreting findings (Creswell, 2009). The overall philosophy of

the PhD study was chosen as critical realism. This philosophical perspective was deliberated alongside other possible approaches in this section.
The interpretivist stance is commonly linked with qualitative approaches and is grounded in the belief that multiple realities exist (Tariq and Woodman, 2013). This perspective facilitates the development of an evidence base informed by group experiences and perceptions, fostering a profound understanding and knowledge that can be integrated into clinical practice (Thompson Burdine et al., 2021). In the pre-trial stage, the qualitative study adopts a practical approach, aiming to complement the findings of the literature scoping review and gather targeted information relevant to conducting the proposed feasibility study, rather than delving into an in-depth exploration of a specific phenomenon. Given this orientation, the interpretivist stance was deemed less suitable for interpreting the findings of the WP2-pre-trial qualitative study. In contrast, critical realism offers a relatively novel perspective, combining elements from both interpretivist and positivist positions (Haigh et al., 2019). Functioning as a comprehensive philosophy of science that integrates these two approaches, critical realism provides researchers with a valuable framework to thoroughly explore phenomena and propose recommendations for addressing the research question (Fletcher, 2017).

One of the key tenets of critical realism is the concept of causal mechanisms, according to Haigh (2019), reality is comprised of structures endowed with features that empower them to activate mechanisms capable of influencing other structures. These mechanisms, when activated, lead to events and their corresponding effects, defining the actual domains of reality. In contrast, interpretivism is rooted in the exploration of experiences to comprehend the diverse realities. However, critical realism posits that the ultimate focus of reality is the understanding of causal mechanisms (Yucel, 2018). When considering the findings of the proposed qualitative study through a critical realist lens, it was apparent that this perspective could offer insights into the underlying causal powers shaping the reality of DTT interventions. This understanding is crucial for assessing the feasibility of such interventions.

For instance, when considering the feasibility, acceptability, or engagement of DTT interventions as constituting a reality, an interpretive perspective posits that each situation represents a unique reality (Thompson Burdine et al., 2021) regarding DTT, providing a deep understanding of their varying levels of feasibility and acceptability. In contrast, a critical realist approach views the feasibility of DTT as one reality, with acceptability and engagement seen as causes of its feasibility. For example, it is important to understand why one group had better results in terms of their balance function. Is this because participation in one training programme was better because the training properties are more engaging? Or the training properties are more beneficial in terms of therapeutic effects? Critical realism allows exploration of these questions, and the researcher to leverage these causal relationships to refine or adjust existing elements within DTT interventions found in the literature, thereby informing the design of future interventions. Therefore, adopting a critical realist perspective was well-suited for this qualitative study, providing a framework to unravel the intricate causal relationships and facilitating the development of a nuanced intervention.

For a feasibility study with an embedded qualitative component, critical realism was considered an appropriate stance. Knowledge is transitive and our understanding of a phenomenon is changeable (Haigh, 2019). While constructed theories or knowledge may change and misconceptions may arise, critical realism embraces this potential for change (Haigh, 2019). Research with only a quantitative component may generate information, but it runs the risk of becoming a misconception over time. In contrast, an embedded qualitative component in a feasibility study offers diverse perspectives, potentially altering previously constructed concepts. While an interpretivist stance for understanding this qualitative component can be valuable, critical realism accommodates both qualitative and quantitative aspects, reflecting its integrative nature from both interpretivist and positivist approaches. This illustrates how the critical realist stance naturally aligns with a feasibility study incorporating a qualitative component, potentially yielding comprehensive insights to inform the future randomized controlled trial.

In summary, given its focus on causal mechanisms and its openness to changing constructed knowledge, critical realism was considered to be better suited for both WP2 – the pre-trial qualitative study, and WP3 – the feasibility study.

2.5 Summary

This PhD study adheres to the early phases of the adapted MRC Framework for Complex Interventions (Skivington et al., 2021), specifically phase 1 (identifying/developing a complex intervention) and phase 2 (testing feasibility). Study designs include a scoping review as WP1, a qualitative study for WP2 to inform the feasibility stage with current evidence from the WP1-scoping review, and a feasibility study embedded with a qualitative component for WP3. A critical realist stance serves as the philosophical underpinning throughout this PhD study. Details about methods and the findings of the scoping review, qualitative, and feasibility studies are explained in the following chapters.

Chapter 3: Scoping Review

3.1 Introduction

3.1.1 Background and Rationale

In Chapter 1, a rationale for employing DTT interventions in balance rehabilitation for pwPD was presented, aligning with the overarching aim of this PhD study. Briefly, DTT interventions demonstrate efficacy in enhancing balance for pwPD at mild to moderate stages. However, a considerable heterogeneity exists across individual tasks, task combinations, training characteristics (including session frequency and duration), overall DTT structure, delivery methods, and balance assessment methods. Further research is necessary to find out the specific DTT interventions that may prove most effective in enhancing balance.

Consequently, there is a critical need for a comprehensive mapping of these factors to identify optimal training components and outcome measures. This mapping was intended to serve as the foundation for designing the intervention study focused on improving balance in individuals with mild to moderate PD. Additionally, there is a necessity to explore whether any studies have investigated the relative effectiveness of different DTT interventions.

This scoping review aimed to scrutinize literature on the utilization and effectiveness of various DTT types, task combinations, and relevant outcome measurements in enhancing upright balance for individuals with mild to moderate PD. Moreover, it investigated whether any studies have examined the superiority of one DTT intervention over another for improving balance in this population. The choice of a scoping review was deliberate, as it accommodates various objectives, including examining the nature, variety, and extent of evidence, summarizing findings from diverse methods or disciplines, clarifying key concepts and definitions, and identifying gaps in the literature to guide future research (Munn et al., 2018, Tricco et al., 2018). A rationale for the choice of scoping review was explained in Chapter 2.

The findings from this scoping review informed the design of DTT interventions and the selection of balance assessment methods in the feasibility study (WP3). Ultimately, it is anticipated that these insights will contribute to the design of a future powered RCT comparing the effects of two different DTT interventions on balance in individuals with mild to moderate PD. Additionally, this scoping review may lead up a future systematic review delving into the types of DTT interventions and their effects on balance in pwPD. The results are expected to offer valuable information for choosing appropriate dual-task strategies in balance rehabilitation for individuals with mild to moderate PD in clinical settings.

3.1.2 Research Question

This scoping review was undertaken to answer the following main research questions:

1. What combination of tasks constitute DTT that is designed to rehabilitate upright balance in people with mild to moderate PD?

2. What are the outcome measures used to evaluate clinical effectiveness of DTT research in PD?

3. What are the opinions and experiences of people with mild to moderate PD about DTT interventions in the qualitative studies?

4. Is there any evidence which has investigated whether a DTT intervention is superior to another DTT intervention to improve balance in people with mild to moderate PD?

These research questions with the following research objectives formed the basis of the scoping review.

3.1.3 Research Objectives

Primary objectives

a) To explore the primary task types involving bipedal balance-related exercises and secondary task types involving motor or cognitive tasks and their combinations in DTT,

b) To explore the balance-related outcome measurements embedded within the clinical effectiveness studies published in the literature.

Secondary objectives

c) To determine existence of evidence investigating the superiority of one dual-task combination over another dual-task combination in training for improving balance in people with mild to moderate PD,

d) To summarise the differences in relevant balance outcomes in trials investigating the superiority of the task combinations within DTT interventions,

e) To identify and summarise the experiences and views of pwPD regarding DTT interventions.

3.2 Methods

The methodological framework work for scoping reviews was originally developed by Arksey and O'Malley (2005). Although there are some enhancements from Levac, Colquhoun & O'Brien (2010) and Peters et al. (2020), the original framework of Arksey and O' Malley (2005) was used for this scoping review because it is suitable for both undertaking and presenting the scoping review. This framework has five stages: (1) identifying the research question; (2) identifying relevant studies; (3) study selection; (4) data charting and (5) collating, summarising and reporting the results (Arksey and O'Malley, 2005). These five stages were completed for this review. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) (Appendix 1) (Tricco et al., 2018) was also used to guide reporting of the review.

3.2.1 Identifying the Research Question

To formulate the research question and title, the Population, Concept, and Context (PCC) mnemonic which is suggested to guide question development for scoping reviews (Peters et al., 2020) was used. Table 2 shows the population, concept, and the context adapted for this scoping review.

Population	Concept	Context
People with mild to moderate Parkinson's disease	Dual-task training interventions and relevant outcome measurements for rehabilitation of bipedal upright balance control and the experiences and perspectives of people with PD regarding dual-task interventions	Studies undertaken in inpatient, outpatient and community settings will be considered. Studies undertaken in any country will be considered providing papers are written in English or Turkish (the primary author's native language).

Table 2: *Population, Concept, Context (PCC)*

The adaptation of PCC also helped for defining the eligibility criteria to identify relevant studies.

3.2.2 Identifying Relevant Studies

Eligibility Criteria

To establish consistent decision-making throughout the scoping review, it is essential to formulate inclusion and exclusion criteria tailored to a particular research question at the review's inception. Eligibility criteria and their rationale for this scoping review can be seen in Table 3.

Categories	Inclusion Criteria	Exclusion Criteria
Population	People with mild to moderate Parkinson's disease (PD).	People with any other diseases that can lead to balance control problems such as other progressive or sudden, non-progressive neurological conditions
Rationale	Any disease (e.g. Multiple Sclerosis and stroke) in addition to Parkinson's disease can interfere with the balance training.	
Intervention	Refers to dual-task (primary and secondary tasks) balance training which has	(a) Exer-games/Virtual reality therapies when tasks or games do not provide a

	(a) bipedal upright balance exercises (includes whole body balance exercises, walking, turning, stepping, etc.). (b) Balance exercises with motor tasks (like holding a tray). (c) Balance exercises with cognitive tasks (counting, naming objects, etc). (d) Exer-games/Virtual Reality therapies focussing on balance when primary and secondary tasks are clear. (e) Complex balance training which involving more than one component including dual-task components, when components are clear.	discrete second task which is independent of motor task as a secondary task. (b) Complex balance training which do not include dual-task components. (c) Balance training including different demanding tasks such as cueing and music apart from dual-tasks or in addition to dual-tasks like dancing. (d) Complex balance training when dual-task components are unknown.
Rationale	The type of dual task balance training is the main concept of interest for this scoping review. Therefore, the intervention should include dual-task components, and task types should be clearly stated.	
Outcomes	Specifically represents the balance-related tests/scales such as Berg Balance Scale (BBS) (Downs et al., 2013), Centre Of Pressure measurements, Self-reported measures such as the Activities Specific Balance Confidence Scale (ABC) (Powell and Myers, 1995).	Do not include any balance-related assessment. Do not be used as an outcome measure in an intervention trial (e.g. studies evaluated the psychometric properties of outcome measures).

Rationale	To provide clinically relevant outcomes for the research question.	
Study Design	Randomized controlled studies (RCTs), non-RCTs, observational studies such as cohort studies, case studies, case series, qualitative studies, systematic reviews, research protocols.	Opinion and text studies.
Rationale	As the aim of a scoping review is to examine the nature, variety, and extent of the evidence for dual-task training interventions, and participants' views regarding these interventions, opinion and text reviews will not meet the research objectives.	
Language	English or Turkish (the primary author's native language)	Non-English or non-Turkish
Rationale	Limited resources of translation	

Table 3: *Eligibility criteria*

Search Strategy

A three-step approach was used to search for published and unpublished studies. An initial limited search of PubMed and CINAHL as a suggestion of Arksey and O'Malley (2005) was completed to identify keywords and index terms from the titles and abstracts by the primary researcher (NC). These initial search terms were planned with an evidence synthesis specialist in healthcare studies. The planned search terms for initial search on PubMed and CINAHL are presented in Table 4. A second search using all identified key words and index terms were then undertaken across all included databases (PubMed, CINAHL, MEDLINE (Ovid), and grey literature (OpenGrey and Google Scholar)). Third, the reference list of all identified reports and articles that were selected after full-text screen stage were searched for additional studies. Articles identified were analysed for words contained in the title and abstract and of the index terms used to describe the articles. To ensure the review comprehensively captured all possible data concerning the review question, there was no lower date limit. Searching was completed in May 2020.

Search	Query
#1	Parkinson*
#2	Dual-task*
#3	Concurrent-task*
#4	#2 OR #3
#5	Training
#6	Intervention
#7	Physiotherapy
#8	Exercise*
#9	“dual task training”
#10	#5 OR #6 OR #7 OR #8 OR #9
#11	#4 AND #10
#12	Balance*
#13	“Standing balance”
#14	“Upright balance”
#15	“bipedal balance”
#16	“Bipedal upright balance”
#17	“Postural control”
#18	#12 OR #13 OR #14 OR #15 OR #16 OR #17
#19	#1 AND #11 AND #18

Table 4: *Search terms used for PubMed.*

3.2.3 Study Selection

Levac and colleagues (2010) suggested that at least two reviewers should independently assess abstracts for inclusion. Reviewers should convene at the start, middle, and end of the abstract review process to address challenges, uncertainties, and refine the search strategy if necessary. Additionally, two researchers should independently review full articles for inclusion, and in cases of disagreement, a third reviewer can make the final inclusion determination (Levac, Colquhoun & O'Brien, 2010).

Three reviewers (NC, AL, and JF) screened the titles and abstracts of articles independently and analysed the full text of potential articles based on the inclusion and exclusion criteria. Any disagreement was resolved by discussing. Where needed a consensus, a third reviewer (LB) consulted to resolve disagreements. Results of the search strategy, including the number of finally included and excluded studies are presented with the reasons of exclusion in a PRISMA flow diagram (Figure 6) in the 3.3 Results section.

3.2.4 Critical Appraisal

The PRISMA-ScR checklist (Tricco et al., 2018) has a critical appraisal section referring to quality assessment but it is optional. It is recognized that assessing quality among a broad variety of published and grey literature included in scoping reviews is challenging (Levac et al., 2010). The findings of this review may give potential to conduct new research exploring the superiority of task combinations within DTT, and hence, critical appraisal of the included studies investigating the superiority of task combinations within DTT interventions is important to guide future research. Therefore, the superiority study was critically appraised using the Joanna Briggs Institute System for the Unified Management, Assessment and Review of Information (JBI SUMARI), which is a web-based application designed to assist researchers to undertake different processes of reviews (Munn et al., 2019).

3.2.5 Data Charting

During the data extraction and charting processes, two different data charts were used. Data extractions were undertaken by two independent reviewers (NC and LB). This iterative process aligned with the recommendation provided by Levac and colleagues (2010).

For the general data set, a pilot data extraction was undertaken independently for four articles. After discussion about the chart, a second pilot extraction was applied. Data categories were finalised after the eighth paper. Abstracted data included the following items: author, year of publication, study setting, DTT interventions, comparing interventions (e.g. single task training, different types of DTT, no intervention, etc.), task combination types (motor-motor/motor-cognitive), primary and secondary task types, delivery of interventions (supervision type, session type etc.), and balance-related measurement tools. For the second chart, in addition to these items, the mean of the pre- and post-intervention assessment results were charted as a count for each DTT types and outcome measurements to achieve the secondary objectives of the review.

3.2.6 Collating, Summarising and Reporting the Results

The data was summarised after the extraction process. The quantitative data was summarised using numerical count and data from qualitative studies was summarised by drawing on narrative/thematic synthesis. Data synthesis was conducted by the researcher (NC). A narrative data analysis was completed. Key themes were constructed iteratively. The main themes were formed across the following questions: (1) how was DTT delivered? (2) what were the task types and task combinations within DTT? (3) what were the comparator interventions?, (4) what balance-related outcome measurements were used?, (5) are here any superiority studies?, (6) were there any superiority between DTT task combinations?, (7) what were the perspectives of participants regarding DTT?.

3.3 Results

3.3.1 Characteristics of included studies

The iterative search process resulted in the selection of 31 studies. The whole process was adapted and presented through the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Tricco et al., 2018) (Appendix 1). Figure 6 shows the adapted PRISMA flow diagram presenting the process of study selection.

Adapted PRISMA Flow Diagram

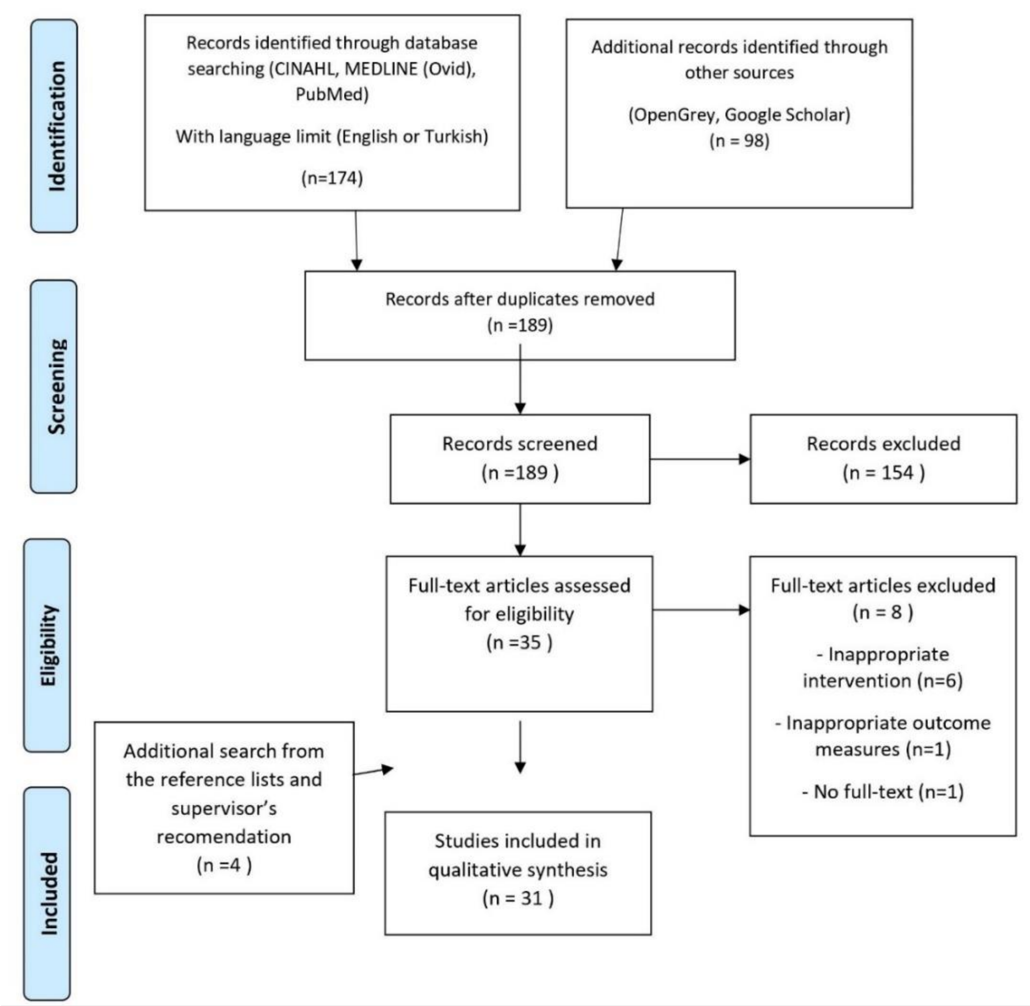

Figure 6: *Adapted PRISMA Flow Diagram*

(Moher et al., 2009)

The scoping review included the following study designs: systematic review (n=4), RCT (n=12), protocol of RCT (n=4), feasibility (n=2), pilot (n=1), retrospective (n=1), randomized cross-over (n=1), quasi-experimental (n=3), case-study (n=1), test-retest (n=1), and qualitative (n=1). The characteristics of the included primary research and protocols are presented in Appendix 2, structured according to the classification of DTT type e.g. a complex intervention inclusive of DTT, Exergaming inclusive of DTT, and solely DTT. Detailed information regarding systematic reviews and the superiority study are given in a different section.

Populations were exclusively comprised of pwPD in the included studies apart from one systematic review (Fritz et al., 2015) and one retrospective study (Cano Porras et al., 2019). In these two papers, participants were people with different neurological conditions in addition to PD such as multiple sclerosis, brain injury, stroke, and non-neurological conditions. These mixed population studies were included as they present clear data for the PD population. The total number of participants with PD was 1929. In terms of disease stage, participants were in the range of H&Y 1 to 4 or Modified H&Y 1 to 5, with the majority of studies comprising participants graded as H&Y 2-3 (n= 16/31). Participants' age range was 45 to 87 years (mean age= 67.92).

3.3.2. Systematic Reviews

Four included articles were systematic reviews. The total number of pwPD in these were 836. One review by Barry, Galna and Rochester (2014) included seven studies solely focussing on exergaming interventions that included dual-task components and the total number of PD participants was 102. The review outcome measures were inclusive of effectiveness (including disease severity, balance, mobility, cognition, and quality of life) but also considerate of feasibility of the intervention, and safety. Four of the seven studies on exergaming were described as DTT. In these four studies, intervention duration, frequency, and session duration ranged between 4 weeks to 8 weeks, 2 times to 3 times a week, and 40-60 minutes, respectively. In terms of setting, all studies were clinic-based. The progression of the intervention was not clearly stated (Barry et al., 2014).

The second review by Fritz, Cheek, and Nichols-Larsen (2015) included 9 studies with PD population and 5 studies with other neurological conditions (brain injury, Alzheimer's disease, and stroke) and elderly adults (total 14 studies). In these 9 studies, the total number of PD participants was 153. Interventions investigated in these studies involved motor-cognitive DTT and some studies where cognitive tasks were delivered via virtual reality or gaming approaches. The intervention duration, frequency, and session duration ranged from one session to 14 weeks, one session to 3 times a week, and 20 minutes to 30 minutes each session, respectively. Progression of training and study settings were not clearly stated in the review. The review outcomes were mobility (gait and balance), or mobility and one domain of cognition.

The main intervention was DTT gait and/or balance intervention in two additional reviews by De Freitas et al., (2018) and Li et al. (2020b). The De Freitas et al. (2018) review included 7 studies with a total of 259 PD participants. The intervention duration, frequency, and session duration ranged from 3 weeks to 10 weeks, once a week to 2 times a week, and 25 minutes to one hour each session, respectively (De Freitas et al., 2018). Li et al. (2020b) included 11 RCTs and 6 non-RCTs; the 11 RCTs, comprising a total of 322 PD participants, were included in the meta-analysis. The intervention duration, frequency, and session duration ranged from one session to 48 weeks, one session to 4 times a week, and 20 minutes to one hour each session, respectively (Li et al., 2020b). The progression of interventions and study settings were not reported within either of these systematic reviews. Reported outcome measures were varied; gait parameters and balance (Li et al., 2020b, De Freitas et al., 2018), and motor symptoms (Li et al., 2020b).

3.3.3 Delivery of Intervention and DTT from Primary Research and Protocol Studies

Of the 31 included studies of primary research or protocols, DTT was delivered in varying forms; DTT alone (n= 5), complex training, where DTT is one part of an extensive training programme (n= 19), and Exergaming/Virtual Reality (VR)-based training (n= 3). The total sample size of the intervention group was 637, and of the control group was 456.

The range of intervention duration (in weeks), frequency (number of times per week), and duration of each session (in minutes) were 3 to 12 weeks, one to 5 sessions per week, and 30 to 120 minutes for each session, respectively (average=8 weeks, 2-3 sessions per week, and an hour per session).

Setting of the intervention delivery varied between the clinic, home and community but was the clinic in most studies (n= 20). In 13 studies face-to-face intervention was delivered at the clinic and participants in the intervention group were also asked to undertake home exercises. Some studies (Liao et al., 2015, Perumal et al., 2017, Sethi and Raja, 2012, Silva and Israel, 2019) did not report clearly the intervention setting.

Intervention sessions for participants allocated to the intervention group were undertaken as a group in most of the included studies (n= 17). Participants engaged in individual sessions in some studies (n=10). Most sessions were supervised (n=26), with only one study delivering an unsupervised intervention.

Complex Balance Training

Of the 31 included studies, a substantial proportion (n=11) investigated the effects of a highly challenging, progressive, group balance training programme called HiBalance. Conradsson and colleagues (2014) developed this programme with a group of researchers and physiotherapists based on four balance components (sensory integration, anticipatory postural adjustments, motor agility, and stability limits). This was undertaken three times a week, for 45 minutes each session over 12 weeks. This programme involved three stages (Block A-first two weeks, Block B-3-6 weeks, and Block C-7-10 weeks) based on the HiBalance training principles and objectives. DTT components were gradually introduced as a progression of the training by starting them after the second week. The HiBalance feasibility study (Conradsson et al., 2014) showed that some participants found the initial training duration of 12 weeks to be too long. For this reason, they amended the final research protocol, limiting training duration to an hour per session, twice a week for 10 weeks, retaining the same overall dosage of training (Conradsson et al., 2012).

The other complex training programme described in the studies was a cognitively challenging Agility Boot Camp programme (King et al., 2020b). This involved 6 different exercise stations (gait training, functional skill training, agility obstacle course, lunges, boxing, and adaptive tai chi). Participants attended each station for 10-20 minutes, total session duration was 80 minutes, three times a week, for 6 weeks. The exercises were chosen because they focused on multidirectional movements, dynamic postural transitions, axial mobility, big movements, and whole-body motor sequencing. DTT was introduced as part of progression by adding cognitive challenges such as counting backward or conversing with the instructor. A study protocol (Peters et al., 2012) described the design of an interdisciplinary, multifactorial group program including physical (balance and gait activities), speech, and cognitive components plus self-management education. The intention comprised participants engagement in 1.5-2-hour sessions, three times a week over 4 weeks, with the difficulty of exercises progressively increased during this time. The protocol described the plan to introduce DTT within gait activities and as a progression of training by integrating speech, cognitive, and physical components at the third and fourth weeks.

Another complex training reported by Wong-Yu and Mak (2015a and 2015b) in their two different RCTs involved a four-week programme of indoor essential balance skill activities and four-week outdoor balance and dual-task activities, applied in weekly two-hour sessions. In phase one of this 2-phase programme, each session included postural re-education, flexibility exercises, strength training with functional tasks, Balance Dance (including music-based exercises focused on weight-shifting, step size, and axial rotation), modified Wing Chun (a traditional Chinese martial arts focus on rapid postural changes and voluntary stepping), and Square Stepping Exercise (comprising eight special patterns with progressive difficulty levels aiming at multi-directional balance and gait skills). In phase two, participants performed flexibility, strength, and functional training, Balance Dance and modified Wing Chun on uneven ground, and advanced balance exercises such as perturbation-based training under different terrains and situations, and fall-prone functional tasks (i.e. pulling or pushing doors, exiting or entering an escalator or elevator, fast walking), daily tasks (i.e. head turns, talking on the phone, shopping) while walking as DTT. Progression of the training was achieved by reducing the participants' base of support, increasing movement speed, amplitude, repetitions, and task complexity (Wong-Yu and Mak, 2015b, Wong-Yu and Mak, 2015a).

Belton (2014) and Smania et al. (2010) trialled a balance training programme including feed-forward and feedback postural control. Belton (2014) applied the training in a one-hour session, once a week over 6 weeks and DTT components were introduced as part of the progression of training (Belton, 2014). Conversely, Smania et al. (2010) introduced focused progression on balance exercises rather than the DTT element of training. Smania et al. (2010) divided the balance training into three different groups of exercises focusing on (1) self-destabilization of the centre-of-body mass (including dual-task component), (2) externally induced destabilization of the centre-of-body mass, and (3) coordination between leg and arm movements during walking as well as locomotor dexterity over an obstacle course. The complexity of the tasks was progressively increased as the patient improved but the improvement level and the type of improvement (e.g. improvement in coordination, locomotion, stability, etc.) were not stated. Participants engaged in the training in 50 minutes-sessions, three times a week for 8 weeks (Smania et al., 2010). Yen et al. (2011) also divided their programme into three categories of exercises: static stance, dynamic weight shifting, and external perturbations. Dual-task components were included within the dynamic weight-shifting exercises (catching the ball thrown from different directions). Training included 30 min-sessions and was applied twice a week over 6 weeks. The progression of training was achieved through increased difficulty by adding more foam pieces and reducing the base of support (shoulder width/partial tandem/tandem) for the static stance category. The progression was not explained for other categories and dual-task components (Yen et al., 2011).

Liao et al. (2015) combined 10-min stretching exercises, 15 min-strengthening exercises, 20-min balance exercises, and 15 min-treadmill walking into a training programme. The training was applied twice a week over 6 weeks. DTT was introduced as a part of balance exercises (catching and throwing balls). The progression of the training was provided by adding more weights during strengthening exercises, increasing the number of repetitions, and increasing the difficulty of exercises, such as increasing the height of the blocks during the stepping-up exercise, increasing the forward/sideward stepping distance during the stepping exercise, holding the squatting position for longer duration during the squatting exercise. The progression of dual-task components was not reported.

Exergaming/Virtual Reality-based Training

Training in virtual environments was undertaken using Xbox Kinect and Kinect sensors (Microsoft Corporation, Redmond, WA, USA) (Vallabhajosula et al., 2017, Shih et al., 2016), and CAREN (a Computer Assisted Rehabilitation Environment by Motekforce Link, Amsterdam, The Netherlands) (Cano Porras et al., 2019). The games and programmes within the virtual environments were developed or chosen depending on the therapeutic goals. While some games (e.g. tilt city, penguin slide, ski slalom, etc.) were not referred to as DTT, some games were, such as bowling, boxing, table tennis (Vallabhajosula et al., 2017); reaching tasks (Shih et al., 2016); tasks within Cradle Reach, Cradle Balls, Cradle Shapes, Road Walk, Road Stand, Forest, and Endless Road environments (Cano Porras et al., 2019). Overall, these studies clearly explained the interventions (games/ environments), 13 of which explicitly referred to DTT.

Vallabhajosula and colleagues (2017) delivered the Kinect games in 30-min's and treadmill walking in the other 30-min's of each 60-minute session. Both treadmill walking and games were performed independently at the participant's home after the first physiotherapist-supervised week. Treadmill walking was progressed by increasing walking speed by 5 to 10% each week with a gradual increase in total minutes walked. Kinect games were performed at the easiest level of games at all times.

In the study by Cano Porras et al. (2019), training comprised 12 sessions with a full assessment session and 11 tailored training sessions of 30–45 minutes each. Shih and colleagues (2016) applied four different exergaming programmes of 50-min sessions, twice a week for 8 weeks. Both Shih and colleagues (2016) and Cano Porras and colleagues (2019) provided the training progression by increasing the challenge level of the games. These challenges were provided by adjusting walking speed, hitting directions, range of motion, target parameters (e.g. number, type, speed of balls), cognitive tasks (e.g. arithmetic operations), amount of repetition of the task. Reported session type was individual in these studies (Cano Porras et al., 2019, Shih et al., 2016).

A sole focus on DTT

Perumal et al. (2017) and Sethi & Raja (2012) applied DTT in two different approaches within each session; (1) fixed priority instruction: participants gave attention on both motor and cognitive tasks all the time, and (2) variable priority instruction: participants gave attention on motor task in the first half of the session, and their attention was focused on the cognitive task during the second half of the session. In Perumal and colleagues' (2017) study, the intervention involved 45-minute sessions, undertaken 3 times a week for 4 weeks. The difficulty of each task progressively increased depending on the participant's ability to master it (Perumal et al., 2017). Sethi & Raja (2012) delivered a training programme of 45-minute sessions, five times a week for three weeks. They did not report the progression of dual-tasks.

Fernandes and colleagues (2015) used a one-hour session of motor-cognitive DTT, twice a week for 6 weeks. They increased the complexity of the exercises progressively by increasing the complexity of cognitive tasks, adding obstacles during gait manipulation activities, and reducing the pause time during gait activities (Fernandes et al., 2015).

Silva & Israel (2019) applied aquatic DTT. The exercises of DTT were performed in a heated (33 °C) pool in 40-minute sessions, twice a week, over a 10-week period. Firstly, the group of participants performed a primary task under single-task conditions, and then new dual-task exercises were introduced as participants progressed.

The other study that involved solely DTT intervention was by Pourkhani et al. (2019). They applied and compared motor-motor DTT and motor-cognitive DTT. As this study is a superiority study, the study is explained in detail in subsection 3.3.8.

3.3.4 Task Combination and Task Types within DTT

The majority of studies reviewed applied both motor-motor and motor-cognitive dual-tasks within one DTT intervention (n=16). While 7 studies (Cano Porras et al., 2019; Liao et al., 2015; Pourkhani et al., 2019; Shih et al., 2016; Smania et al., 2010; Vallabhajosula, McMillion and Freund, 2017; Yen et al., 2011) applied only motor-motor dual-tasks within one DTT intervention, 6 studies employed motor-cognitive dual-tasks within one DTT intervention (Cano Porras et al., 2019; Fernandes et al., 2015; King et al., 2020; Peters et al., 2012; Pourkhani et al., 2019; Sethi and Raja, 2012).

Within the exergames/virtual environment studies, task combinations of the DTT were mostly motor-motor, with only one virtual environment-Endless Road (Cano Porras et al., 2019) that included motor-cognitive dual-task activities. Progression of individual secondary tasks was not clearly explained in the included studies.

Primary balance-related tasks and secondary cognitive tasks were categorized according to therapeutic goals (Conradsson et al., 2012; Fernandes et al., 2015). The primary and secondary DTT activities used in the included studies are described in Table 5.

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Task combinations of the DTT were mostly motor-motor within the exergames/virtual environments, with only one virtual environment-Endless Road (Cano Porras et al., 2019) including motor-cognitive dual-task activities. Progression of individual secondary tasks was not clearly explained in the included studies.

Primary balance-related tasks and secondary cognitive tasks were categorized according to therapeutic goals (Conradsson et al., 2012; Fernandes et al., 2015) and the primary and secondary tasks used within DTT in the included studies are detailed in Table 5.

Balance-Related Primary Task		**Secondary Cognitive Task**		**Secondary Motor Task**	
Category (Conradsson et al., 2012)	Tasks	Category (Fernandes et al., 2015)	Tasks	Category	Tasks
Sensory Integration	Standing on top of a foam mattress with eyes closed, standing under tandem and semi-tandem condition with eyes open or closed, walking on various surfaces.	Verbal Fluency Spelling	Saying fruit, colour, or city names, saying names starting with a given letter Spelling words	Upper limb activities	Reaching, catching, holding, hitting, carrying, throwing an object, reaching a target within virtual environment, Alternating an object with two hands, flexion-extension, abduction-adduction with dumbbells,

Anticipatory Postural Adjustments	Postural transitions (e.g. sit to stand on different chair heights, sit to stand, walk and stop etc.), multidirectional stepping, walking over an obstacle, fast walk, arm alteration,	Auditory discrimination Auditory Stroop Task	Identifying voices, noises. Verbally responding to congruent and incongruent high and low tones	Daily tasks	Doing up buttons, using phone, getting keys out of pocket
Motor Agility	Drawing letters with right/left foot while standing, figure of eight walking, tandem/semi tandem walking, trunk rotation, marching,	Working Memory	Digit backwards and forwards (repeat the numbers dictated by the instructor), Stroop Task (naming the colour of the ink, while ignoring the meaning of the word.		
Stability Limit	Standing with narrow base of support, weight shifting (onto toes and	Visuo-spatial	Description of a picture shown by instructor previously in detail		

	heels), single leg stance,				
		Counting	Counting backward from 200-90		
		Calculation	Simple calculation, answer to simple arithmetic problems as <10 or >10		
		Communication	Listening, speaking, conversation		
		Description of daily activities and routines	Saying the stages of taking a shower		

Table 5:*Task types within DTT in included studies.*

3.3.5 Control Group Interventions

In some studies (n=12) participants in control groups did not undertake any intervention. In three studies, conventional/standard exercise programmes were used as the control group intervention. These exercises involved balance and gait activities, strengthening and endurance activities with warm-up and cool-down exercises (Peters et al., 2012), warm-up, cool-down, and progressive balance exercises (Shih et al., 2016), joint mobilization, muscle stretching, and motor coordination exercises (Smania et al., 2010). Single-task training was the other type of control group intervention in three studies (Perumal et al., 2017; Pourkhani et al., 2019; Sethi and Raja, 2012). Tasks in these interventions were balance exercises focused on different aspects of balance (anticipatory postural adjustments, motor agility, sensory integration, and stability limit). Wong-Yu and Mak (2015) applied upper limb training (flexibility and strengthening, dexterity training, knot-tying practice, and Chinese calligraphy) in their two studies. Other interventions were a speech and communication exercise programme-HiCommunication (Franzén et al., 2019, Johansson et al., 2020), and fall prevention education (Liao *et al.,* 2015).

3.3.6 Outcome Measures and Assessment

The primary outcome reported was a measure of balance in the majority of the included studies (n=19). The studies which have used these outcome measures can be found in Appendix 2. Non-balance-related outcomes varied: gait parameters (n=18), activities of daily living (n=7), quality of life (n=8), anxiety/depression (n=6), physical activity (n=7), motor symptoms (n=8), fall-related (n=9), freezing of gait (n=2), speech-related (n=2), cognitive function (n=12), mobility (n=18). TUG test was the most frequently used test to assess mobility (n=13) and was also described as a balance assessment in one study (Pourkhani et al., 2019). Carer-burden was one reported outcome in a single study (Peters *et al.,* 2012); safety, participants' attendance rate, participants' perception regarding training, and blinding were other outcomes (Cano Porras et al., 2019; Conradsson et al., 2014; Johansson et al., 2020; King et al., 2020). Evaluation of process measures (fidelity and recruitment) and barriers and facilitators for implementation were also outcomes in one study protocol (Leavy et al., 2017).

Follow-up assessments were conducted after completion of the intervention at 1-month (Liao et al., 2015; Pourkhani et al., 2019; Vallabhajosula et al., 2017; Yen et al., 2011), 3-months (Silva and Israel, 2019; Smania et al., 2010), 6-months (Wallen et al., 2019; Wong-Yu and Mak, 2015 (1,2)), and 12-months (Wallen et al., 2018; Wong-Yu and Mak, 2015). All assessments were completed within the participants' ON medication status (approximately 2 hours after taking anti-parkinsonian medication) in the included studies which reported it. Table 6 shows the balance-related outcome measures employed in the studies, along with details on which balance features were assessed and the frequency of their usage.

Balance-Related Outcome Measures	**Number of studies**	**Balance aspect assessed.** **(Dixon et al., 2017; Conradsson et al., 2012)**
Activities-specific Balance Confidence Scale (ABC)	10	Confidence performing different activities without fear of falling

Berg Balance Scale (BBS)	7	Anticipatory postural adjustments, stability limits, sensory integration, dynamic stability
Balance Evaluation System Test (BESTest)	1	Anticipatory postural adjustments, sensory integration, stability limits, dynamic stability
Brief BESTest	1	Anticipatory postural adjustments, sensory integration, stability limits, dynamic stability
Community Balance & Mobility Scale (CB&M)	1	Anticipatory postural adjustments, stability limits
Centre of foot pressure self-destabilization test (CFP)	1	Anticipatory postural adjustments, stability limits
Centre of pressure (CoP) measurement	4	Stability limits
Dynamic Gait Index (DGI)	2	Anticipatory postural adjustments, sensory integration, stability limits, motor agility, dynamic stability
External Perturbation Test	1	Anticipatory postural adjustments, stability limits
Four Square Step Test (FSST)	2	Anticipatory postural adjustments
Functional Reach Test (FRT)	2	Stability limits
limits of stability test (LOS)	2	Stability limits
Modified Figure of Eight Test (MFE)	3	Anticipatory postural adjustments, and everyday walking ability. Individuals walk a figure of eight shape around two cones.
Mini Balance Evaluation System Test (Mini-BESTest)	15	Anticipatory postural adjustments, sensory integration, stability limits, dynamic stability.
Modified Clinical Test of Sensory Interaction and Balance (Mod-CTSIB)	1	Sensory integration,
One-Leg Stance Test (OLS test)	3	Sensory integration, anticipatory postural adjustments, stability limits.

Postural transfer test	1	Anticipatory postural adjustments.
Step test	1	Anticipatory postural adjustments.
Sensory Organization Test (SOT)	2	Sensory integration
Timed-Up and Go test (TUG)	1	Anticipatory postural adjustments, motor agility, dynamic stability (it is a mobility test but was used as balance assessment in one study).

Table 6:*Balance-related outcome measures within included studies*

3.3.7 Perspectives of Participants Regarding DTT Intervention

One qualitative study (Leavy et al., 2017) explored the perception of people with mild to moderate PD regarding a balance training programme. The authors used semi-structured interviews with 13 participants with mild to moderate PD who had undertaken complex balance training on the HiBalance programme. Participants found performing dual-task challenging and so they reported taking one task at a time as an everyday strategy to compensate for their decreased capacity to manage daily tasks requiring a combination of motor and cognitive tasks. As illustrated by the quote from a 66-year-old man: *''You know how you are supposed to do something, but to then get your mind and your muscles to understand that and get it down to your arms and legs, it doesn't work automatically anymore, and that is hard. It's like your brain doesn't keep these things together anymore; it concentrates on the important parts… It's better to take it slowly and surely and then things solve themselves… take it easy so that I can regain my energy and so that my muscles don't get exhausted.''* (Leavy et al., 2017, p. 85).

Dual-task exercises were often considered demanding and resulted in feelings of accomplishment once completed, as reflected by the following comment of a 78-year-old woman: *''Some of the things they showed us, they would say, Do this, then do that, now off you go, and I would think but I will never be able to do that! But it was so exciting to see if you could do it or not, there was suspense, it was amazing…Then when you did manage to call out names and handle the ball at the same time, you felt like Oh, did I just do that? You felt like it was good for your brain as well.''* (Leavy et al., 2017, p. 85)

Although most participants found dual-task exercises challenging and exciting, the meaning of dual task performance could not transfer always to daily life. *''The dual-task exercises, they weren't ones that you do in everyday life, they were a little more specific, and in a way challenging and exciting to do, but not movements that you can say that you have a lot of use for.''* (70-year-old man) (Leavy et al., 2017, p. 85).

These conclusions were in line with the findings of a feasibility study investigating the HiBalance programme, undertaken by Conradsson et al. (2014) who reported that the exercises within Block B and C (including a dual-task component) were reported to be challenging but not too challenging by participants with mild to moderate PD. Participants found the training regimen motivating and stated they would recommend it to others. Two of the participants found training too long.

3.3.8 Superiority Study

There was one quasi-experimental study that explored the superiority of two different DTT types (Pourkhani et al., 2019). They compared the effectiveness of motor-motor DTT (M-DTT), motor-cognitive DTT (C-DTT), as well as a third condition of single-task training (STT) on balance and gait in people with mild to moderate PD. Training was undertaken in 45-min/sessions, three times a week over 10 weeks under supervision by a physiotherapist. Primary tasks were the same for all three groups. They were inclusive of standing exercises incorporating the support of a wall, freestanding tandem stance, single-leg stance, standing on toes, squatting, marching, and undertaking a side-bending exercise, a trunk rotation exercise, and figure of eight walking. In the M-DTT group, participants performed some daily tasks as a motor secondary task such as doing up button, carrying a plate with a glass on top, and transferring coins between pockets or objects like a cell phone between hands while they were simultaneously training balance. Cognitive tasks within C-DTT were counting backward by 3's, memory recall, generating category lists (e.g. fruit, sports, names starting with a specific letter), and simple calculation tasks.

They recruited 10 participants to each group, all at H&Y 2-3 disease stage and aged between 50 to 75 years. Initially, 32 patients participated, with one dropping out of the M-DTT group, and another of the C-DTT group because they did not complete the training programmes. Pourkhani and colleagues (2019) did not report why these two participants did not complete the training programme. So, 30 participants were included the analysis.

There was no significant difference between the groups in clinical and demographic variables at baseline. The mean age with standard deviation (SD) was 67.20±3.79 for C-DTT, 68.9±4.12 for M-DTT, and 67.9±3.78 for STT groups. Mean H&Y stage with SD was 2.80±0.42 for M-DTT, 2.70±0.63 for C-DTT, and 2.65±0.57 for STT groups. MMSE score was higher than 27/30points for all three groups, indicating normal cognition as determined by this measure.

The primary outcome of the study (Pourkhani et al., 2019) was not reported. The assessments were completed by a physiotherapist in a private physical therapy clinic. The authors stated the study was single-blind but not specifically as to whether the assessor was blinded. The TUG test was used to assess balance. Gait parameters (stride length (cm), cadence (step/ min), stride time (stride/s), swing % (% of gait cycle), and stance % (% of gait cycle) were also assessed. The main effects for "Time" were significant for TUG for within-subject comparisons in each of the three groups ($F=530.54$; $P<0.001$). Post hoc within-group analysis showed significant decreases in TUG test time both immediately after treatment and one-month follow-up in all three groups ($P \leq 0.05$). There were no significant effects between time and group for TUG ($P>0.05$). Detailed tabled information regarding this study is presented in Appendix 3. The study concluded that M-DTT, C-DTT, and STT are equally effective for improving balance and some gait parameters, with the positive effect remaining for one month for all three groups.

This study was critically appraised by using Joanna Briggs Institute (JBI) critical appraisal tool for quasi-experimental study via JBI SUMARI software (Appendix 4).

3.4 Discussion

This review aimed to examine the literature concerning task combinations and types within DTT, the outcome measures used for assessing balance, perspectives of pwPD regarding DTT interventions, and whether any studies had investigated the superiority of one DTT over another in improving balance for pwPD.

When the goal of a DTT intervention is to enhance balance individually, it is crucial to select optimally suitable and evidence-based exercises for a primary balance-related task. The majority of the included studies employed similar balance exercises as the primary task within DTT interventions, chosen to achieve specific therapeutic goals (Conradsson et al., 2014). Various aspects of balance, such as anticipatory postural adjustments, reactions to unpredictable perturbations, and inter-limb coordination during walking, are essential for facilitating balance improvement in pwPD (Conradsson et al., 2012). Therefore, it is imperative to choose and design balance exercises in DTT based on an individual's specific needs.

Sensory integration is another important aspect of balance control (Horak, 2006). Virtual environments and games have the potential to provide rich visual and vestibular inputs, thereby enhancing the ability to process sensory information to maintain balance against various challenges (Liao et al., 2015). In a study by Vallabhajosula and colleagues (2017), significant improvements were observed in the decreased centre-of-pressure range in both mediolateral and anteroposterior directions, under both eyes-open and closed conditions. Cano Porras et al. (2019) reported a statistically significant change in Mini-BESTest scores after virtual reality training. Additionally, they found that among neurological cohorts, patients with Parkinsonism and PD engaged in the highest number of treatments (62 and 52, respectively) within three years. This suggests that virtual reality/exergaming can potentially serve as an effective and motivating method for delivering DTT interventions.

Secondary motor tasks mainly involved manual activities (e.g., carrying a tray with glasses, coin transfer, buttoning, etc.) while walking and/or standing. Cognitive tasks varied, including memorizing a list of words, verbal responses, and conversing. Conradsson et al. (2015) demonstrated short-term transfer effects, showing increased physical activity levels and improvements in activities of daily living (reflected in an increased UPDRS-ADL score) after a complex balance training program, HiBalance. This suggests that integrating manual and cognitive tasks within DTT can effectively transfer gains to real-world scenarios.

Including highly challenging balance training in exercise programs has been suggested to enhance balance in pwPD (Allen et al., 2011). Due to the prolonged motor learning process and delayed automatisation in people with PD compared to their healthy counterparts, implementing an intensive, goal-based training protocol becomes crucial for achieving optimal results (Abbruzzese et al., 2016). In the development of an intensive, goal-based, and challenging training protocol, it is essential to consider an individual's potential capability for performing exercises, tailoring the training accordingly (Abbruzzese et al., 2016). The HiBalance program, as applied by Conradsson *et al.* (2012) and others (Fernandes et al., 2015, Peters et al., 2012, King et al., 2020a, Wong-Yu and Mak, 2015b, Wong-Yu and Mak, 2015a), applied a similar protocol with a progression of balance exercises. These exercises involve increased variation, such as decreasing the base of support, manipulating sensory information, and changing movement velocity/direction.

Despite detailed accounts of progression in terms of exercise variation, the majority of included studies did not clearly explain how they progressed secondary motor or cognitive tasks within dual-task exercises. While stating that task complexity increased as sessions progressed, most studies were not explicit about how this complexity was provided (Wong-Yu and Mak, 2015b, Wong-Yu and Mak, 2015a, Smania et al., 2010, Perumal et al., 2017). Silva and Israel (2019) introduced new dual tasks as participants completed existing ones, leaving the progression strategies of secondary motor and cognitive tasks unclear throughout the training course.

DTT is typically administered individually by physiotherapists or sports therapists (Hofheinz and Mibs, 2016). Individual training is favoured due to the potential challenges in supervising each participant during group training, particularly in managing adverse events like falls that can occur under dual-task conditions (Hofheinz, Mibs and Elsner, 2016). In this review, a significant number of studies (n=17) employed group training, demonstrating promising effects on balance outcomes. A feasibility study of HiBalance group training reported a high attendance rate (84.3%) and documented two non-injurious falls during training (Johansson et al., 2020). This suggests that group training may be feasible for individuals with mild to moderate PD.

One study incorporated DTT intervention with unsupervised training sessions (Vallabhajosula, McMillion and Freund, 2017). However, the majority of included studies (n=23) involved participants undertaking DTT interventions under supervision. Previous research has indicated that supervised balance training is more effective than home-based training with the same protocol delivered via DVD, particularly in terms of stride velocity, cadence, balance confidence on the ABC scale, and overall motivation (Atterbury and Welman, 2017). Thus, a supervised DTT program may be more feasible and preferable than an unsupervised, home-based intervention for pwPD. Nevertheless, further studies are needed to explore the effectiveness of home-based DTT interventions undertaken with and without supervision on balance in pwPD.

The assessment of balance in the included studies employed a variety of outcome measures. The most frequently used measure was the MiniBESTest, consisting of 14 items that assess different components of balance (n=15 studies). The MiniBESTest has demonstrated high reliability in terms of both test-retest reliability (ICC≥0.88) and inter-rater reliability (ICC≥0.91) in individuals with PD (Leddy et al., 2011). It evaluates various aspects of dynamic balance, including movement during gait and transfers, external perturbations, and cognitive dual-task performance (Leddy, Crowner and Earhart, 2011).

The second most commonly used clinical measure was the Berg Balance Scale (BBS), which assesses static and dynamic balance in both sitting and standing positions (n=7 studies). The BBS holds clinical validity in the PD population and is a sensitive measure for detecting changes in balance function (Qutubuddin et al., 2005). However, when comparing the BBS with the MiniBESTest, it may not cover the evaluation of each component of balance, such as dynamic gait and reactive control (King et al., 2012). Therefore, relying solely on the BBS for assessing changes in balance may not suffice, whereas the MiniBESTest appears to be useful for detecting changes in different components of balance.

A single qualitative study focused on participants' perceptions of a highly challenging group balance training program (Leavy et al.,2017). Although DTT was reported to raise awareness about participants' weaknesses in common daily tasks, these dual-task activities didn't always transfer to daily life (Leavy et al., 2017). This situation emphasizes the importance of future research intervention designs to yield meaningful real-life results for individuals. Selecting appropriate individual tasks within DTT, such as using a telephone while walking or retrieving keys from a pocket while standing in front of a door, may provide gains that are transferable to real-life scenarios and may be meaningful to pwPD.

The group-based context of the training was noted as reassuring and encouraging. Participation in a group with similar levels of motor impairment allowed participants to feel confident, making group training an essential factor for achieving optimal challenges during the training program. Therefore, when deciding on an intervention design, group-based training may be considered as a supportive approach. The qualitative study offered valuable insights into the perceptions of individuals who underwent the HiBalance program, shedding light on future research designs exploring participants' acceptance of such complex balance training. While the literature encompasses various types of DTT and delivery methods, this study specifically focused on the HiBalance program. Consequently, further qualitative studies could contribute additional insights into different types of DTT from the participants' perspective.

Performing two tasks simultaneously requires divided attention and increased cognitive resources. Engaging in dual-task activities may enhance automatisation independently of the secondary task type. To discern potential differences in the motor learning process between cognitive and motor secondary tasks, exploring and comparing the effects of these two types of DTT could provide valuable insights. In a study by Tedla and colleagues (2017), the effectiveness of motor-motor DTT and motor-cognitive DTT on walking gait parameters in individuals with mild to moderate PD was compared. The conclusion drawn was that motor DTT is more effective than cognitive DTT in improving gait parameters (Tedla et al., 2017).

Similarly, Her et al. (2011) investigated the effects of motor DTT (M-DTT), cognitive DTT (C-DTT), and motor and cognitive DTT (MC-DTT) on balance function in individuals recovering from stroke. They found no significant difference between M-DTT and C-DTT concerning balance. However, the MC-DTT group demonstrated significantly greater improvement in the Korean version of the Berg Balance Scale compared to both M-DTT and C-DTT groups. Additionally, a significant difference was observed between MC-DTT and C-DTT in terms of body sway (Her et al., 2011).

Pourkhani et al. (2019) conducted a study comparing the effectiveness of M-DTT and C-DTT on gait and balance in individuals with mild to moderate PD. Their comparison included single-task training, revealing that M-DTT, C-DTT, and single-task training were equally effective in improving balance for people with mild to moderate PD. The researchers used GPower 3.1, a freeware program for sample size analysis, considering α=0.05, effect size: 0.5, and analysis power of 0.8 to estimate the sample size. However, they did not explicitly explain the assessment method used for this estimation. The estimated sample size was 30 participants, but it remains unclear whether 30 participants should have been recruited for each group or in total.

To assess balance, Pourkhani et al. (2019) employed the Timed Up and Go (TUG) test. While the TUG test is commonly used to quantify functional mobility, it was not specifically developed to assess balance (Lopes et al., 2016). Despite a meta-analysis supporting the sensitivity of the TUG for balance and gait stability assessment (Schoene et al., 2013), it may not capture every component of balance, such as processing sensory information to maintain balance. The minimally detectable change on TUG for pwPD was found to be 3.5 seconds (Huang et al., 2011). According to Huang et al. (2011), these results may not represent a true change, despite the study demonstrating an improvement in the TUG score. Additionally, the clinical significance of these results is uncertain, as there is no evidence regarding the minimal clinically important change on TUG for PD. Therefore, while this study may contribute valuable insights to the field, its results should be cautiously considered in the context of expectations from these types of DTT interventions in a clinical setting.

The equivalent effect of both DTT and single-task training may be attributed to the working mechanism of DTT. It is postulated that dual-task practice automates the performance of individual tasks by eliminating demands on central resources responsible for a central bottleneck (Ruthruff et al., 2006). Therefore, the applied training intensity becomes a crucial factor in achieving automatisation of the balance task (Kiss et al., 2018). However, standardizing intervention intensity poses a challenge. A systematic review revealed that there was no reported validated instrument or method used to measure the intensity of balance exercises in 148 clinical trials (Farlie et al., 2013). Consequently, applying DTT with a different intensity from that in the Pourkhani et al. (2019) study may yield different results. While this study contributes to the field of DTT interventions in the literature, there is a need for more research to understand whether there is a superiority between M-DTT and C-DTT in improving balance in pwPD.

3.5 Conclusion

This scoping review reveals a diverse landscape in the literature concerning the delivery form, task combinations, and task types within the DTT interventions. A progressive and challenging training program that targets specific components of balance, such as anticipatory adjustments and sensory integration, appears to be both feasible and effective for enhancing balance in individuals with mild to moderate Parkinson's disease. The utilization of exergaming/virtual reality holds promise in providing a sensory-rich environment for delivering DTT.

The literature displays a wide range of intervention frequencies, durations, and session durations, making the standardisation of intervention protocols challenging. While an overall progression strategy is evident in the majority of studies, the specific progression strategy of individual secondary tasks or the introduction of new secondary tasks during the training remains unclear. There is a need for more well-documented training protocols within research studies to enhance clarity and comparability.

Selecting suitable outcome measures to assess various aspects of balance is crucial for identifying patients' capacity to perform individual tasks and establishing a progressive, patient-tailored DTT program. Among the included studies, the MiniBESTest emerged as the most commonly used outcome measure, covering a broad spectrum of balance components. Incorporating an additional outcome measure, such as the BBS, to evaluate sensory integration alongside the MiniBESTest could offer a more comprehensive overview of balance with enhanced sensitivity to change.

There is only one qualitative study that explores participants' perceptions regarding DTT. Therefore, there is a need for further qualitative studies to provide different insights regarding different types of DTT from the participant perspective.

This scoping review reveals that, as of May 2020, there is only one study that has explored the superiority of M-DTT and C-DTT in terms of improving balance in pwPD. However, this study has some methodological limitations, including a small sample size and a non-randomized trial design. Consequently, there is a clear need for further studies to understand whether there is a difference between M-DTT and C-DTT in enhancing balance outcomes for individuals with mild to moderate PD, to ultimately guide evidence-based practice.

Chapter 4: Exploring the key features of a dual-task training programme and acceptability of a future trial design to investigate the effects of dual-task training on balance outcomes in people with Parkinson's disease: A qualitative study.

4.1 Introduction

This chapter describes the background for this study, its aims and objectives, methods of the study processes, study findings, discussion of the findings with the current literature, and conclusion.

4.1.1 Background

The scoping review (Chapter 3) showed that there is a variety of delivery forms, task combinations and task types within DTT interventions. Despite some studies (Conradsson et al., 2014, Johansson et al., 2020) evaluating some feasibility aspects such as acceptability and safety of interventions, relatively little is known about the acceptability of DTT approaches from the perspective of pwPD and their supporters. Some studies did not provide an explicit training protocol and most publications stopped short of reporting a replicable dual-task training procedure, which may lead to a different understanding of the training approach and variability of its implementation by therapists. The scoping review highlighted the importance of transparently reporting training protocols, especially where these are supported by improvement outcomes of clinical trials. In addition to the variability in intervention designs, clinical trials varied in their setting of delivery as well as their use of blinding, control groups, and adopted balance-related outcome measures. The significance of balance outcome measurement to pwPD and their supporters also remains largely unknown and has not yet been reported in any clinical trial or qualitative literature. Physiotherapists are typically the professional group that implement DTT within physiotherapy programs but the feasibility, acceptability, and perceived effectiveness of DTT interventions is largely unknown from their perspective.

Although the existing literature goes some way to informing a DTT intervention design and outcome measure option, lacking is information from the perspective of pwPD and those professionals who will undertake the DTT. The scoping review revealed only one qualitative study that explores participants' perceptions regarding an existing intervention that was trialled, but no information about patient involvement and engagement at the stage of designing the study or the intervention (Leavy et al., 2017). There is a clear need for further qualitative studies to provide insights regarding different types of DTT from the perspectives of both pwPD, their supporters, and physiotherapists.

There is an increasing prominence on patient-centred research, because this type of research engages patients in recognizing unfulfilled needs and clarifying the design and conduct of clinical studies (de Wit, Cooper and Reginster, 2019). Therefore, the perspectives of patients are essential in health research. The project steering group of the NHS Health Research Authority (2023) defines people-centred research as emphasizing what is significant for the majority of individuals participating in and impacted by research outcomes. Mutuality is one of the key elements to achieve people-centred research according to them (Health Research Authority, 2023)

Qualitative studies can provide an opportunity to patients and their carers to share their experiences regarding undertaken treatments (de Wit et al., 2019, Gibson et al., 2004). Qualitative studies can be used at different stages of clinical trials (Gibson et al., 2004). Findings of such studies at pre-trial stage can be a way to keep mutuality in research by allowing researchers to be led and informed by the patients' and carer's needs without holding all the power in trial designing processes.

A systematic review mapped the different aspects of qualitative research run at different points of RCTs in the field of health (before, during, or after running RCTs) (O'Cathain et al., 2013). They found that qualitative research addressed different aspects of trials such as design, process, interventions, and outcome measures used. The authors suggested that qualitative studies conducted at pre-trial stage can increase the impact of this work on trials in terms of development of the intervention content and delivery, acceptability of the intervention both in principles and practice, and trial participation (O'Cathain et al., 2013). Nevertheless, only a limited number of studies encompassed a broad spectrum of the health field in terms of participant population, interventions, and outcomes (28%, 82/296) at the pre-trial stage.

The scoping review highlighted one key qualitative study (Leavy et al., 2017) that explored the perspective of 13 pwPD recruited to a RCT evaluating a DTT intervention in balance management (Conradsson et al., 2015). Whilst this study offers some insight of the perceptions of pwPD it was limited in that it was conducted at post-trial stage, with the potential for recall bias.

Around 88% of males and 79% of females with PD designate a supporter/caregiver to provide support in handling the challenges associated with the condition (Prizer et al., 2020). These caregivers offer a diverse spectrum of both direct and indirect assistance with emotional support, daily care, and facilitating activities that contribute to the overall well-being and autonomy of PD patients (Prizer et al., 2020, Leroi et al., 2012). It is therefore important to understand supporters' perspectives regarding DTT interventions and how they might support pwPD to engage with the intervention. As DTT interventions are commonly delivered by physiotherapists in clinical settings, their perspectives on the optimal use of these interventions for effective balance results are also important. The key qualitative study (Leavy et al., 2017) is limited by not seeking the views of supporters and physiotherapists regarding DTT interventions.

Therefore, there is a clear need to undertake a qualitative study at the pre-trial stage of a clinical trial.

4.1.2 Study Aim and Objectives

Aim:

This qualitative study aimed to inform the design of a feasibility RCT that will assess the feasibility and acceptability of two DTT interventions to improve balance in people with mild to moderate PD, by exploring the views of pwPD, their supporters, and physiotherapists with an interest in PD management.

Objectives:

1. To explore the perspective of people with mild to moderate PD, supporters, and physiotherapists regarding DTT interventions, informed by their past experiences and examples, shared in the interviews, from the scoping review

(e.g., primary balance and secondary task options, duration of the training, etc.).

2. To explore the perspective of people with mild to moderate PD, supporters, and physiotherapists regarding outcome measurement sets which would be relevant for inclusion within the feasibility RCT, informed by the results of the scoping review.

3. To explore the perspective of people who are supporters of people with mild to moderate PD regarding delivering the DTT intervention, and their role in any home-based elements of an intervention.

Table 7 shows the study objectives and factors are considered to achieve.

Objectives	Factors
1. To explore the perspectives of people with mild to moderate PD, their supporters, and physiotherapists regarding dual-task training intervention, informed by the results of the scoping review.	1) Type and combination of dual-task training (cognitive-motor), 2) Duration of the intervention (e.g., number of weeks) 3) Frequency of the intervention (e.g., number of sessions per week) 4) Length of session 5) Progression of intervention (standard progression or participants-tailored 6) Level of support with intervention (remote supervised, physiotherapist-led, semi-supervised or independent practice) 7) Location (home, clinic, community)
2. To explore the perspectives of people with mild to moderate PD, the supporters, and physiotherapists regarding outcome measurement	1) Proposed primary and secondary outcome measures and any considerations.

sets informed by the results of a scoping review.	2) Rating method (completed by clinicians or self-reported, remote or face-to-face) 3) Location of assessment (home-clinic) 4) Duration of follow-up and intervals for outcome measurement
3. To explore the perspective of people who are supporters of people with mild to moderate PD regarding delivering the dual-task training intervention, and their role in any home-based elements of an intervention.	1) Type and combination of dual-task training (cognitive-motor) 2) Duration of the intervention (e.g., number of weeks) 3) Frequency of the intervention (e.g., number of sessions per week) 4) Length of session 5) Progression of intervention (standard progression or participants-tailored 6) Level of support with intervention (remote supervised, physiotherapist-led, semi-supervised or independent practice) 7) Location (home, clinic, community) 8) The level of support from supporters (coaching, supervising, acting like an exercise buddy, etc.) in a home-setting training

Table 7: *Study objectives and considered factors to achieve.*

4.2 Patient and Public Involvement and Engagement (PPIE)

Involving patients and the public in research is intended to benefit the research process by ensuring research is relevant, conducted ethically, participant friendly, and the results made accessible and provided with sensitivity to trial participants and the wider public once the trial is complete (Bagley et al., 2016).

Positive impacts of PPIE have been reported in all trial stages from the development of user-focused research questions to implementation and disseminations of the study results (Brett et al., 2014). Also, PPIE importantly may contribute to an increase in recruitment rates and aid researchers in designing research protocols and selecting relevant outcomes (Domecq et al., 2014). Although this qualitative study is not a clinical trial, PPIE is also important to decide optimal conditions for a qualitative study.

Two people who are supporters of pwPD and representatives from Parkinson’s UK southwest branches were invited for PPIE activities. Meetings were conducted on two separate occasions via Zoom. Their opinions were asked regarding preference about the data collection method (individual interviews/focus group), interview duration, and approaches for interviews (telephone, online platforms, face-to-face). Both participants highlighted the importance of the time of the day to conduct interviews, stating that pwPD often prefer morning times as they are more active during the “on” phase of medication following the first dose since waking. They cautioned that evening times (anytime later than 4 pm) may not be good but depended on the individual. They recommended to ask potential participants their preferences about the timing of an interview, before arranging a meeting. They stated that telephone interviews may work for pwPD, but they should be short, lasting around 20 minutes. They shared their opinion about online interviews by saying that they would be good for pwPD for both individual interviews and focus groups. They highlighted that whilst some pwPD may be concerned about confidentiality when using online platforms, it should be offered as an option.

The number of people in a focus group is another important point they raised. They commented that many people might prefer to one-to-one interviews, if this option was available to them. However, if the only option is focus group, they felt that it might be better with a maximum of 4 people because some may feel anxious when they see so many people on a screen. It is known that anxiety symptoms have high prevalence among pwPD (Caillava-Santos et al., 2015). There was recognition that the duration of a focus group may expected to be longer than a short individual interview since two or three people contribute to the conversation. Also emphasised was the importance of an acceptable duration of the interview/focus group as pwPD may also experience fatigue and speech problems. Longer sessions are also more likely to coincide with medication wearing off periods, with associated increase in symptoms, including anxiety (Caillava-Santos et al., 2015). PPIE participants suggested that two 20 minutes-slots with a break for focus groups and 30-40 minutes for an of an individual interview, may be acceptable.

Another question was whether the attendance of a carer/partner at the interviews a good idea is. The representatives stated that pwPD would most likely prefer to attend alone. Also, one of the representatives highlighted that the word “carer” was not favoured by most pwPD, suggesting the use of “supporter” instead. Positive emotions can be correlated with motivation, while negative emotions are correlated with avoidance (Chen et al., 2020a). Acknowledging the potential impact of language on emotions, and subsequent impact on motivation to engage in studies, “supporter” was used for both interviews/focus groups and all patient-facing documents in the qualitative study (WP2) and feasibility study (WP3).

4.3 Research Approach

This qualitative study design was conducted with a critical realism philosophical stance (Haigh et al., 2019). Critical realism allows flexibility whilst at the same time providing a structure around the study objectives, which helps to inform the choice of methods and tools for data collection, recruitment strategies, data analysis and interpretation of the findings. A detailed discussion of this critical realism approach is provided in Chapter 2.

4.3.1 Data Collection Method

Qualitative research is an adaptable approach that uses different data collection methods for different purposes (Gill & Bailie, 2018). Interviews, focus groups, and observations are common qualitative data collection methods that are traditionally conducted face-to-face. Interviews can provide in-depth knowledge about perspectives, opinions, and experiences of participants on a certain matter (Gill et al., 2008, Gill and Baillie, 2018).

Pragmatic adoption of interview versus focus group approaches

Semi-structured interviews include some key questions which can give the researcher autonomy to explore certain ideas, while giving the participants guidance about what to talk about (Gill et al., 2008, Adeoye-Olatunde and Olenik, 2021). They are commonly used in healthcare research as they enable researchers to more deeply understand a certain phenomenon from the individuals' subjective perspective (Adeoye-Olatunde and Olenik, 2021). The current study aimed to understand different ideas about how acceptable DTT is from the perspective of pwPD, their supporter and physiotherapists responsible for delivering this intervention. It also explored options for potential assessments to be used in the feasibility trial. The study objectives were suited to open-ended questions about these issues, with inductive probing of responses (Guest et al., 2017). Therefore, a semi-structured interview approach was considered suitable.

Focus groups involve moderated group discussions on a particular topic (Leung and Savithiri, 2009). They can provide rich and in-depth data and highlight agreement or inconsistencies within and between groups (Gill & Baillie, 2018). Focus groups may provide richer data from participants who have experienced the topics raised in the focus group and those who have not, enabling different ideas and perspectives to be expressed. The group interaction within focus groups allows participants to comment on each other's experiences (Duggleby, 2005), question each other's opinions, and generate new ideas (Lambert and Loiselle, 2008).

While both semi-structured interviews and focus groups were deemed appropriate for achieving the study objectives, the focus group approach was ultimately chosen as the preferred method due to its inherent advantages. The original plan involved conducting three separate focus groups for each participant population (pwPD, supporters, and physiotherapists), each comprising five participants. However, logistical challenges arose from participants' diverse schedules and the fluctuating "on/off" phases in medication times, making it challenging to convene people for a focus group. The impact of the COVID-19 pandemic added another layer of complexity, particularly in coordinating research activities with busy physiotherapists. Faced with these time constraints and practical challenges, it became imperative to explore alternative data collection methods.

Since both focus groups and individual interviews were considered suitable options by PPIE participants, the decision was made to employ both semi-structured interviews and focus groups to ensure comprehensive data collection from all participants.

Online methods for focus group and semi-structured interviews

Although focus groups and interviews are conventionally conducted face-to-face, evolving digital technologies have transformed how researchers communicate and engage participants and collect data, potentially reducing the problems of face-to-face methods (Gill and Baillie, 2018, Janghorban et al., 2014). Digital technologies can provide different opportunities to qualitative researchers, including collecting data via messaging or online chat (Lobe et al., 2020). This qualitative study was undertaken during the first and second wave restrictions in the COVID-19 pandemic in the United Kingdom. All data therefore was required to be collected remotely, through an online videoconferencing platform.

There are different online videoconferencing platforms. These include Zoom, Skype and Access Grid (Thunberg and Arnell, 2022). Zoom was chosen for use in this study as it supported real-time audio and full-motion video, was user-friendly, the University held a licenced account, and it allowed for unlimited call durations with more than two participants. It is acknowledged, however, that Zoom also had some potential disadvantages, such as reduced audio/video quality, sound delays, and privacy concerns (Lobe, Morgan & Hoffman, 2020).

The privacy of participants and confidentiality of data are important issues to consider when conducting online focus group/interviews. Zoom offered a range of security features that helped ensure the safety of the online focus group discussions. The following security features were used in the conduct of this study: the host created a password for participants to join the session and activated the option to 'wait for the host' to join the session to prevent unauthorized access. These options enabled easy identification of those attempting to join the session and ensured that only expected participants were admitted.

Another benefit of Zoom was that it provided a convenient and secure way to store recordings of the discussions. The researchers stored the data in their Zoom Cloud account, eliminating the need for third-party storage options (Archibald et al., 2019).

It is important to address the attitude of pwPD to the use of digital technologies. Factors that affect this attitude can be categorised as accessibility in terms of affordability and availability of the internet/broadband and devices, and people's knowledge and ability to use it (Andrews et al., 2019). People who have no access may be digitally excluded from benefitting its advantages both in public health and health research. A national survey showed that 96% of the UK population have internet access, and laptop, mobile phone, and personal computer access were relatively high across most demographic characteristics, with internet connection in households with adults aged over 65 years estimated at 80% (Sounderajah et al., 2021). Although accessibility is an issue which can limit inclusivity in research, these numbers indicate that use of digital technologies is potentially a feasible data collection method within the UK.

PwPD too often have access to the internet, mobile phones and computers and feel comfortable using these to reach information and social support (Riggare et al., 2021). Representatives of the southwest branches of Parkinson's UK mentioned that during the national Covid-19 lockdowns regular online group social chats were undertaken, with some also participating in online exercise sessions. Whilst acknowledging that pwPD living in the southwest may not be representative of the broader population, this information was important to inform the decision to use Zoom for the focus groups, all of which were held with pwPD living in the southwest.

Finally, the University of Plymouth (UoP) provides all students with free individual accounts for Zoom use. The decision to use Zoom for this qualitative study was therefore made based on its security features, convenience, and accessibility.

4.3.2 Ethical considerations and consent

Ethical approval was granted for this study by the Faculty of Research Ethics and Integrity Committee, Faculty of Health, University of Plymouth (Review Reference: 2021-2512-1877).

4.3.3 Recruitment

PwPD, and their supporters were recruited via local Parkinson's UK groups. An email advertisement (Appendix 5) was prepared, and the group administrators shared this via email with potential participants who had indicated they were happy to be contacted regarding research-related activities. If interested in participating in the study, potential participants were asked to send an expression of interest email to a designated UoP email account. The relevant participant information sheet (Appendix 6 and 7) was sent via email, followed by an invitation to an online meeting via Zoom to answer any questions and to understand their eligibility for the study via a further email.

For the recruitment of physiotherapists, an email invitation was sent via the Parkinson's UK Excellence Network administrator. Additionally, an email advertisement was shared with students, known to be physiotherapists in practice, and who were currently studying master's or PhD programmes in the School of Health Professions (UoP). Those interested in participating in the study were asked to send an expression of interest email to a designated UoP email account. An email was sent to them containing a participant information sheet (Appendix 8), along with an invitation to discuss the study, ask questions, and express concerns before the formal invitation.

4.3.4 Consent

For digital interviews both written or oral consent may be used. If a verbal consent is used, it is suggested that separate consent should be obtained (Gray et al., 2020). Participants should have an opportunity to discuss the information sheet and consent process, making sure that they are clear about the research process before the interview begins (Thunberg and Arnell, 2022).

Potential participants with PD who attended the Zoom session had the opportunity to ask questions before being asked whether they agreed to continue with the eligibility screening process. Those who agreed (via verbal consent, Appendix 9) were then screened.

After completing this screening process, eligible participants were presented with two options to provide their consent to participate in the study. The first option was to provide their consent immediately after the screening process, while the second option allowed them time to think and decide before meeting again in another online consent session. All potential participants opted to participate in the study and provide their consent immediately after the screening process. The consent-taking session was recorded with the participant's permission and stored in the university-licensed OneDrive account for safekeeping.

4.3.5 Participants

Participants were purposively selected from people with mild to moderate PD, supporters (e.g., a partner, adult children, or a carer), and physiotherapists who deliver DTT intervention. In qualitative research, purposeful sampling is commonly employed to identify and select information-rich cases linked to the phenomenon of interest, which in this case was people with experience of PD (Palinkas et al., 2015).

Purposive sampling is applied with a set of criteria for participant selection. The criteria for pwPD were established based on their motor and cognitive abilities, potentially relevant to their balance function. Through the use of maximum variation sampling, the aim is to capture the widest range of perspectives possible (Suri, 2011). Various variations that could potentially influence pwPD perspectives on undertaking DTT interventions and their acceptability, such as age, disease duration, or experience with DTT, may differ among pwPD. The goal is to select pwPD without restrictions on these variations, including all eligible individuals with different variations, to encompass a broader range of perspectives.

Similarly, the aim is to select supporter participants, including partners, caregivers (regardless of whether they are paid or not), and children where possible. Eligible physiotherapists were also sought, with diverse experiences in different settings and delivery methods (e.g., telerehabilitation use, community and clinic settings, individual and group applications, etc.). The objective is to gather comprehensive and meaningful data with this strategic sampling approach to achieve the study objectives.

- Eligibility criteria

Potential participants with PD were included if they:

- Have mild-moderate PD severity, which is the population of patients in whom we anticipated the DTT programme might be most relevant.
- Are cognitively able to understand questions and engage with the interview discussion.

The Hoehn & Yahr (H & Y) scale is a commonly used scale for describing symptom progression in PD (Hoehn and Yahr, 1967), and pwPD can often be aware (on the basis of feedback from their neurology appointments) of which H & Y stage they are.

The Mini Mental State Examination (MMSE) (Folstein et al., 1975) is the most cited cognitive impairment measure in the scoping review The use of these scales for screening potential participants in person by a clinician was not possible because time and space was limited, and a face-to-face assessment would add additional participant burden. Instead, individuals were asked to provide their H & Y score if they knew it. For those pwPD who did not know their scores, a brief screening form was created with items adapted from the MDS-UPDRS, as this there is evidence to support its validity to rate PD (Goetz et al., 2008). The screening form also included balance-related questions for assessing the disease stage and cognition-related questions to assess cognitive status from the MDS-UPDRS (Appendix 10). Potential participants were also screened against this form to confirm eligibility for this study.

- Had the ability to communicate in English (because of lack of translation opportunity), as demonstrated by the level of fluency of the conversation held during the online screening process.

They were excluded if they:

- Had a severe speaking or hearing problem to ensure that participants were able to effectively communicate, determined during the online screening process.

Potential participants who were the supporters of pwPD who were willing to participate in the study were included, if they:

- Were an English speaker.
- Deemed themselves to be cognitively able to effectively communicate.

Potential participants who were physiotherapists were included if they:

- Were Chartered physiotherapists, with experience in neurological rehabilitation, and had used DTT approaches as part of their intervention with a minimum of three pwPD in the last year.
- Were an English speaker.

As, a group of five or six participants is considered preferable for a focus group (Barbour and Kitzinger, 1999), the target was for approximately five participants to be recruited to each of the three focus groups (namely pwPD, supporters, and physiotherapists).

4.3.6 Interview/Focus Group Process

After obtaining consent, participants were asked about their availability for a focus group session. Since each participant had different schedules, various options for days and times were offered to them. For the pwPD, two different focus groups were held with two participants in each group (n=4), and two individual interviews with the other two pwPD. For the supporters, one focus group was conducted. For the physiotherapists, two individual interviews were held. All sessions were conducted via Zoom for the convenience of participants and to comply with COVID-19 restrictions.

The approach to gaining consent and scheduling the interview, enabled the researcher to build rapport before embarking upon the interview. This also facilitated understanding of potential language barriers that could affect the flow of the session. This was especially relevant given the challenge faced with English as a second language (Squires et al., 2020), in particular with participants with Parkinson's related speech impairment (quiet speech with little facial expression to aid non-verbally), and/or strong regional dialect and accents.

Following discussion with the PhD supervisory team, it was agreed that the researcher (NC) led the semi-structured interviews/focus groups, with support, when necessary, by a member of the English-speaking PhD supervisory team (LB) to help paraphrase questions or to use follow-up questions when required. The intention was to maintain the general flow of communication and to optimise probing for more in-depth information. Before the beginning of each session, verbal consent was obtained from all participants to record the session. Recording the sessions enabled the researcher to played back them whilst viewing an auto-captioning system to assist with interpretation of what was spoken. Whilst on some occasions the auto captioning system within Zoom was helpful in deciphering communication, on many occasions this system also struggled to interpret the spoken word in the presence of regional accents.

To ensure consistency across interviews/focus groups but also individualisation relative to differing sub-groups (physiotherapists, supporters, and pwPD), separate interview/discussion guides were developed for each subgroup, containing key questions mapped to the study objectives. These questions were asked (Appendix 11), with further prompt questions when necessary to elicit clearer responses or keep participants engaged (e.g., "Can you explain that further?"). Participants were also given a lay summary of the scoping review before their interview or focus group session to provide them with a basic understanding of DTT and the literature surrounding it. This helped to facilitate the flow of the session, especially since participants with PD and supporters were not required to have prior experience with DTT as an eligibility criterion.

The individual interviews lasted 50 minutes on average (regardless of group), while the focus groups lasted around an hour. Following conclusion of the data collection sessions, participants were thanked for their time and the recording manually stopped. Participants were reminded about the data storage security in place.

4.3.7 Data handling and management

Data was handled in compliance with the Code of Good Research Practice, which sets out the UoP's commitment to research integrity (https://www.plymouth.ac.uk/research/governance/research-ethics-policy). All collected data will only be used for the purpose of this study by the research team. This includes the online verbal consent records which were securely stored in a separate university licensed OneDrive folder. In line with this policy, UoP will keep data about participants for 10 years after the study has finished and then will destroy them permanently.

Participants' names were removed and replaced with a code to provide anonymization of all information so that participants were not identifiable during the study or when sharing the results. Once the audio-recordings were transcribed, participants were no longer able to withdraw from the study, so their personal contact details were securely deleted from our records. At this point, the transcribed data were anonymous. Direct quotes included personal information were depersonalised. These depersonalised quotes were used when reporting on the study results, in this dissertation as well as they will be used in journal articles and other dissemination materials.

The research team is the only entity that has access to personal contact information, audio recordings, or indirectly identifiable information within the original transcripts.

4.3.8 Data Analysis

Framework analysis was developed in the 1980s for analysing qualitative data in applied policy research by Ritchie and Spencer (Goldsmith, 2021). Although framework analysis also known as 'framework method' or 'framework approach' was built for generating large-scale policies, it is popular in health and medical research (Gale et al., 2013).

This method is not subjected to any particular philosophical or theoretical approaches (Gale et al., 2013). It was relevant for the analysis of results from this qualitative study because of its flexible nature. This method originally reflects the accounts of the people studied that is inductive, also, it starts deductively from the study's pre-set aims and objectives (Pope et al., 2000).

Overall, the framework analysis method allows for a structured and systematic approach to analysis, enabling the phenomenon under study to be explored from multiple perspectives (Gale et al., 2013). In doing so it enables similarities and differences in the participants' experiences and perspectives to be identified for the total sample and between sub-groups (pwPD, their supporters, and physiotherapists). It is important to explore which aspects of the phenomenon are similar, which aspects are different for the three sub-groups, and how all these aspects can be merged. The framework method allows these questions with its structure and analytical nature. In this study, the deductive approach of framework analysis was chosen due to the specific aims and objectives set out in the research design.

The first stage of the qualitative data analysis was to write verbatim transcriptions of the recorded data generated from the interviews and focus groups. Different pseudonyms were used to code each sub-group of participants so as to clearly see the data accounts separately and compare and synthesise them. "P" represented, participants with PD, "PT" represented physiotherapists, and "S" represented supporters.

Following the initial transcription, and then cross-checking this with Zoom's auto caption generator, an English-speaking assistant with a local regional accent and experience of undertaking transcription (CL) independently checked the transcripts with the audio recordings and resolved any errors. All transcripts were entered into NVivo 12 which is a qualitative computer software programme designed to assist with qualitative analysis (QSR International, NVivo 12 (released in 2018)). The five stages of framework analysis were then applied to the data: (1) familiarization, (2) identifying a thematic framework, (3) indexing, (4) charting, and (5) mapping and interpretation of data (Ritchie and Spencer, 2011).

The familiarization stage involved reviewing the data and becoming familiar with its content. The thematic framework was developed deductively based on the research aims and objectives, and themes were identified and indexed in the third stage. The fourth stage involved charting the data into a framework matrix, with each row representing a theme and each column representing a participant group. Finally, the data was mapped and interpreted to draw conclusions and insights from the findings.

1. Familiarization

The researcher must be familiar with the whole dataset to get an overview before starting the process of sorting data (Ritchie & Spencer, 2011). This stage provides the researcher with a purposeful understanding of the data (Goldsmith, 2021). The transcripts were first read, then the recordings listened to while re-reading the transcripts to make sure understanding was clear. During the re-reading process notes were taken of initial thoughts about the data relative to the study objectives. Another member of the supervisory team (LB) who attended the interviews/focus groups also made notes from the records independently. In a supervisory session, an in-depth discussion with LB was held to discuss initial thoughts around the dataset, decide the potential themes, and move forward with the next stage of analysis.

2. Identifying a thematic framework

Framework analysis is a powerful approach that enables transparent comparison and contrast of different views (Collaço et al., 2021). To this end, it is essential to create a thematic framework or index that organizes the data according to key themes and subthemes. In cases where there are multiple targets or sub-groups, separate thematic frameworks may be necessary. However, it is preferable to keep a common framework for different groups, as this can help identify both common and distinct themes immediately (Ritchie & Spencer, 2011).

To create a common framework for the qualitative data analysis, an iterative process was conducted by the researcher and a member of the supervisory team (LB). The process began with an inductive approach that drew on initial thoughts generated during the familiarisation process, as well as the interview and focus group discussion guides that included the pre-set issues. This initial framework was then reviewed and refined through further discussions, resulting in a final version that was used for indexing, charting, and mapping the data. This approach allowed for a structured analysis that could identify common and distinct themes across the different participant groups, while also remaining flexible enough to capture any unexpected insights that emerged. This frame was broad and descriptive to address study objectives. One transcript from each participant group was selected and the initial frame was applied to this independently. Some new categories and sub-categories were identified through applying the frame. The frame was shared, and potential categories/sub-categories were discussed with the relevant extracts from each transcript. After reaching an agreement on required framework amendments, a revised and more structured framework was developed that could be applied to the remaining transcripts. This final framework incorporated the themes that emerged from the familiarization stage and was deemed to be comprehensive enough to capture all relevant themes, while also being concise and manageable enough to be used effectively in the data analysis process. Once the revised framework was developed, it was applied to all of the transcripts using the indexing and charting stages of the framework analysis process.

3. Indexing

Indexing is a crucial process in the framework analysis, as it involves systematically applying the created framework to the data in all transcripts (Ritchie & Spencer, 2011). This linking process helps to establish connections between the data components and the framework, thereby aiding the interpretation of the data. In order to effectively index the data, it is important to carefully consider the meaning of each item in the framework (Goldsmith, 2021). This involves making decisions about how each frame item relates to the data and how it can be used to categorize and organize the data.

The UoP offers site-licensed QSR NVivo software for qualitative data analysis (https://liveplymouthac.sharepoint.com/sites/WorkAtHome/SitePages/QSRNvivoCA.aspx). NVivo version 12 was used for the indexing process. After importing all transcripts into NVivo, each passage was read and linked to the relevant section of the frame, referred to as a "node" in NVivo. Nodes and sub-nodes were created, allowing for a common frame to be applied to all data. NVivo's ability to display extracts from different participants linked to a specific node in one screen was particularly useful. An example of how indexing was accomplished in NVivo, along with extracts linked to a specific node, can be seen in Figure 7 and Figure 8.

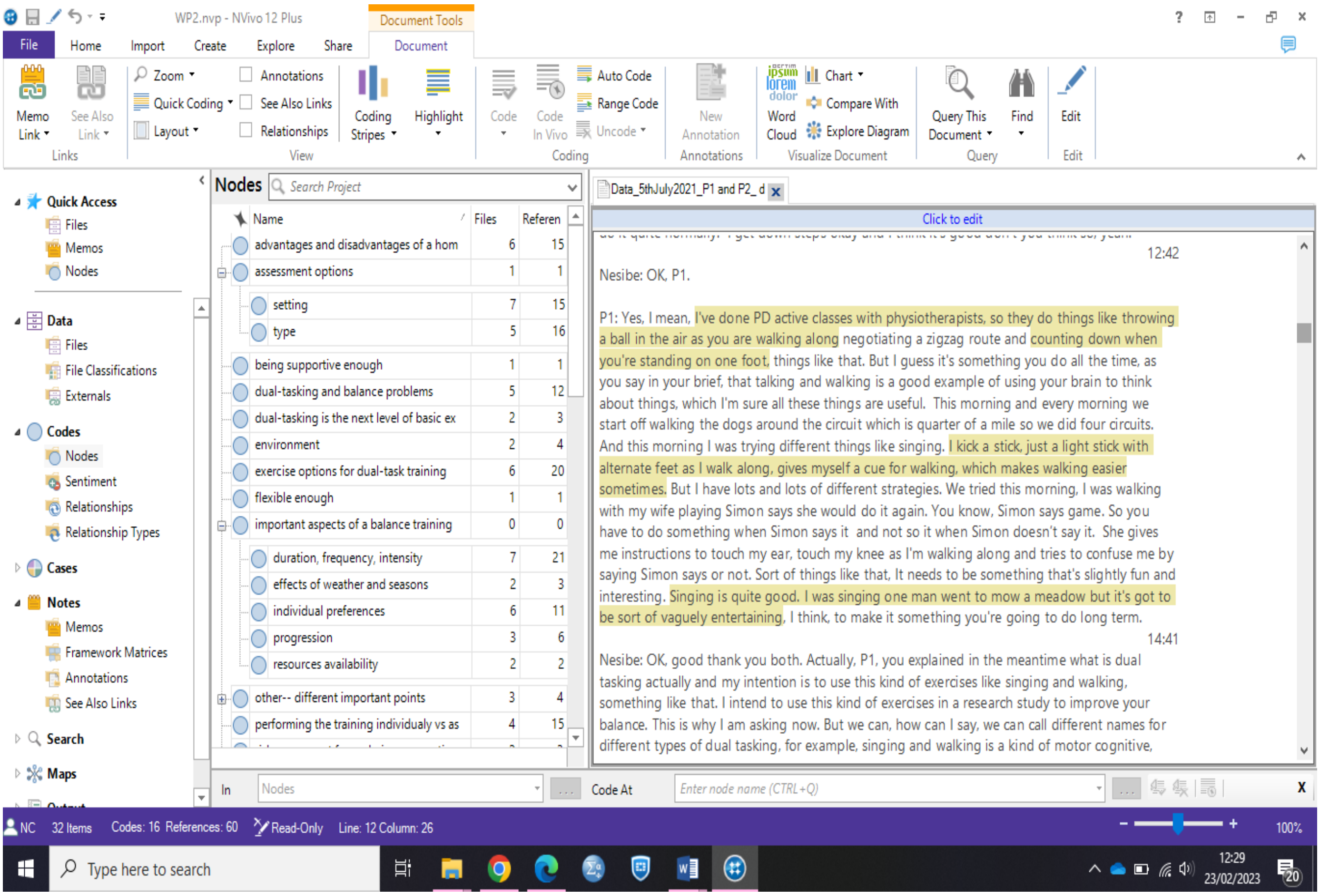


Figure 7: An example of data indexing in NVivo.

During the indexing process, each common and unique node from each group's data were identified, leading to the creation of sub-themes and themes. This process allowed for a comprehensive exploration of the data, highlighting both similarities and differences across the participant groups. As each extract was linked to a specific node, it was easy to see how each theme and sub-theme emerged from the data. The nodes were then grouped and coded to create the sub-themes, which were then synthesized to generate the overarching themes.

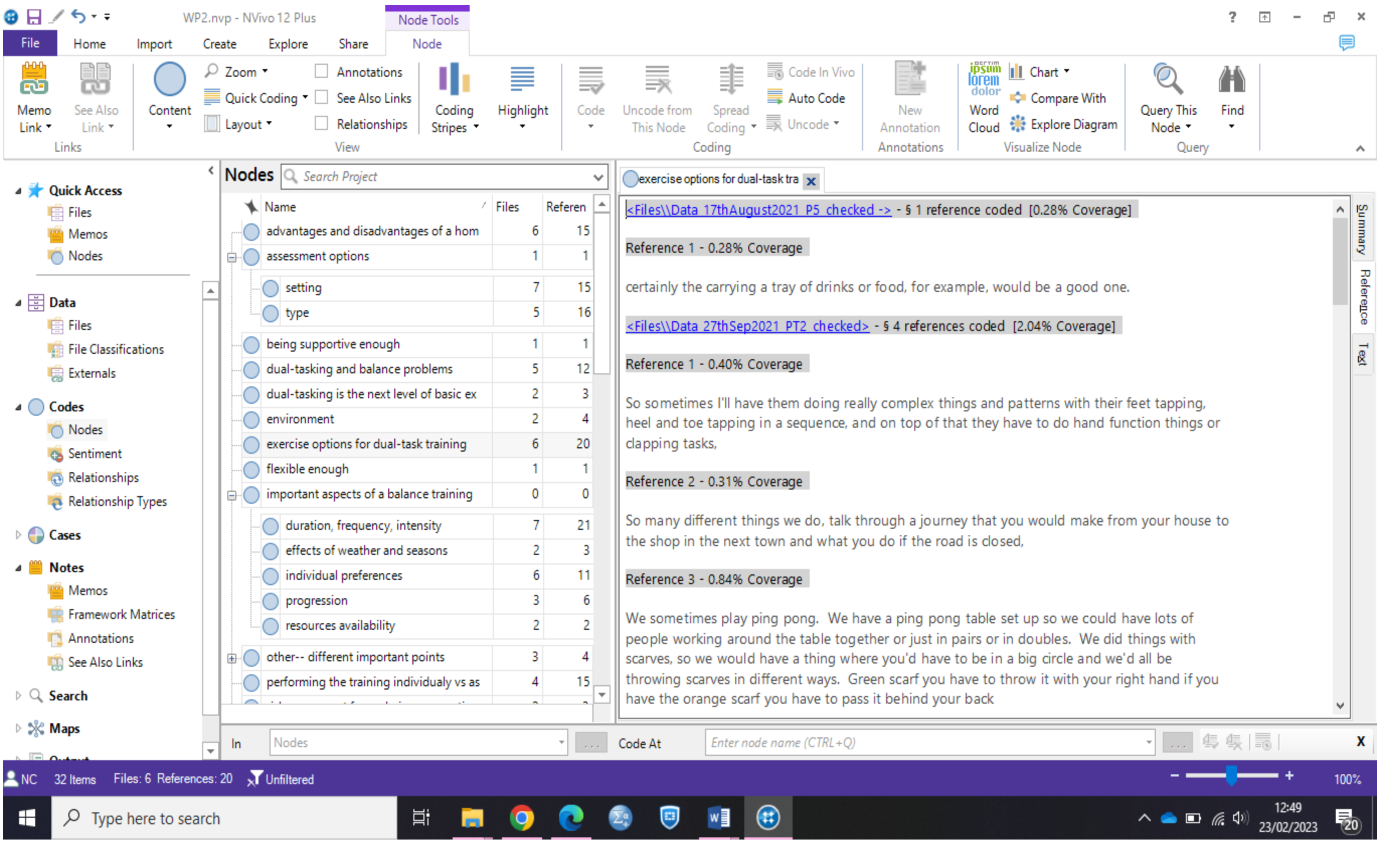


Figure 8: An example of extracts from different participant groups in NVivo.

4. Charting

The charting process is the way in which data is summarised from each transcript, enabling the data to be examined systematically and in totality (Goldsmith, 2021). For this process, a matrix was created by adopting a thematic approach (for each theme across all respondents) (Ritchie & Spencer, 2011). The indexed data was thematically summarised by using the common matrix, looking at the patterns regarding nodes and sub-nodes. These patterns helped to develop sub-themes and themes.

5. Mapping and Interpretation

This step aims to bring together all key learnings from earlier stages (Goldsmith, 2021). This stage is important to map connections between themes to explore causalities and relationships (Gale *et al.,* 2013). Through this stage, the opinions from each participant group were contrasted, patterns were searched for, and potential explanations within the data explored (Ritchie & Spencer). All of those processes provided an overall picture and enabled interpretation of the data around both the initial study objectives and the emerged themes (Ritchie & Spencer, 2011). Interpreted data are presented in the “Findings” section (section 4.5).

4.4 Findings and Discussion

This section presents (1) a brief introduction with the characteristics of the participants, and (2) interpretation of focus group and interview data from pwPD, physiotherapists, and supporters within themes.

4.4.1 Introduction and Participant Characteristics

The study involved ten participants, consisting of six pwPD, two supporters, and two physiotherapists.

Seven pwPD initially expressed interest, but one was excluded due to being diagnosed with a different neurodegenerative disease, not PD. Only two supporters demonstrated interest in participating, both meeting the eligibility criteria, attending the focus group sessions. Among the four physiotherapists who expressed interest, one did not respond to follow-up emails and lost contact. Another physiotherapist, due to personal circumstances, could not arrange a suitable time within the restricted recruitment period for this study.

The data were collected through three focus groups, each consisting of two participants, and four individual interviews. Five of the six pwPD were male. Their ages ranged from 50 to 68 years old, with an average disease duration of 5 years. Individual information of pwPD is presented in Table 8. The two supporters were family members (a wife and a daughter) of one of the participants with PD. Both physiotherapists had expertise in neurological rehabilitation, with one currently leading regular exercise classes for pwPD and the other serving as a clinical lead with experience in community settings.

Participants ID	Gender	Age	Disease duration	Receiving balance rehabilitation in last 6 months	Having experience with Dual-task Training
P1	Male	64 years	5 years	No	Yes
P2	Female	68 years	2 years	Receiving physiotherapy	No
P3	Male	48 years	4 years	No	No
P4	Male	50 years	4 years	No	No
P5	Male	56 years	12 years	No	No
P6	Male	54 years	3 years	No	No

Table 8: *Demographic information of participants with PD*

4.4.2 Themes

The common matrix and charted data with the themes and sub-themes are presented in Appendix 12.

Theme 1: Dual-Task Training as an engaging approach and its impact on participation

This theme explores the factors and aspects that make DTT engaging and how it may impact participants' participation in the training.

One of the key study objectives was to gain a deeper understanding of the elements that make DTT acceptable to pwPD. The findings revealed that engagement with the training is a crucial factor, which can be influenced by various parameters. Specifically, the study identified that creative, enjoyable, and challenging tasks can increase engagement, but it is important to ensure that these tasks are tailored to individuals' capacity and confidence levels.

Subtheme 1: The secondary task: Creating a challenge or a facilitator.

Recent research has explored the motivators and barriers to engaging in exercise training for pwPD. Schootemeijer *et al.* (2020) found that physical discomfort with exercise can be a barrier to starting and maintaining engagement. Patient self-efficacy, which is the person having confidence and believing that they are capable enough to perform the tasks, was another factor shown to affect engagement with the exercise programme (Schootemeijer et al., 2020).

Secondary tasks may be a determining factor for the challenge level of DTT. PwPD and supporters offered their ideas about what tasks they would find challenging, and a physiotherapist noted that some patients may struggle with dual-tasking. As illustrated by the quotes below, some participants found that performing two tasks simultaneously was challenging as it could distract their focus from the primary task.

> *"I also tried spelling the names of cities or birds as I walk along. That tends to take my mind off the walking and makes walking more difficult." (P1)*

> *"Getting dressed and getting my foot caught on a garment and then nearly falling over. That's the kind of thing that happens these days that never used to happen…" (P5)*

> *"They get frustrated when they can't do two things at once because nobody ever walks around a room and not does anything else." (PT1)*

Some pwPD and supporters described that secondary tasks could become a facilitator, being helpful in improving balance or walking activities, describing it as a form of 'cue'.

> *"Singing is useful for walking because you can do it, you can walk in time to the singing and it's a cue. So, singing makes it easier, because it's sort of part of the rhythm." (P1)*

> *"I kick a stick, just a light stick with alternate feet as I walk along, gives myself a cue for walking, which makes walking easier sometimes." (P1)*

> *"Having to balance on the bike and multitask with the iPod on top of the bike and trying to do both at the same time. I think using the different parts and actually having to think it through has definitely helped his balance, I think." (S2)*

In line with the findings of Schootemeijer and colleagues (2020), this qualitative study pointed out the importance of the physical capacity of pwPD in terms of participation. For example, pwPD commented that the secondary task should be challenging enough to require concentration to use their full capacity and stimulate their interest, but not so difficult as to feel overwhelming or discourage their participation. The quotes below illustrate the importance of difficulty level with ideas about what is engaging.

> *"I think that just talking while you're walking is relatively easy and not particularly challenging, and for that reason perhaps not so beneficial as something which you're pushing your cognitive aspect of it to a limit that then interferes with your walking." (P1)*

> *"…Simon says it's a good game to play when you're walking, because if somebody is asking you quick fire questions until you start to get confused, that makes it more difficult and that's more of a challenge to keep the autonomous walking whilst you're doing that rather than complex cognitive tasks." (P1)*

From the physiotherapists' perspective, ensuring appropriate level of challenge in the task was crucial. Some participants from each group stated that adding any type of secondary task to the main motor task is a challenge itself and that may make the dual-tasking the next level of a traditional balance training programme.

> *"You know, the level of challenge…you can challenge the motor, or you could challenge the cognitive component of it. And I guess that's probably what I think about dual tasking." (PT1)*

> *"So once people have learned their basic exercises, the next level of maybe dual tasking is to mess the exercise up in some ways to make it more complex." (PT2)*

> *"…if he's thinking about things or if he's trying to do another thing. It's multitasking, yeah, that would be the challenge adding more things in." (S2)*

Overall, by finding the right balance of challenge, participants can feel engaged and motivated to continue with the DTT.

Sub-theme 2: Combining enjoyment and benefit in DTT.

This sub-theme highlights the importance of incorporating enjoyment and benefit into the design of DTT.

According to a recent research, enjoyment is a crucial factor for exercise participation (Chen et al., 2020a). This finding is in line with literature showing that people's decision to commit to participation can be influenced by their level of enjoyment, as they are more likely to avoid activities they find boring and reinforce those they find interesting (Teixeira et al., 2021). This reflects the thoughts of the two physiotherapists in this qualitative study, who emphasized the need to consider patients' perspectives when selecting exercise types for specific therapeutic goals. One physiotherapist noted, for instance, *"I think dual tasks are more interesting as well as having therapeutic benefits as a whole" (PT1)*.

During the interviews, it was found that the choice of the secondary task is crucial in determining the level of engagement and interest for the participants. Secondary tasks can be either motor or cognitive. Common cognitive tasks used in rehabilitation programs or research include singing, spelling the name of a city or animal, or engaging in conversation. On the other hand, motor tasks like throwing a ball can be used as a secondary task. Regardless of the type of secondary task used, participants agreed that the tasks should be enjoyable, engaging, and diverse enough to maintain their interest and motivation to continue the training. For instance, one physiotherapist with experience in delivering dual-task activities in regular exercise classes highlighted the importance of making the training fun and challenging. She provided examples of both motor and cognitive tasks that she found to be effective in achieving this goal:

> *"Talk through a journey that you would make from your house to the shop in the next town and what you do if the road is closed…sometimes I'll have them doing really complex things and patterns with their feet tapping, heel and toe tapping in a sequence, and on top of that they have to do hand function things or clapping tasks." (PT1)*

> *"We try and get it as really good and strong and precise and find the nice rhythm and then I say okay keep the size, keep the rhythm, now I want you to list these things, and we have so much fun with the cognitive tasks." (PT1)*

PwPD also reported enjoying dual-task activities aimed at improving their physical abilities such as walking and cycling. Some stressed the need for creativity in keeping the interest going, and that diversity in the secondary task would be important. For example, one participant (P4) mentioned that the inclusion of music made the training more fun and motivating. Another participant (P1) suggested incorporating games or competitions to make the training more engaging. Different examples were given:

> *"Spelling words is quite a good one, I guess. Just to sort of keep your mind going, because there's an awful lot of words you could choose to spell. You will never run out of words, but you would soon run out of cities and countries and animals." (P1)*

> *"Singing is quite good. I was singing one man went to mow a meadow, but it's got to be sort of vaguely entertaining." (P1)*

> *"I've got the indoor bike with which I'm still trying to do the effort and be a little bit creative rather than just pedalling at the same speed. So, it's a bit like spinning and a bit like training and also, I'm multitasking by trying to change my music to match the speed I want to go to as well." (P4)*

Supporters also talked about the possible effect of pwPD' interest and diversity of the tasks on maintaining their concentration.

> *"…added music, he'd concentrate so much more on music, especially if it's something he likes… He'd be singing along and then he'd have to concentrate on both to get it all done." (S1 & S2)*

> *"Whereas with the TRX* (commercial physical exercise equipment) *there's lots of different exercises you can do that allow you to exercise different parts of your body whilst maintaining your balance all the time." (S1)*

Overall, the discussions underlined that dual-tasking can be an engaging and interesting activity in itself, as people may find it interesting to perform two different tasks simultaneously that they may not ordinarily perform. Thus, incorporating dual-tasking into exercise routines may enhance the motivation to participate and continue with the training. If an exercise is enjoyable, diverse, and interesting for the participants it may not only increase adherence (Teixeira et al., 2021) but may also maximize the potential benefits of the training. Therefore, it was apparent that DTT may be an acceptable intervention for both physiotherapists and pwPD in terms of enjoyment, potentially contributing to increased attendance rates.

> *"I think also dual tasks are more interesting as well as a whole, as well as having the benefits therapeutically. They're more interesting for the patient to be doing sort of two things at once." (PT1)*

> *"If they were interested in sports, even they may never play basketball, but that might be something that they'd be interested in doing. And through that you can increase their balance, or their arm control, or their standing balance, or their movement abilities. We all know we know ourselves, if we're interested in something, we'll do it." (PT1)*

Another important aspect of successful DTT is progressive overload (Conradsson et al., 2012), especially important from the perspective of physiotherapists. Progression can be achieved by increasing the challenge level of the individual task, changing the exercise environment, changing the rhythm of the training, or increasing the session duration. One supporter highlighted the importance of progression, suggested different ways, such as by regularly changing both the primary and secondary tasks. Systematic review evidence shows that adding variety and interest to the training within the context of a well-structured and highly challenging progressive DTT can lead to improved outcomes for pwPD (Allen et al., 2011). Other PD studies have similarly shown that pwPD felt progression of training regimens was motivating (Conradsson et al., 2014).

> *"I have to start somewhere, so I started off with simple and safe. And as he moved through the task, I think he is managing that okay, let's make it a little bit harder." (PT1)*

> *"I'll maybe get them first of all for 30 seconds to work on their normal motor activity that they're familiar pattern they get it going. And we try and get it as really good and strong and precise and find the nice rhythm…" (PT2)*

> *"So, to start off with he was balancing on the ball side and then he'd got the flat base. Then he progressed so that we turned it and you're balancing on the*

base and obviously you're on a ball, so you have to literally keep up. I found it very good." (S1)

"So, we kind of started from the gym ball and balancing and doing all the shoulder exercises and putting your arms out and all of that and then raising one leg and trying to maintain your balance…" (S1)

One way to keep pwPD engaged in their training is to provide an intense workout. One physiotherapist suggested that the intensity of training may have a better impact than the frequency or volume of sessions. She believes that working hard, intensely, and then taking a rest can led to a bigger impact:

"Intensity, I feel, has a much better impact than frequency or volume. Because I firmly believe if you work hard, really intensely and then have your rest, you'll have a bigger impact. The other thing is patients see the progress quicker, are much more motivated and actually feel this is working for me, so I'm going to do it again. "(PT1)

Undertaking DTT as a group activity may provide some additional benefits in terms of motivation, social interactions, and peer-support, (Claesson et al., 2020) along with the training effects. One physiotherapist (PT2) emphasized the advantages of group training and gave an example of how the dynamics within the group may contribute to positive results. For instance, group training creates a sense of community and support among participants, which may increase their motivation and engagement with the training. In addition, participants may learn from each other, and the trainer can provide individual feedback and guidance based on the group's needs. A mixed-method study explored the perspectives of pwPD and physiotherapists regarding group-based programme which incorporated multitasking by integrating a music intervention (Pohl et al., 2020). Similarly, their participants believed that being together was one of the key factors for successful training. Also, they stated that they gathered after the programme for a coffee where they discussed Parkinson's-related issues, illustrating how group training may also facilitate friendships.

However, individual preferences and abilities may vary within a group, and this may affect the level of engagement and benefit obtained from the training. One physiotherapist highlighted the advantages of group training and gave an example of how the group dynamics may contribute to positive results:

> *"They only learn a little bit at a time to take away with them. But they also then learn from each other in the classes as well…We vary whether we have it muted or unmuted because sometimes it's really nice when we're all doing things and shouting out together because there's quite a lot of fun, you know when we do the dual task and the cognitive tasks it's more fun if everyone's doing that together out loud…" (PT2)*

Although most of the pwPD found group training more fun and motivational, some preferred one-to-one training:

> *"… but my instinctive reaction is that the group would probably be more fun than one to one?" (P1)*
>
> *"I feel the same doing PD Active classes* (regular exercise classes led by specialist physiotherapists for PD) *because of the social aspect of it it's more motivational." (P2)*
>
> *I've always been a bit of a lone exerciser. I don't have a strong preference, but if I was to express a preference, it would be an individual one…" (P5)*

To maintain engagement in group training, it is essential to consider each participant's individual condition and abilities, but this may be difficult in group exercises where abilities vary (Pohl et al., 2020). For example, one pwPD shared that some members of their exercise group were at a more advanced stage of the disease which presented challenges for the physiotherapist for keeping everyone motivated and finding a balance between difficulty of the dual-task activity and individual abilities. The participant emphasized that this individualization made the group training more enjoyable and beneficial for everyone. One pwPD explained this with a good example:

> *"I think it might even be a bit more complicated than that. So, if you put everybody together and split everybody up in a group by ability, you know, I can walk a mile, you can walk two miles, you can walk three miles. On that morning on that day, you meet at eleven o'clock in the morning, how I'm feeling could be completely different to how I feel at one o'clock or when I*

filled out the form. So, you have to differentiate the activities you are going to do, even within that class, even though they can all run three miles." (P4)

Taking part in an exercise class seemed acceptable to most of the pwPD and physiotherapists because it was felt to facilitate interactions among pwPD which may contribute to their motivation, enjoyment, and engagement with the training (PT2, P1 & P2). However, an important consideration for individuals with PD would be the right time of the day for scheduling an exercise class; this could be a constraint for some pwPD: *"I think longer time, I would want the flexibility to do things in my own time, to set aside an hour twice a week for myself and my partner probably." (P1).* Overall, these findings highlight the importance of considering individual needs and preferences when designing and implementing DTT programs for pwPD.

Sub-theme 3: Training as part of daily life

This sub-theme explores the importance of incorporating the training into the patients' daily lives, considering their individual interests, weather and season, duration, and frequency of the training session, as well as the meaningfulness and functionality of the exercises.

Making the training exercises meaningful or functional to the patients is crucial in keeping them engaged, and to allow transfer of real world benefits (Soke et al., 2021). One physiotherapist emphasized the significance of this aspect and how dual-tasking can provide both the meaningfulness and therapeutic effect of training.

> *"My whole aim with any patient really is to get them to engage in what they see as meaningful and have a therapeutic background to it… I guess that's dual tasking in some respects, putting it into the functional situation…" (PT1)*

Sometimes this meaningfulness can be provided with the DTT itself. This may be a usual daily life functional activity, a sport activity, or a hobby that patients can enjoy and feel comfortable doing.

> *"I've done things like patients hoovering. In their homes. And that is dual tasking really when you think about this, where they're trying to stand, and they want to do something to help in the home…" (PT1)*

“What they can do if they're gardening, cooking, just doing housework, how they can incorporate some of the principles so they're still getting that 20-minute, high intensity, challenge themselves and get them know do their cognitive tasks, while they're out for a walk…” (PT2)

PwPD emphasized the importance of perceiving potential benefits of the training, both in terms of symptom management and improvements in daily life. Low expectations from a training program can act as a barrier to participation, according to a review (Schootemeijer et al., 2020). Conversely, knowledge and beliefs about the positive effects of exercise on symptoms and general health can serve as a motivator for participation and engagement in the training. For example, a study by Rosenfeldt et al. (2022) surveyed pwPD to explore the factors associated with participation in a community-based exercise program called Pedalling for Parkinson's. The study found that pwPD believed that cycling improves their PD symptoms and cognition, provides a sense of well-being, and has scientific evidence supporting its effectiveness in managing PD symptoms. These personal beliefs and knowledge were found to be positively correlated with participation in the programme (Rosenfeldt et al., 2022).

To ensure engagement and participation in dual-task training, it is crucial to demonstrate the practical benefits of the training on patients' daily life. This way, pwPD can better understand the value of dual-tasking and remain motivated to continue the training. For instance, a physiotherapist can emphasize how improving balance control through DTT can help patients perform daily activities with greater ease and confidence, such as getting dressed or doing household chores. This approach can help patients experience the results of the training in a more meaningful and tangible way, which can improve their adherence to the program.

“It needs to be meaningful in the sense that when they're doing the task, that they see the value of it to encourage their improvement.” (PT1)

A pwPD also stated the importance of the meaningfulness of an activity to improve participation in training. They need to see those potential meaningful benefits because “there are so many different things where balance comes into play” (P5).

“The only impediment to getting people involved in the programme like that would be to make them see the potential collateral benefits rather than just

perceive that I'm going to get better at standing on one leg whilst one's humming Dixie. But you're also going to get better at getting in and out of the shower, getting dressed, doing the hoovering, whatever it might be…" (P5)

To ensure that the training is meaningful, it is important to consider the individual condition and their preferences. Physiotherapists play a crucial role in identifying the appropriate training type that is tailored to the needs and capabilities of each patient. For instance, choosing tasks that pwPD feel more confident in performing can increase their motivation and sense of accomplishment. Moreover, understanding the patient's daily routines and challenges can help to design exercises that simulate or improve relevant activities of daily living.

"When I see them one to one, they get a few very specific exercises based on how I've assessed them to go away with and learn and to work on at home to really work with it." (PT2)

"…So, I guess the people who chose to do it will be more motivated and maybe more confident in their own physical ability." (PT2)

Feeling confident or having the ability to perform a task can come from a person's pre-morbid activities and interests. For instance, some pwPD find singing to be a fun and beneficial task. However, for others this may be more challenging and less enjoyable. The need to consider individual preferences and abilities was highlighted by Paul and colleagues (2021) who found that if pwPD had already engaged with any kind of exercise routine, they were likely to be willing to add another session of exercise. They also highlighted that the preference of exercise type may be influenced by gender. While most of female participants in their training preferred multimodal exercises to add to the exercise routine, male participants preferred strengthening exercises (Paul et al., 2021). PwPD in this PhD study shared their different life experiences showing how those factors may affect the results of performing different tasks:

"Where if you said to me you've got to run 10 miles by the end of the month, I wouldn't really like that. If you said you've got to cycle 50 miles by the end of the month, I'd be quite happy with that. That's tapping into individual's personal things" (P4)

“I'm not a computer whiz and I'm an outdoors person. I use computers every day in work, but I'd rather go outside and go for a cycle, go sailing, rather than sit inside and play with your machines.” (P6)

The influence of weather or season on the choice of training can be an important consideration for pwPD because they can affect a person’s motor and non-motor symptoms (Rowell et al., 2017), and influence engagement with exercise (Forkan et al., 2006). Therefore, these considerations are important when designing an exercise training. For instance, during winter or rainy seasons, indoor exercises like exergames or other forms of indoor workouts may be more practical and enjoyable. Similarly, gardening might be a more enjoyable and meaningful activity during the summer. Therefore, considering individual preferences and the season or weather can help facilitate engagement in meaningful and enjoyable training.

“Wii balance games, which I think, it is hard to assess how I think, I haven’t played it for a long time, and I should do. Last time I played it balance was not so much of an issue as it is now. So, it’s something I definitely should do and perhaps will do more in the winter… Something I know I should be doing and haven’t been because it's summer and I’ve been out gardening and doing things.” (P1)

The duration and frequency of a training program are important considerations for both patients and physiotherapists (Hecksteden et al., 2018). Patients' responses to individual sessions can play a role in determining the appropriate duration and frequency of subsequent sessions. For example, one physiotherapist (PT1) reported that although she typically conducts one-hour, one-on-one sessions with her patients, she sometimes works for less than an hour if the patient cannot manage a full hour. Conversely, if a patient responds well to a session, the physiotherapist may decide to extend the session or increase the frequency of subsequent sessions to maximize the therapeutic effect. Ultimately, the duration and frequency of a training program should be tailored to the individual needs and abilities of each patient, with the goal of achieving the greatest possible therapeutic benefit.

“The frequency…I probably only see patients once a week. Those are the ones that I feel are really responding to therapy and there are other ones that I need to see once a week because they're changing quickly. So, I need to

keep my therapeutic intervention up with that change. So, if I feel that kind of a little bit stagnating, I might move them to every two or three weeks." (PT1)

Also, pwPD may want to see the potential of the sessions in terms of its effectiveness and those factors may be important from their perspectives.

"I think that if people have got an active lifestyle outside of therapy sessions, then two or three, three times a week would be manageable. Anymore and again, you're likely to get people starting to default. Any less and people would be likely to be sceptical about the benefits." (P5)

"I think it's going to be long enough to feel, worthwhile and not too long to feel intrusive or onerous. Thirty minutes would be fine for me. I think that any longer than that would tend to put some people off. Any shorter than that people would probably default more often than attending. So, it's going to be long enough to feel worthwhile." (P5)

To enhance the integration of training into the daily lives of pwPD, one physiotherapist (PT1) emphasized the importance of completing training sessions in a flexible and feasible way. She (PT2) keeps a strict 10-week programme, which includes a one hour, one-to- one weekly session, and 20 minutes daily for patients to exercise on their own. She suggests that patients can divide a 20-minute session into two 10-minute sessions or complete the whole session in one go according to their own schedule. This approach provides patients with the flexibility to create their own training routine and see it as a manageable task that can be integrated into their daily life. Her perception was that this can increase adherence to the training and improve the therapeutic effect in the long run.

PwPD emphasized the importance of their working status and usual activities in their daily routine. They considered it essential that the training program is achievable and does not interfere with other commitments. The conclusion was that both the duration and frequency of the training sessions are crucial factors in deciding the time for it. This allows them to plan and integrate the training into their daily routine, potentially making it more feasible and sustainable in the long term.

"Two or three times a week. It depends how much on other life activity people are doing." (P5)

“Half an hour…Time, I still work full time. I don’t work like five days a week, but half an hour I could give up easy, but an hour it would be a struggle.” (P6)

PwPD often experience fluctuations in their symptoms throughout the day, which can be related to medication (DeMaagd and Philip, 2015). When their medication wears off, they may struggle with severe symptoms affecting both their physical and cognitive abilities and may tire more quickly (Caillava-Santos et al., 2015). Consequently, the timing of training sessions is important to ensure sustained participation and maximum benefit from the training. Some pwPD reported that the only reason they had difficulty performing dual-tasking was due to being in the "off" phase of medication during the performance, underscoring the importance of timing in planning and scheduling training sessions.

“Actually, multitasking and balancing tends to be fine, it is just when my meds go off that’s when I start to struggle.” (P4)

“I think there's an element of timing that in order for it to be beneficial, it needs to be when the person is on and not experiencing severe off symptoms because I don’t think it would work. I think they would tire very quickly if they were off. He wouldn't have the cognitive function. He gets the brain fog.” (S2)

A study showed that exercise is one of the most reported management strategies for wearing off symptoms for pwPD (Mantri et al., 2021). It may be valuable to discuss the exercise options in terms of individual capacity to engage with the training and potentially help to reduce wearing-off symptoms. One participant with PD gave an example:

“I do Pilates not yoga, same as P3. But recently I’ve had to do some of the sessions when I’ve been off my meds. So, I’ve had to do it lying on the floor otherwise I’d probably fall over, but normally my balance is really, really good.” (P4)

Sub-theme 4: Different sorts of support

This sub-theme emphasized the role of supporters and role of physiotherapists.

To ensure the successful participation of pwPD in a training program, support from others can be valuable (Quinn et al., 2010). The discussions held indicated that this support can come from different sources and individuals and may involve various roles. For instance, partners or family members talked about assisting the participants in performing tasks and providing help in case of any adverse events that may happen during the session. This type of support was thought to be particularly important when people have physical or cognitive difficulties that require additional assistance. One study found that pwPD who experience higher cognitive symptoms and motor impairments are more likely to identify a carer (Prizer et al., 2020). Of note, the participants in this qualitative study commented that the support person does not necessarily have to be a family member or partner; it could be anyone willing to provide the needed assistance.

> *"But I can certainly see some of the people I've met with their condition needing a fairly large space and needing somebody else, some kind of support." (P5)*

> *"…they can check that they are doing what they should be doing safely. Or they haven't totally misunderstood what they've been asked to do. If they want to go along and do that, I don't know, but ideally, I would like the option to take them with me to some of the things." (P4)*

Physiotherapists also emphasized the importance of involving a carer or family member as a support system to ensure that essential information regarding the training, its objectives, and its benefits are fully understood by both the patient and the supporter. They suggested that this support can be particularly helpful in ensuring that the patient performs the tasks correctly, achieves the desired targets, and obtains the maximum benefit from the training. In some cases, the supporter may even assist with the training, providing physical assistance or encouragement to the patient during the training sessions. Participants felt that this support can play a critical role in the success of the training program, particularly for patients who may require more extensive support due to their physical or cognitive condition.

> *"I do think carers and family members and spouses and friends are very well placed because at the end of the day, they're there twenty-four hours a day and I'm not, for the hour. And I think it's so important that we include their observations, but don't have them as the main observer…" (PT1)*

> *"I think it's really valuable in this sort of setting to have a member of family or a carer come to the sessions, that we do so that there's both a sense of continuity if they are working on into home…" (PT2)*

The supporters also can contribute to the decision-making process to tailor an appropriate training programme. They can provide a more comprehensive perspective about the disease symptoms and needs than information gathered from a patient report (Prizer *et al.,* 2020). One physiotherapist said:

> *"I do ask them to bring somebody with them as well for that (one-to-one assessment), a member of the family or somebody who would maybe exercise with them in the community afterwards as well. So, they have somebody who's there with to listen to what I have to say to them, but also to maybe give some more information. Sometimes people forget to say things and then the other person has a little bit more to offer." (PT2)*

In the meantime, in this sort of support emerges a collaboration:

> *"…also, a sense of collaboration. You know it's not just me working with this person that we're all working together, and some people really like that some people love to have a member of family, or whoever come and be part of it and see what they're doing and share it and work on it with them." (PT2)*

> *"Some people think they are going along just to support somebody when actually when they look back at it, they used it just as much as the other person, but they just didn't imagine in that way when they started." (P4)*

Some participants from each group expressed the view that supporters can contribute to make the training more fun and more motivational. For example, this could be as a training buddy by just being with them or more actively involved in the training, adding in some element of competition.

“I think having the carer or supporter there is vital…they can motivate the person…” (P4)

“I think he'd be more motivated to do it, if mum was there.” (S2)

“Yes. I think he'd enjoy doing it, and we would we get a bit competitive.” (S1)

The view was expressed that it is important to consider individual situations and preferences when involving a supporter in the training program. While some pwPD said they would find having a supporter distracting and prefer to train alone, others felt they may benefit from having someone else involved.

“I don't use them if I feel the individual can manage on their own two feet, literally, because I think that's an unnecessary distraction.” (PT1)

However, also highlighted was the importance of considering the preferences and wishes of the supporter, as they may not always wish to participate in the training program. Commonly, supporters of pwPD are their family members or spouses and caring responsibilities can affect their daily life, in terms of their social life and careers, and their relationship with the pwPD (Leroi et al., 2012). Findings of one study suggested that to maintain the well-being of supporters of pwPD, they should reserve one-third of their time for their own needs (Prado et al., 2020). To balance caring responsibilities and their individual needs, it may be important to be clear about their role in the training. The participants emphasised the importance of having open and honest communication with both the participant and their potential supporter to find a solution that works for everyone involved.

“Some people really don't want to do that, and some people's families don't want to be that person either, they don't want to come in and be involved in that, that's just a step too far for them.” (PT2)

“I don't use carers or family members if there is conflict because that won't work, it will work to anyone's advantage.” (PT1)

The study participants highlighted that the role of physiotherapists is crucial in meeting the expectations of pwPD and providing them with adequate support. They play a pivotal role in decision-making processes such as determining how the training can be beneficial and meaningful for individuals, as well as how to progress the training to maintain a suitable level of challenge to create a therapeutic effect. Similarly, Claesson and colleagues found in their qualitative study that their participants with PD needed a leader to supervise them, and a leader who could adjust the exercises to the right level (Claesson et al., 2020).

> *"…Because you can look at all of the research which is coming out from America or anywhere… So, we kind of need a bit of an approach…" (P4)*

> *"I think you need somebody there, if you're performing actions or exercises. You need some nursing, you're leaning forward, you're leaning back, you tend to do this to counteract the physical posture…And getting it right is important, otherwise it is easy to have the wrong consequence." (P5)*

In line with the literature, the physiotherapists believed that they must tailor their approach to individual needs, taking into account the person's physical and cognitive abilities, preferences, and goals to keep them engaged. They should also feel they should consider the participant's daily routine, lifestyle, and potential barriers to participation when creating a training plan (Ellis et al., 2011).

> *"I think that's what we need to do, we need to think about what it is I'm trying to achieve with this individual, how can I make it safe where they are right now and if they cope with that, how can I progress it, how can I challenge the task a bit more each time." (PT1)*

While one pwPD (P2) talked about the difficulty of finding the right person who has the necessary skills, one physiotherapist (PT1) expressed the view that patients are not interested in what the physiotherapist knows. The important point here is that physiotherapists need to consider each individual's needs and develop a person-centred approach to achieve meaningful results with the training.

> *"They're not interested in what I know. They just know that I'm a physio who knows how to help them get better or to achieve something. And I think that's where this tailored approach to our individual who's sitting in front of us or standing in front of us, we've got to think outside the box." (PT1)*

The importance of perceiving potential benefits of the training, is evidenced by another sub-theme in this study. In this context, it is important for health professionals delivering the training to educate pwPD about the benefits of the programme to motivate them to participate and continue with the program (Hunter et al., 2019). This type of support is seen as an important contributor to the engagement and participation of pwPD, as illustrated by one physiotherapist:

> *"…I would see that* (education) *as really beneficial and I think what I do with most of my patients, I try to educate them as to why we're doing this." (PT1)*

The importance of taking exercise training may not be less than taking medication for the overall management of PD; and healthcare professionals play a crucial role in emphasising this, so that pwPD take exercise training seriously (Schootemeijer et al., 2020).

> *"…they are one of the key preventions that people with Parkinson's should have at a very early stage would be my view. Because you can look at all of the research…, exercise can be, not just activity, exercise is very different. It has to be as good as medication if not better." (P4)*

Theme 2: Home-based DTT

This theme with the following sub-themes explains different aspects of undertaking and delivering DTT at home, comparing those in a clinical/community setting with being at outside for training.

Sub-theme 1: Advantages and disadvantages of being at home.

This sub-theme explored the advantages and disadvantages of home, and environment of the exercise area.

Integration into daily life was found as a key factor related to exercise adherence in older adults (Collado-Mateo et al., 2021). This was also highlighted by the participants in this PhD study (sub-theme training as part of daily life. Home-based training may provide different advantages for both pwPD and physiotherapists to enable DTT to be more adaptable to the daily life of pwPD. Physiotherapists' perspectives showed that delivering training at home provides them with unique opportunities, such as utilizing familiar objects and focusing on specific abilities that patients can incorporate into their daily lives. Participants suggested that home-based dual-task training can be particularly meaningful to pwPD, by integrating training within their daily life. One physiotherapist shared a detailed example of how she achieves this as a progression element:

> *“that's where he lives and that’s where he has to function. So, I did loads of work with him just walking up and down his living room at different paces and different speeds and high knee lifting and just walking slowly. And then I started putting objects on the floor that he had to pick up and I started off with the big object, so he didn’t have to bend too far, pick it up and put it on the table at the end when he got there, then walked down the other end of the room… So, he started … dual tasking and then he had to reach down and pick it up. And then I slowly made the bottles smaller…So, you can progress the balance and the dual tasking that way in someone’s environment. This bottle could have fallen on the floor ...So they were all objects that had meaning to him…” (PT1)*

Undertaking training at home was raised as providing several advantages from the perspective of pwPD. One of the primary benefits was reduced travel burden. A recent study exploring the associated factors to participate in a pedalling programme for Parkinson’s exercise showed that the cost of transportation and parking is important to pwPD (Rosenfeldt et al., 2022). Also, pwPD may not choose to participate in an exercise training if the class location is not convenient to access and transportation options are inadequate (Schootemeijer *et al.,* 2020). The perspectives of the pwPD in this qualitative study resonated with those findings.

> *“I think with traveling, it is easy in your own home…” (P6)*

> *“When you're home on your own it's less expensive because you are not having to drive anywhere, just do it at home…” (P2)*

Collado-Mateo and colleagues found that adequate place, good accessibility, and flexibility in the schedule were key factors associated with exercise adherence in older adults with long-term conditions (Collado-Mateo *et al.,* 2021). Similarly, pwPD talked about how when they have to attend a training class at a different location, they need to factor in the travel time in addition to the actual training time. Moreover, they highlighted how their physical condition may prevent them from driving, making it challenging to attend in-person training. Therefore, participating in online classes or performing training sessions at home was considered by some to be a more convenient and preferable option.

> *"It's easy to duck out being at home. We've been talking, getting exercises at home, it's easier to kind of say, right, I'll stop that and then start it when I'm feeling better." (P3)*

> *"I'm always mindful of the fact that I've got to get somewhere, do I have to drive and how do I get there and am I going to be okay to get there and am I going to be okay to get back. Because obviously, if you do it on Zoom you don't have that travel time. It takes far less time because you don't have half an hour either side." (P3)*

Although they saw advantages of , they also acknowledged the home-based approach might be limited because of the lack of interaction with people compared to group exercise programmes, which have found to be helpful in increasing confidence, independence to cope with disease symptoms, and competence (Sheehy et al., 2017), all of which potentially improve adherence to training programmes. From the perspective of a person who had group class experience, a home-based approach was thought to be potentially less enjoyable and less motivating.

> *"When you're home on your own it's less expensive because you are not having to drive anywhere, just do it at home, but it's more fun doing it with other people." (P2)*

> *"…perhaps if there is a regular routine that you can adopt for 12 weeks at home might be easier, I guess it's less enjoyable…" (P1)*

Noting the motivating nature of group exercise classes, it may be worthwhile to adopt group exercise into a home-setting through online options. For example, Bennett and colleagues found that pwPD found the transition of an in-person group exercise to a virtual group exercise safe and beneficial not only in in terms of their balance but also on non-motor symptoms like social isolation (Bennett et al., 2023).

It was important that pwPD can take control of the situations they experience during doing exercise themselves according to physiotherapists. Safety during the training was an important point and the familiarity of a home environment was thought to prevent some risks and it can allow pwPD to manage any risky situation themselves raised by both pwPD and physiotherapists.

> *"You might actually find for home-based programmes Nesibe that the risk is less at home because it's a known environment. Yeah, it's a comfortable environment." (PT1)*

> *"We have got a conservatory, or we have got the garden outside. It's always easier to fall on the grass if you are going to fall over." (P2)*

At some points, it was discussed that a supervised dual-tasking session may not be safe to deliver at home. For example, Domingos and colleagues (2022) reported that physiotherapists recognise that DTT in pwPD introduces a higher risk of falls, especially in the group setting (Domingos et al., 2022b), but this may still be at an acceptable level even for non-supervised training in a home-environment. They found that an online group C-DTT programme with medically stable pwPD was safe in their acceptability study (Domingos et al., 2022a).

> *"…in their own homes, sometimes dual tasking is just not possible to be able to execute given the environmental hazards, shall I put them down as, and the constraints and also to do around social circumstances of that individual." (PT1)*

> *"I did send out sort of suggestions of the space, …having something either being near a wall or a high back chair, or something that could provide support if they needed to have another member of somebody in the household with them or telephone that they could reach easily beside them…" (PT2)*

Reduced balance confidence and concerns about falling are important factors of falling in pwPD, and reduced balance is correlated with a decrease in participation of motor-demanding leisure activities and activities of a social character (LaGrone et al., 2020). From a safety point of view, balance impairment, disease severity, and confidence in performing tasks at their home were all considered key factors according to both the pwPD and physiotherapists.

"The safety was based around his cognitive status rather than anything else. There weren't environment issues, there wasn't carer issues, it was his cognitive status and his fatigue, probably to some degree as well." (PT1)

"A small uptake from the people that could have come, maybe 30% actually. So, it wasn't for everybody. So, I guess the people who chose to do it were more motivated and maybe more confident in their own physical ability." (PT2)

"I think once somebody is comfortable with the exercises and knows how much space they need and what their likely balance problems or issues are then it's something you can translate into the home environment…" (P5)

People's confidence was sometimes felt to depend on both the ability of the pwPD, and also the availability of a suitable home environment as a training area:

"Walking, moving in confined spaces I find more difficult indoors. So, moving around the room is more difficult than it is moving around outside… "(P3)

There was no relevant statement to this sub-theme from supporters.

Sub-theme 2: Use of different technological options for different purposes.

This sub-theme explores what kind of tools can be used as a delivery method, what are the strengths and weaknesses of those tools, and how a class or individual training may be transferred into distance/online training.

Reduction in physical activities was one of the consequences of the Covid-19 pandemic because many pwPD were unable to go out of their homes for a walk or attend a fitness class (Helmich and Bloem, 2020). However, a positive outcome has been the emergence of web-based exercise activities such as online exercises or dancing classes (Helmich and Bloem, 2020). The perspectives expressed by participants in this PhD qualitative study, predominately founded on their experience gained during the pandemic, lend further support to the use of online/digital platforms as a potentially acceptable delivery method to keep pwPD active and engaged with their exercises. There was a recognition that, although physiotherapists believed in the effect of face-to-face one-to-one or group training, they also needed to consider online delivery options.

They had several different considerations to make when providing online training.

> *“When we started lock down, I was not convinced I wanted to do these classes online, I was concerned from a safety perspective and I just wasn't sure how it would flow, because part of the group coming together is how we all communicate and interact, and it is also everybody having the equipment…” (PT2)*

Then, they tried to find solutions or different approaches to make online training acceptable and manageable to both themselves as a deliverer and the patients.

> *“I've kept the numbers quite small online, so the maximum I think I've had in a class has been eight and that's maybe just a little bit too many and I've now got it back down to six maximums in one of those classes. And that way I can still see everybody reasonably well. They know that they should pin me as their big screen. And they have themselves as the smaller parts, so they're mostly able to see what I'm doing.” (PT2)*

It was initially believed that online options were only necessary during the lockdown era. However, physiotherapists acknowledged their advantages and disadvantages. While they recognized that certain aspects of training may not work as well online, they also saw the benefits of using digital tools. For example, a video link was considered a potentially important tool when a patient’s in-person appointment is not possible. One physiotherapist mentioned that understanding the different components of online training can help integrate it as a part of an intervention, rather than just a temporary solution. She also said that she could think about using this kind of method as a video consultation and as a tool to follow the patients’ progress in the future where suitable:

> *“I will also use it to follow people up when I know the background of the individual and know that the video consultation can just be a support mechanism or a checking mechanism, because I think it's like any other concept that no one size fits all and it will be useful in some situations and a hazard in others and a constraint in others.” (PT1)*

From the pwPD perspective there were both advantages and disadvantages to undertaking online training. One of the common disadvantages raised was the lack of social interaction.

> *"I think there are real positives using zoom but there are some negatives because that kind of social interaction that you can get from being able to get a coffee and have a chat and say oh do you know so and so. Kind some of that social bit doesn't happen…" (P4)*

Individual situations and preferences appeared to influence peoples' perspectives about whether online training is acceptable; this is supported by the literature. For example, anxiety is one of the PD non-motor symptoms which can influence motor symptoms such as freezing of gait (Lovegrove and Bannigan, 2021). In a recent qualitative study, some pwPD described anxiety as a personal weakness related to the stigma and which can lead to social isolation (Blundell et al., 2023). This reflected the findings of this PhD study where some pwPD reported their anxiety can be triggered when people are able to see them; believing therefore that the use of Zoom may provide an opportunity to hide themselves from other people. This was not the case for everyone, with one person preferring face-to-face training (P2).

> *"If I refer back to the point I made earlier on about anxiety, indoors on Zoom to me is a lot easier. I'd certainly be a lot less anxious, a lot more calm and less anxious than if I could be fully seen…" (P3)*

> *"So, I kind of prefer Zoom if I had a choice to get up and wander out of frame if I had to. Where being in a group setting now, it would be quite challenging and would probably make my symptoms worse, rather than more enjoyable." (P4)*

With these individual differences, a combined approach that includes both face-to-face and online sessions was viewed by the participants' as an alternative way to be more inclusive. This view is held more widely, with one review suggesting that combining centre-based class training with home-based exercises may be feasible and cost-effective (Picorelli et al., 2014). This would also enable different aspects to be covered because "*There's certainly some things that can be done effectively over zoom, and other things that cannot be done effectively over the zoom." (P5)*

“I haven't tried anything on Zoom and I'm not particularly keen on that. I'd rather just go and work on my exercise machines, but a combination would perhaps be good.” (P1)

“A combination would be good … having gone to the classes, sitting on zoom you still see her it’s still okay, but it's not the same as having others in the room with you.” (P2)

Recorded training videos like YouTube videos were considered an option for intervention. Most people were aware of it and used it, especially during the lockdown (P5 & S1). One advantageous aspect of recorded videos was that they gave flexibility to the patients to control their time and their condition. So, they can find a way to value the training.

“I think it's the kind of thing that you need to be shown in person first and thereafter YouTube videos could, I mean we do all sorts of things via YouTube videos these days. And it can be very effective and certainly cost effective and flexible.” (P5)

“If I couldn’t make it to a like a live video, to perhaps to then have it sort of recorded for the times you couldn’t make it, because then you are not so committed for when something else cropped up. That would be okay to do something like that.” (P1)

It was also reported that this may help pwPD who attended face-to-face training to remember tasks and perform them correctly. For example, one physiotherapist (PT2) mentioned that supporters of some patients filmed them whilst they were performing the tasks in the face-to-face class and used that film the tasks at their home. Also, sometimes she sends a video of her doing the training tasks.

“Sometimes the carer will film them doing some things with me. So, they can work on it better at home and sometimes I will send everybody a video of me doing it to remind them what they're looking for a home…” (PT2)

Theme 3: Acceptable Assessment Options

This theme explains (1) preferred assessment methods to evaluate DTT (from self-report questionnaires to technological equipment), and (2) whether a clinic, home, or online option is suitable and reliable from each group of participants' perspectives.

To ensure effective assessment of any healthcare intervention, physiotherapists play a key role, drawing on their expertise to determine the most suitable methods (McGinnis et al., 2009). Examination of both physical and cognitive factors should be used to plan appropriate and individualised DTT (Coster, 2013). Both physiotherapists interviewed for this study reported doing this adjusting the examination for the situation, either by using the task or exercise itself to assess the patient's condition or using standardized tests with necessary modifications.

> *"I'm using a situation to kind of judge how he responds to it, or they respond to it. And then that in its own right allows me to make a judgement about whether the individual can continue." (PT1)*

Their decision on the assessment method was also reported to be influenced by factors such as time constraints and available equipment.

> *"I did find that it was really hard to find a balance test that isn't really time consuming or needs equipment or whatever, that is replicable. So, it was just kind of using the MiniBEST as the basis, but I've just put in a couple of other things that were maybe more salient or pertinent for what I was looking for." (PT2)*

The two physiotherapists gave examples of tests they used. For example, the 10-meter walking test and MiniBESTest as a baseline assessment tool, sometimes adding cognitive tasks to understand its effect (PT2) and looking at whether a patient can retain a task and instructions throughout the task (PT1) for balance and cognitive assessments.

While there are objective standardised tests, there are also patient-reported forms or technological devices like wearable sensors (Lopes et al., 2016, Lu et al., 2020). From the perspectives of the pwPD, robustness and objectivity were considered important for their assessment in a research trial. They felt that self-reported questionnaires can be useful but should be used as a complementary tool to objective measurement methods like wearable devices.

> *"I have been doing this patient reported outcome … I think it is very subjective and the temptation to be optimistic about your condition makes it very unscientific. I would say I think a more objective assessment by the third party is much more useful, perhaps and a wearable equally I think would be useful." (P1)*

With the COVID-19 pandemic, face-to-face consultations and sessions for pwPD were moving to the online format (Soilemezi et al., 2022). One study showed that healthcare professionals have different perspectives in terms of acceptability of remote options (Soilemezi et al., 2022). For example, some found it useful to reach more pwPD in this pandemic era, others thought it was not suitable to detect specific needs. The acceptability of the online setting for assessment among physiotherapists was explored in this study. A main consideration was whether the preferred assessment methods, which have been found to be practically and scientifically suitable within a face-to-face setting, could be effectively performed in an online platform. The physiotherapists noted that certain assessments, such as balance and gait tests, may be more challenging to conduct online due to the limitations of technology and the inability to provide hands-on assistance. They cautioned that careful consideration and adaptation of the assessment methods may be necessary when conducting online home-based assessments.

> *"Things like I was doing a six-minute walking test first of all, so measuring how far people walked in six minutes and analysing their gait, so obviously that's not possible online like that…" (PT2)*

In some cases, travel to a laboratory or clinic for assessment may be difficult for pwPD, especially if they require a supporter to accompany them. One pwPD suggested having equipment delivered to their home and a virtual consultation with a professional when needed could be a practical solution for all concerned (P4). Others believed that travelling to a clinic would be worth it to obtain more realistic and scientifically valid results from the assessment. *"I think it's important to do the science if you like and do the travelling." (P1)*

Supporters also believed that the use of Zoom may be difficult to assess a person's condition, believing that clinic/laboratory settings may provide opportunities to undertake more specific and comprehensive measurements.

> *"I think zoom is really difficult to try and assess somebody. I don't know how that would work." (S1)*

> *"…you could get more out of the research by doing specific tests at uni, if that makes sense. So, like you could probably do more tests and more specific ones and get more information out of what you need really and be able to target specific things whereas you can do generalised tests at home." (S2)*

The participants were of the opinion that it is feasible for most pwPD to travel for key assessments, and this was valued by participants. However, where travelling was not possible, a remote mini-assessment or monitoring was suggested as an alternative to keep pwPD included and engaged in the programme. They felt this could also be undertaken more frequently as an opportunity to provide encouragement and ensure that participants were making progress. Such remote assessments were also thought to be able to serve as a check-in to identify any potential issues and make necessary adjustments to the programme.

> *"I think it's perfectly reasonable to ask people to attend the clinic for that initial assessment and if you've got the tech and the tech is available then using it for incremental assessments is going to facilitate the greatest level of participation. So, I'd be quite happy to go into clinic to have initial, interim and final assessments, for example." (P5)*

> *"…So small mini assessments along the way. It gives you the reassurance that people are doing what they're doing, people also have got the impression that they're being monitored." (P4)*

4.4.3 Summary

These findings provide valuable insights from multiple perspectives on various concepts related to DTT in pwPD. The insights help to address several important questions related to DTT, such as how it potentially affects balance in pwPD, how it is understood as a training approach, what are the expectations from DTT, how to implement it, and what are the advantages and disadvantages of a home-based DTT. The findings have been used to design the DTT interventions for the proposed feasibility study, in combination with the results of the scoping review.

4.5 Limitations of the Study

This study has some limitations. The small sample size and relatively limited spectrum of sample characteristics may be considered insufficient and may affect generalisability of findings (Vasileiou et al., 2018). As the researcher is a non-native English speaker this may affect the trustworthiness of data (Yoon and Uliassi, 2022). Using an online approach to collect data (dictated by the COVID-19 pandemic) rather than face-to-face may affect the quality of data (Krouwel et al., 2019). Therefore, it is important to consider these points when interpreting the results.

The researcher’s identity and philosophical position can be related to the quality of a qualitative study (Yoon and Uliassi, 2022). Some characteristics compromise a researcher’s identity such as ethnicity and language. One study suggested that more active interactions with participants help to establish trustworthiness (Dennis, 2018) which is an important quality element (Yoon and Uliassi, 2022). Language and cultural factors of the researcher’s identity may have different effects on this interaction. The study sample was comprised only of English speakers. The researchers first language is not English, resulting in some difficulties in understanding some phrases. Sometimes the accent was not understood by the participants. As an international PhD student and researcher, and of a different cultural background, different non-verbal conversation channels like facial and vocal expressions are sometimes used. These may have affected the quality of conversation as the participants may not have accurately recognized the researchers emotions (Elfenbein and Ambady, 2002). During this knowledge production process, these factors may be barriers for establishing trust and keeping interactions, with the potential to affect the trustworthiness of the study.

As a critical realist researcher, the focus of the study aim was to gather the data and achieve the study objectives, which is the positivist part of critical realism. A member of the supervisory team (LB) who is a native English speaker was involved as an assistant in the interview/focus groups to optimise how they were conducted. The role rather than leading the interviews, acting as an interpreter. One of the roles of interpreters within research is to contribute to the study with their experience (Squires et al., 2020), as was the case with LB, bringing both clinical and research experience. It is acknowledged that this may bring her mind set into the flow of the conversation, which may decrease trustworthiness of the study by affecting the interpretation of data (Squires, 2009). Although, there is an interpreter's bias risk, this was minimised through the use of discussion guides for each participant group, used for the interview/focus groups.

Appropriate sample composition and sample size is an important element in evaluating the quality and trustworthiness of a qualitative study (Vasileiou et al., 2018). One of the inclusion criteria of this study was being an English speaker because of the lack of resources in translation. Whilst this inclusion criteria were for pragmatic reasons to decrease the language barrier, it means the study is less inclusive, and the findings may not represent a wider population to inform the proposed feasibility study. The pressures of globalisation increase the demand for qualitative research that is linguistically and culturally representative of study participants to increase the standard of care given by healthcare professionals (Squires, 2009). In future qualitative studies involving a translator or interpreter with discussion of how they play a role with the research team may be considered to achieve a more inclusive and higher quality study.

The previous experience of participants with the phenomenon may be an important factor influencing both data richness and interpretation of findings (Kirkevold and Bergland, 2007). While participants who have experience with DTT can provide more specific examples of tasks, others without DTT experience may share opinions rather than firsthand experiences or describe their experiences with exercise in a more general manner. Only one participant with PD mentioned having experience with DTT in this qualitative study. This disparity in participants' experiences may limit the study's ability to inform the design of a novel, home-based DTT program. Although a summary of a scoping review was provided to participants before the focus groups/interviews to introduce them to the concept of DTT, it cannot replicate the lived experience of DTT. Therefore, while the findings may offer valuable insights for designing training, they may fall short in informing the specific design of a DTT programme.

The total number of participants was ten. In terms of determining and evaluating the sufficiency of the sample size in qualitative research, the most commonly used principle is data saturation, which means continuing with data collection until no new theories or themes emerge (Vasileiou et al., 2018). Whilst data saturation is an appropriate way to determine the sample size in grounded theory research, it may be less appropriate for another research (Vasileiou et al., 2018). This qualitative study aimed to inform the proposed feasibility study by understanding the parameters of potentially acceptable and feasible home-based DTT interventions alongside the scoping review findings. A deductive approach was used to achieve the study aim rather than to inductively generate a theory. Also, this qualitative study was conducted within a limited timeline, and within the challenging context of the COVID-19 pandemic. Recruiting new participants at different time points to reach data saturation may not be applicable. However, there are some numerical recommendations from experts in qualitative research that may be indicate a sufficient sample size. For example, a group of five or six participants is considered preferable for a focus group (Barbour and Kitzinger, 1999). In this study, there were three focus groups with two participants in each. This may mean that the sample size was insufficient to generalise the findings; this is the main study limitation. Another issue in terms of the sample is the imbalance in the number of participants among pwPD and other groups. Two physiotherapists and two supporters may not represent the population. However, the framework analysis allowed comparisons of the data from each group, and there was consistency across groups enabling common themes to emerge.

Adding individual interviews to focus group into the data collection process may change the nature of the data, as these two methods may result in different sets of data, differing in depth and detail (Baillie, 2019). As focus groups benefit from participants' interaction it has the potential to generate synergistic further ideas about the phenomenon which cannot produce in an individual interview (Cleary et al., 2014). On the other hand, individual interviews may enable people to express their views without any distraction. Data was pooled in the analysis, using the same matrix, which may have increased the richness of the data in this study. However, this reduced the ability to specifically compare and understand how the data from each type of method (interview or focus group) may have affected the findings of the study. The specific contribution of each method to understanding the phenomenon is frequently not explicitly analysed (Lambert and Loiselle, 2008). Therefore, it may be valuable to explore any differences in terms of data from each method (Lambert, 2008) and its effect on the study conclusions.

One other potential limitation was using a digital platform for data collection, rather than face to face. This approach may affect the quality of data; whilst in-person interviews are typically considered as the gold standard compared to online methods, there is a lack of evidence to support this argument (Lindsay, 2022). One study found that in-person interviews generated more words and more statements in support of similar number of codes than those in video calls (Krouwel et al., 2019). However, this difference was modest and there were many advantages of video calls in terms of savings in budget and time. The use of video call interviews, therefore, is increasingly viewed as acceptable (Krouwel et al., 2019).

4.6 Conclusion

Despite the methodological limitations, the data gathered by pwPD, supporters and physiotherapists were consistent with the DTT task options for DTT discovered within the scoping review. This study has been useful in informing the feasibility study. The findings suggest that enjoyment and right level of challenge are major factors in deciding the individual tasks within DTT. Home-based DTT is potentially acceptable with the right number of sessions and session durations from the perspectives of pwPD. Standardised objective assessment tools, undertaken face-to-face in the research clinic seems acceptable to pwPD despite the need to travel for these assessments. These key factors, together with the findings of the scoping review, all inform development of the intervention in line with the MRC's framework for developing and evaluating a complex intervention (Skivington et al., 2021).

Chapter 5: The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson’s disease: a feasibility study of a randomised controlled trial.

5.1 Introduction

This chapter includes a brief background section to provide a recap of how prior stages of this PhD explain the study aim, study objectives, explanations of the methods used to achieve the study objectives, findings of quantitative data and qualitative data, and discussion and conclusion sections.

5.1.1 Background

A scoping review forming the first part of this PhD, showed that only one study compares the effectiveness of M-DTT and C-DTT on balance but this study has some methodological limitations (Pourkhani et al., 2019), namely small sample size, using only TUG test for balance assessment, and no mention of randomisation. This clearly identified a need for a future RCT to investigate the superiority of M-DTT and C-DTT on balance in pwPD.

Since conceptualisation of this PhD, the COVID-19 pandemic has shifted physiotherapy deliveries to encompass telerehabilitation (Ramage et al., 2021). A recent systematic review showed that telerehabilitation is feasible for pwPD and effective in improving and/or maintaining balance and gait and some non-motor aspects (quality of life, patient satisfaction) of the disease (Vellata et al., 2021). DTT delivered to people in their homes via telerehabilitation may therefore be an applicable alternative to traditional face-to-face physiotherapy service delivery (Pang, 2021).

The scoping review showed that there is some published evidence about home-based DTT, but that all studies to date have mixed approaches to DTT and no studies have investigated and compared the effectiveness of M-DTT and C-DTT interventions on balance in people with mild-moderate PD.

So, this project aimed to (1) design home-based M-DTT and C-DTT interventions based on the information from the scoping review and the qualitative study findings, and (2) test the feasibility and acceptability of these interventions, plus the associated predominantly balance-related outcome measurement, which may be used in a future RCT, intended to determine the superiority of these DTT interventions.

5.1.2 Study Aim

The overarching aim is to test the feasibility including acceptability and safety of a future novel RCT, designed to investigate and compare the effectiveness of M-DTT and C-DTT, with a focus on improving upright balance in pwPD.

For this PhD study, the principal focus on feasibility was from the perspective of participants undertaking the home-based interventions and predominantly site-based outcome measurement; the reported acceptability of each, attendance and adherence to the intervention and safety.

5.1.3 Study Objectives

- To test the feasibility and acceptability of home-based C-DTT and M-DTT interventions from the perspective of participants and their training buddy (the person assisting them at home during training).
- To assess the acceptability of the outcome measures taken by the physiotherapist on site visits, from the participant perspective.
- To assess safety by monitoring for any adverse events or serious adverse events.
- To assess the feasibility and acceptability of the safety monitoring process, from the participant perspective.
- To tentatively explore clinical outcome measure data to explore any signal of effectiveness of each C-DTT and M-DTT intervention on standing balance and walking of individual participants.

5.2 Methods

The approach adopted for this study incorporates a feasibility study of a RCT with an embedded qualitative component, using the advantages of mixed method approach. The rationale for this choice of design can be found in Chapter 2. In this section methods for recruitment, data collection, data management, data analysis, and stages of the study for both quantitative and qualitative components are presented.

This study was approved by the Faculty of Health Ethics and Integrity Committee (reference 2022-3332-2865) and registered to ClinicalTrials.gov (reference NCT05710588). It ran between the dates of 06/07/2022-30/08/2023. This study was funded by the Republic of Türkiye, Ministry of National Education.

5.2.1 Sampling

There were two key considerations for sampling relating to this study:

1. An impression of the recruitment strategy for a future RCT design was needed to define eligibility criteria and sampling strategy.
2. To remain within the scope of this study's aim, an appropriate smaller sample of participants was required to first evaluate feasibility.

Whilst this study does not aim to generalise findings to a larger population, when evaluating feasibility, it is good practice to inclusively seek views that could represent people as diversely as possible (Kendall, 2003).

The eligibility criteria for this feasibility study (and future RCT design) were therefore defined with the target population's ability to complete the intervention in mind. Rehabilitation of balance fundamentally puts participants at risk of falling. In juxtaposition, identifying a pwPD with a risk of falling or possessing impaired balance is an indication for balance rehabilitation. Combining dual-tasking with balance training could potentially increase the risk of falls further raising safety concerns. Furthermore, due to the unsupervised, home-based nature of these training interventions, safety must be carefully considered against rehabilitation potential. Therefore, pwPD who have mild to moderate PD but not severe motor disabilities which can risk their safety while training were identified as potential participants who could benefit from such interventions. It is acknowledged that pwPD with more severely impaired balance may still benefit from DTT but with a more physiotherapist-supervised approach, less conducive to a home-based remote delivery such as under consideration in this trial. The following criteria for this study were therefore set as:

Inclusion criteria

The potential participants were eligible for inclusion in the study if they;

- Self-reported a diagnosis of PD
- Were categorised as having mild to moderate PD (based on scoring of the UPDRS scale modified by the researcher using the motor and cognitive items of it, undertaken by the physiotherapist researcher via an online interview).
- Could understand and follow instructions (based on self-report and ability to follow instructions to navigate the online screening process).
- Could independently, or with the help of a supporter, complete self-report outcome measures.
- Could use web-based/online platforms/applications independently, or with help of a supporter.
- Had a supporter (carer, spouse, family member aged ≥18) who was willing and able to act as a training buddy.
- Had an available safe training area according to the definition: A 2-metre square clear area immediately next to a wall, with no trip hazards and with the potential to place a chair within the space (for seated rests). The wall needed to be free from hanging objects or shelves and not wallpapered or featuring flaking plaster. This was to ensure safety during training and prevent unintended damage to the wall. (Closed doors could be considered as part of the 'wall' only if they could be securely shut, so that should a near-fall occur with the participant falling against the door, they would not open. They should also be guaranteed not to be opened by other household members (including pets) during the training session (which could potentially cause a fall).

Exclusion criteria

The potential participants were excluded if they;

- Had any other current medical problems (other than PD), which could affect standing balance, such as stroke, cerebellar disorders, a vestibular impairment, a skeletal fracture (occurring within the past six months), or severe visual impairment, which could risk safety within a standardised training protocol and independently affect treatment outcomes.

- Had severe deafness without the support of a signing translator, to ensure they were able to effectively receive communication.
- Were unable to communicate in English, as no translation was available, and communication was essential in ensuring safety.
- Were unable to stand independently for more than 1 minute without requiring external postural support, to ensure safety (and prevent falls) during training and outcome measurement.
- Did not have a suitable training area according to the definition provided in the inclusion criteria.

In RCT design, one option for sampling would be to access a full population and randomly select potential participants to invite to the study (Suresh et al., 2011). This however requires the existence of a database reflecting a population and permissions to access this, which was not possible in this study owing to several factors, including restricted timescales, the impact of the Covid pandemic, and restricted mobility of international student study visas. Given these constraints and since relatively low numbers are required for a feasibility study, a pragmatic sampling strategy was adopted. Consecutive sampling is a strategy that means taking every potential participant who meets the eligibility criteria over a certain period; an approach which may help to reach a large sample (Kendall, 2003). Once the eligibility criteria were set, this strategy was applied to recruit from the target population between November 2022 and March 2023. Convenience sampling from local PD support groups was adopted to both expedite recruitment and ensure that no participant was travelling for more than an hour for site visits.

Sample Size

As a feasibility study, there is no requirement to estimate sample size (Eldridge *et al.,* 2016). Feasibility and pilot studies may try to offer a reliable estimate of anticipated recruitment and follow-up rates to inform sample size calculations for future powered trials, however, this was not the main aim of this feasibility study. This study focused on evaluating the feasibility (incorporating an evaluation of acceptability and safety) of the intervention. As a result, no sample size calculation was undertaken for this study. A pragmatic decision, in line with other similar studies published in this field, was made that each intervention group should include five participants (Conradsson *et al.,* 2012).

5.2.2 Recruitment

PwPD were recruited with the support of Parkinson's UK (https://www.parkinsons.org.uk/). They shared the research advertisement (Appendix 13) and Participant Information Sheets (PIS) (Appendix 14 and 15) via email with local support group administrators and research interest groups in the South-West, the geographical region for this study. This request and all recruitment materials were first approved by the Parkinson's UK research team. If interested in participating in the study, potential participants were asked to send an expression of interest email to a designated UoP email account. If they had any questions, or were happy to be involved, they were invited to a Zoom meeting. Their questions were answered and then their agreement was asked to engage in the screening process during this Zoom meeting. The agreement of pwPD who were happy to participate was then obtained during the same meeting.

Parkinson's UK advertised the study at two different time points. First, they advertised on 1st November 2022. By mid-January 2023, only three participants were recruited. Hence, Parkinson's UK resent the advertisement to member's emails to optimise recruitment. An invited visit to a local Parkinson's UK group meeting in East Taphouse Community Hall provided a further opportunity to recruit participants.

Screening

It was not possible for a medical clinician to screen potential participants in person due to financial, time and resource constraints. Interviewing using an online Zoom meeting with the research physiotherapist, was considered a suitable method for the study's screening process; this decision was supported by the qualitative study findings. NC interviewed potential participants (following verbal consent) to determine eligibility through a standardised screening form (Appendix 16). The procedure for deciding disease stage and cognitive status used standardised, valid and reliable scales; the balance and cognition related questions of parts 1, 2 and 3 of the MDS-UPDRS scale (Goetz *et al.,* 2008).

5.2.3 Randomisation/Group Allocation

Participants who were eligible and willing to consent to take part in the study were invited to the Peninsula Allied Health Centre, UoP. Here, a written informed consent sheet was first completed before baseline demographic and medical details were collected.

Baseline characteristics were also used to allocate the participant to either the M-DTT or C-DTT group, using Pocock and Simon's minimisation method of covariate adaptive randomisation (Pocock and Simon, 1975, Suresh, 2011). This type of randomisation is used to reduce imbalance between groups, which is particularly relevant when the trial has a small sample size (Suresh, 2011). The covariate was PD severity according to self-report MDS UPDRS-II (asked within the Demographic and Medical Data Collection Form-Appendix 17). This scale includes questions about how motor aspects of PD affect the experience of daily living. Higher scores represent higher disability (Rodríguez-Blázquez et al., 2017). Motor symptoms of PD can affect the daily life of pwPD in different ways. This covariate was chosen to balance each intervention group's characteristics in terms of the disability so that the findings in both groups may represent a wider group of pwPD. Each new participant was sequentially allocated to a particular intervention group by taking into account this covariate (mild or moderate disability) and the previous allocation of participants by ultimately then using a coin-toss method.

The number of people requesting information about the study was logged at this stage, contributing to the CONSORT-feasibility extension reporting template (Eldridge et al., 2016). The number of those eligible from those enquiring was logged, as well as the number providing consent, dropping out or withdrawing from the study. Where possible, the reason for drop out or withdrawal was noted to inform interpretation of feasibility and acceptability.

5.2.4 Blinding

Blinding the assessor, clinicians, participants, and data analysts are important controls that reduce the possible biases at different points in a clinical trial (Karanicolas et al., 2010). Clinician and assessor blinding may provide unbiased assessment and interpretation of study results and increase the reliability of the study findings. Participant blinding in terms of group allocation may support the fidelity and retention to the intervention because knowing which group they were assigned to may lead to a change in expectations from the intervention and a tendency to withdraw from the trial (Karanicolas et al., 2010). As the baseline assessments, group allocation, and the first training session were completed in the same visit and by the researcher, with limited resources, an assessor and/or clinician blinded design was not practically possible. Participants were aware that they were allocated to one intervention group which involved dual-tasking elements, but they did not know whether they were in the M-DTT or C-DTT group. This study is therefore a single-blind study with participant but not researcher blinding.

5.2.5 Dual-task Training Interventions

The design of the intervention for this study was informed by the scoping review and the findings of the qualitative study. The findings of the qualitative study showed that a home-based telerehabilitation approach, which includes exercise videos, alongside remote individual or group exercises via online video communication, may be acceptable for pwPD.

> *“I mean, we do all sorts of things via YouTube videos these days. And it can be very effective and certainly cost effective” (P5)*

Qualitative study participants also valued that an initial face-to-face supervised session would be better to be sure about how to undertake the exercises properly.

> *“I think it's the kind of thing that you need to be shown in person first… needs to be a combination.” (P5)*

Information from a range of sources (a focused scoping review, the qualitative study, and a general review of the literature), was used to define the intervention and its methods of delivery.

Delivery of the Intervention

The intervention consisted of both face-to-face supervised sessions and home sessions, all of which were conducted on an individual basis. The initial training sessions took place in a designated room at the Peninsula Allied Health Centre, UoP, with the researcher providing one-on-one supervision. Subsequently, a recorded training video program was developed and made accessible through Panopto, a web-based platform facilitated by the university (https://www.panopto.com/).

To ensure convenience and personalized access, each participant was assigned their own individual link to the training videos. These links, along with instructions, were emailed to participants based on their preference of using either their own tablet or a tablet provided by the university. For participants using their own tablet, the link was sent directly to their personal email account. For those utilizing a university-provided tablet, a dedicated email account was created and used to send the link. This personalised access allowed the researcher to monitor their engagement with the training sessions individually.

By clicking on their unique link, participants were able to access their individual Panopto folder, allowing them to navigate and locate each session within the training program. This approach ensured that participants could engage with the training videos at their preferred location in the comfort of their own homes.

After the baseline assessment at PAHC, participants had their first session on the same day. During this initial session, the training area was set up together with participants and their training buddies to familiarize them with setting up the training environment in their own homes. For participants assigned to the M-DTT group, a set-up video was recorded and uploaded to their individual Panopto folders, as the following week's sessions required specific equipment arrangement.

The set-up involved mounting a tablet onto a clear wall using the non-damage tablet wall mount and placing the exercise mat in a 2-meter square area adjacent to the wall. Subsequently, participants commenced their first training session according to their assigned group, alongside their training buddies and NC. The role of the training buddies was explained, emphasising their responsibility in scoring the participant's movements and entering the scores into the training workbook.

At the end of the session, participants were provided with the training workbook and the necessary pack of training equipment to support their home-based sessions. Participants in both groups were equipped with non-damage tablet wall mounts for viewing training videos and were provided with individual exercise mats. Those allocated to the M-DTT group were provided with the necessary equipment required for their training sessions throughout the 6 weeks. Figure 9 shows the wall-mounted tablet, exercise mat, and a sample of equipment for M-DTT group. This ensured that participants were equipped to continue their training independently.

Figure 9: *A visualization of wall-mounted tablet, exercise mat and some equipment for M-DTT*

The subsequent training sessions were undertaken in participants' homes, allowing them to engage with the programme in their familiar environments. To monitor progress and gather feedback, participants were invited to a scheduled Zoom session with NC at the end of every two weeks. During these sessions, their overall feedback at each stage of the training intervention, any adverse events (e.g. fall or near fall) they may have experienced but not yet reported, and their readiness for progression to the next phase of the training were discussed.

Content of the Intervention

The key finding from the qualitative study highlighted factors that potentially influence engagement and participation in the training program. Previous research suggests that higher adherence to the training protocol and increased likelihood of continued participation are associated with better engagement (Adcock et al., 2020). Therefore, it is crucial to consider the parameters that contribute to engagement when developing the training program.

According to the perspectives of pwPD in the qualitative study, tasks within the DTT should be enjoyable, creative, and avoid excessive repetition. Incorporating game-based elements into the training may enhance engagement and improve intervention outcomes for clinical populations (Chua et al., 2021). In this context, exer-games specifically developed as rehabilitation tools were mentioned in the study. While exer-games rely on technology, the therapeutic effect can be attributed to the dual-tasking nature that targets both physical and cognitive functions. Traditional games like table tennis or basketball that incorporate dual-tasking mechanisms may yield similar results in terms of engagement and effectiveness. Both pwPD and physiotherapists in the qualitative study commented that integrating games into the DTT could make it enjoyable and encourage sustained participation.

Based on these findings, the idea of utilizing games or developing game-based elements within the DTT held significant potential for enhancing the intervention in the feasibility study. By considering and implementing engaging game-like tasks, the DTT intervention might be further developed to maximize participant enjoyment and involvement.

Gaining 'points' and increasing personal scores within game mechanics can serve as a positive feedback and reward system, effectively encouraging players to beat their personal bests and take on greater challenges (Lee et al., 2017). This system has the potential to enhance motivation, engagement, and participation. Therefore, integrating a scoring element into the DTT could leverage the concept of gamification. It could add both a sense of achievement and progress and also enable participants to monitor their own performance, provide self-feedback, and ultimately help adherence.

To incorporate the scoring element, successful completion of secondary tasks was integrated into the DTTs. Since pre-recorded movies were not conducive to self-scoring during the training sessions, the involvement of training buddies was crucial in this feasibility study. In the qualitative study, it was revealed that interaction plays a significant role in participants' engagement and willingness to participate (P1, PT2).

The qualitative study also showed that supporters considered it acceptable to be a training buddy. The involvement of them in this feasibility study aimed to sustain the participant's motivation and ensure ongoing engagement.

Considerations about tasks in the main training sessions

The interaction between the motor and sensory systems and the cognitive system is vital for balance control in pwPD (Barbosa et al., 2016). The dual-tasking approach naturally engages the cognitive system by requiring individuals to divide their attention between two simultaneous tasks. While both the M-DTT and C-DTT interventions involve cognitive load, the intention behind developing and differentiating the C-DTT from M-DTT was to deliberately allocate attention to performing two distinct tasks.

In the C-DTT, the secondary tasks specifically require cognitive functions, whereas in the M-DTT, the secondary tasks primarily involve motor functions. Consequently, it may not be possible to completely isolate cognitive load from the M-DTT to differentiate it from the C-DTT. However, it can be noted that the C-DTT places a greater cognitive load on participants, which can help understand whether there are differential effects between cognitive secondary tasks and motor secondary tasks on the outcomes. Therefore, both the M-DTT and C-DTT interventions are designed to facilitate the cognitive system and are based on the interaction between sensory, motor, and cognitive systems (Silsupadol et al., 2006). By targeting these interconnected systems, the interventions aim to optimize balance control and enhance overall functional outcomes for pwPD.

The integration of somatosensory and visual information is crucial for developing a representation of the body, which is essential for maintaining balance and mobility (King and Horak, 2009). In light of this, the selection of secondary cognitive and motor tasks aimed to engage both the motor system (e.g., tasks requiring hand dexterity) and sensory systems (e.g., listening to podcasts). The balance tasks chosen were based on commonly used exercises in balance rehabilitation for pwPD (e.g., stepping, marching, lunging, etc.).

Considering that the tasks were delivered through pre-recorded training movies viewed on wall-mounted tablets, it was important to establish a training area that allowed clear visibility of the movies. During the task selection process, the individual balance tasks and secondary tasks were initially evaluated as standalone activities, ensuring they were feasible within the designated training area. While this approach may limit the inclusion of tasks that target different aspects of balance, it is important to prioritize suitable tasks that can be safely performed in a home environment. For example, walking is a common task used in DTT research (Zheng et al., 2021). However, it was not a viable option due to potential limitations in visibility of the movies and the requirement for a larger training area, which could hinder the monitoring and management of any adverse events. Consequently, tasks such as stepping at different challenge levels or marching were deemed more appropriate alternatives to walking. It was also aimed at improving inclusivity with this consideration by increasing the likelihood of people having enough space at home for the training and ensuring the tasks did not require special or difficult-to-access equipment.

By selecting suitable balance and secondary tasks that can be effectively performed within the designated training area, the intervention aimed to optimize safety and facilitate participant engagement in the home environment. Additionally, the practicality of performing the tasks simultaneously was considered during the task selection process. The primary focus was on ensuring that the individual primary and secondary tasks could be successfully integrated into a dual-task format. This was particularly important for the M-DTT, as the tasks should not impede each other's performance. Given that both tasks involved physical activity, it was essential to avoid any restrictions or limitations that may arise when attempting to perform them simultaneously. Furthermore, for the secondary motor tasks that relied on upper limb activity, it was crucial to choose tasks that did not obstruct participants' vision while watching the training movies.

As a result, the tasks within the DTT interventions were carefully selected through this two-stage process while embracing a game-like concept. For instance, when integrating the scoring element of games into the C-DTT, tasks involving memorisation, naming objects, and making calculations were incorporated to create a game-like experience. In the M-DTT, secondary tasks such as fidget toys and Lego bricks (Fig 10) were used to provide engaging motor activities.

The balance-related portion of the sessions was divided into two separate blocks, with a 1-minute seated break in between. This approach was inspired by a highly challenging exercise program for balance in pwPD (Conradsson et al., 2012). The introduction of secondary tasks in both interventions introduced a new concept and required additional time for participants to perform. For example, reaching tasks were introduced in Block B of the M-DTT, which required two minutes to complete, while Block A included gripping tasks that lasted 70 seconds. In the C-DTT, the introduction of audio stories in Block B provided a new type of sensory input, adding to the complexity and engagement of the intervention.

(a) (b)

Figure 10: *(a) Right leg lunging while attaching Lego bricks, (b) popping with left hand while marching.*

Warm-up and cool-down sessions

Warm-up exercises can act to begin to mobilise joints and have shown to increase blood flow to the target muscles when performed for 5-15 minutes before engaging in training sessions. Both active and passive warm-ups have been found to decrease the risk of muscle and tendon injuries (Park et al., 2018).

Cool-down exercises, which involve voluntary, low-to-moderate intensity exercises or movements performed within an hour after a training session, are considered to be an important component of post-training recovery interventions (Van Hooren and Peake, 2018). By promoting the recovery process after exercise, individuals are better prepared for subsequent sessions, and the risk of injuries is reduced (Van Hooren and Peake, 2018). Therefore, a five-minute warm-up and cool-down period of exercise, incorporating self-administered stretching exercises, were included for both M-DTT and C-DTT interventions in every session.

Each session in both interventions consisted of a five-minute warm-up and a five-minute cool-down, a standardised guided exercise around the two blocks of session-specific-movie-led DTT (of 20-minute duration). This totalled an average of 30mins of training per session. The detailed training protocols can be found in Appendix 18.

Training characteristics

Duration and Frequency

The duration and frequency of each training session, as well as the overall duration of the exercise training program, are important considerations in designing an effective intervention (Hecksteden et al., 2018). Among exercise studies involving PD populations, the most commonly reported prescription parameters are 60 minutes per session, two-times-per week, for 12 weeks (Bouço-Machado et al., 2019). Based on the scoping review, most DTT programs were conducted three-times-a-week for 6 weeks. In the qualitative study, pwPD expressed that a three-times-a-week programme for six weeks was feasible within their daily schedule. Additionally, pwPD mentioned that sessions longer than 30 minutes might lead to fatigue and might not be acceptable, because of the risk of experiencing off periods during longer sessions.

Taking these factors into account, the training characteristics for the intervention were set as 30 minutes per session, three-times-a-week, for six weeks. This duration and frequency were chosen to ensure feasibility and minimize the risk of fatigue or off periods during the training sessions.

Progression

Progression is an important characteristic of training programs (Hecksteden et al., 2018). It has been found that progressive and challenging balance training programs are effective in improving balance in pwPD (Conradsson et al., 2015). Additionally, progression can contribute to engagement with the training, as pwPD are more likely to start and continue an exercise program when they believe in its effectiveness (Schootemeijer et al., 2020).

In the qualitative study, one pwPD who was familiar with the DTT approach expressed that DTT is a challenging training that pushes them to their limits, rather than simply performing everyday dual-tasks like talking and walking (P1). Physiotherapists also suggested introducing challenges to both the physical and cognitive tasks once the participants became familiar with the initial tasks.

To address the need for progression and challenge and maintain the standardisation of the progression strategy for both M-DTT and C-DTT groups the balance tasks remained the same and the stance position for these tasks was individually progressed by narrowing the base of support. The progression strategy involved narrowing the stance position from the initial comfortable stance position by 30% at the end of each two weeks (narrowing 60% from baseline stance width for Weeks 5-6) (Fig 11). To determine when to progress the stance position, the participant needed to demonstrate confidence and the ability to stand independently in the new position for one minute. This new stance position served as the starting position for each balance task and was also used for standing tasks in both interventions.

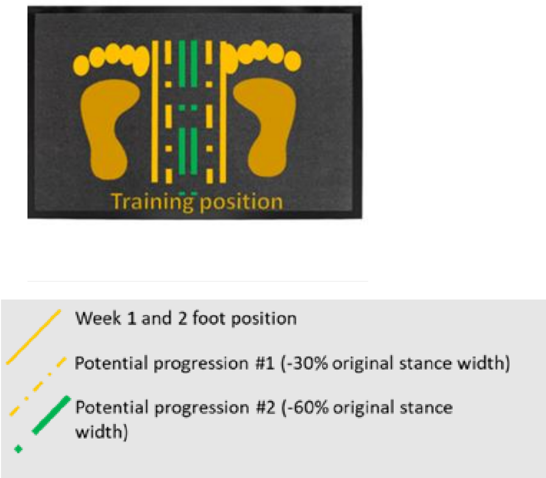


Figure 11: *A visualisation of exercise mat.*

representing the original stance position, first progressed stance position, and second progressed stance position at the end of each two weeks

By gradually narrowing the stance position over time, the participants were challenged to maintain their balance and stability. This progression strategy aimed to promote improvements in balance control and increase the difficulty level of the tasks. It was important to ensure that participants felt confident and stable in each new stance position before progressing further.

By individualising the progression of stance positions, the interventions could accommodate the participants' abilities and readiness for increased challenge. If participants expressed confidence in continuing the training independently at the twice weekly online progression assessments with NC, they progressed to the next two-week phase. This approach allowed for a gradual and controlled progression that was tailored to each participant's capabilities and addressed any concerns or challenges that arose during the training program.

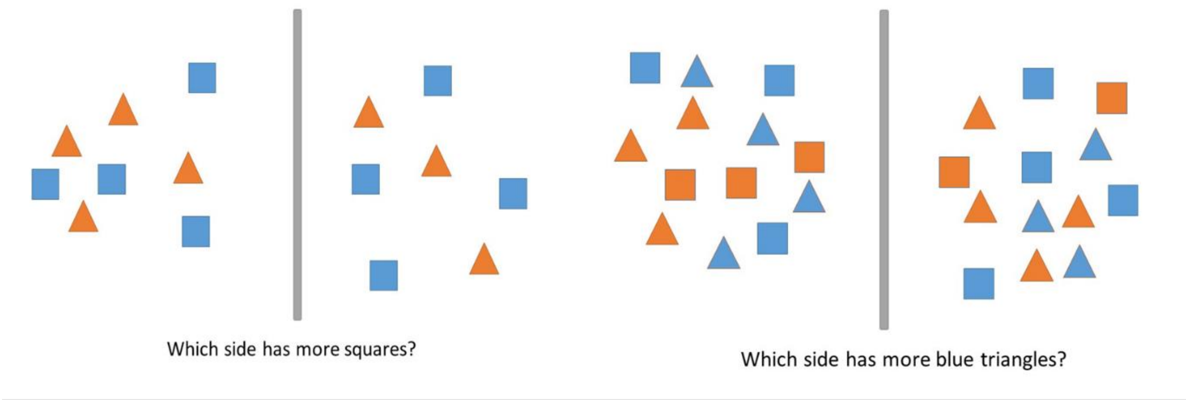
To address the need for progression and challenge, both the primary balance tasks and secondary tasks within M-DTT and C-DTT were individually progressed at the end of each two-week period. The goal was to ensure that the level of challenge remained within participants' capabilities and did not restrict their ability to perform other tasks. For example, in C-DTT, as the balance tasks progressed, the participants' visual area was considered to ensure they could see the cognitive tasks on the screen.

It also aimed at providing standardisation of the progression level for each DTT intervention as much as possible with this individual task progression. It was not possible to standardize the level of challenge for secondary tasks, as motor and cognitive tasks are not comparable. Additionally, the overall perceived challenge for performing dual-tasking may not be comparable because the relative cognitive load cannot be calculated in motor-motor dual-tasking and motor-cognitive dual-tasking. However, applying the same strategy for primary-balance task progression (which was mostly based on increasing the range of movement in both groups) may help maintain with standardisation of the challenge level between groups. To maintain the standardisation of balance task progression the balance tasks remained the same in both groups.

While there is no strong evidence indicating the most effective progression model, the progression approach in this study was designed to be challenging yet feasible for the participants, taking into consideration their abilities and task requirements.

Progression of secondary tasks in C-DTT

The progression of the secondary cognitive tasks included incorporating different sensory inputs and increasing the challenge level of cognitive functioning. For example, in the first two weeks of the training participants were asked to count the specified shape or colour of objects, in Weeks 3-4 they were asked to match both shape and colour for the objects they were asked to count (Fig 12).



(a) (b)

Figure 12: *(a) an example of cognitive task for Weeks 1-2, (b) an example of progressed cognitive task for Weeks 3-4 in C-DTT*

Another task involved listening to an audio story from a children's book and responding to related questions. By Weeks 3-4, this task advanced to answering questions about an audio story from a different book, which presented more intricate details. In Weeks 5-6, participants were required to watch a video clip, demanding the simultaneous tracking of conversations and visual details.

Progression of secondary tasks in M-DTT

Progression of the secondary motor tasks was achieved by changing the tasks or increasing the difficulty of the tasks. This included increasing the range of motion of upper extremities and challenge level of hand dexterity. Each individual task was carefully chosen and practiced by both NC and a member of the supervisory team (LB) to ensure the applicability of the progression in M-DTT.

One of the secondary motor tasks in M-DTT involved touching Lego plates on the wall as targets for the initial two weeks. Following this, the task progressed to attaching Lego bricks onto the same plates on the wall, requiring fine motor skills. To determine which size of brick was more difficult to attach, a mini pilot activity was conducted with 10 healthy volunteers.

During the pilot activity, participants were instructed to be seated in front of the same table, pick up the Lego bricks placed on the table, and attach them to the Lego plate placed on the same table. There were different sizes of Lego bricks; 2x2 dots and 4x2 dots. The participants were instructed to attach each size of Lego bricks in a different order each time, in four different attempts: red bricks with random order, red bricks with line order, blue bricks with random order, and blue bricks with line order. The researcher (NC) recorded the time for each trial of attaching for each participant. The average time was calculated for each combination, as well as the first and last tries to see if there was any possible effect of practice (Table 9).

Average Time					
4x2 dots brick- Line order attaching	**4x2 dots brick- Random order attaching**	**2x2 dots brick- Line order attaching**	**2x2 dots brick- Random order attaching**	**First Try (regardless of combination)**	**Last Try (regardless of combination)**
31.8 sec	31.3 sec	31.1 sec	29.1 sec	32.2 sec	28.5 sec

Table 9: *Average time of trials for each brick-attaching order combination*

During this small pilot of the use of Lego bricks as a motor challenge, participants had varying experiences, with most of them perceiving that randomly attaching the bricks was more difficult. However, the times recorded for the first and last trials indicated that the last trial was easier, which may be attributed to a practice effect. The times suggested that attaching 4x2 dot bricks may be more difficult. However, it is important to note that the participants were in a sitting position and close to the

Lego plate, primarily relying on wrist function and hand dexterity. In a standing position, additional shoulder movement would be required, introducing different parameters that could affect the results. Therefore, making a definitive decision based solely on the pilot activity results challenging.

The average times for performing each combination were similar, with the blue random combination appearing slightly easier than the others. However, the volunteers felt that attaching the 2x2 dot bricks was more difficult. Taking into account the potential challenges of using hand dexterity in a standing position, it was decided to progress by attaching 4x2 dot bricks in a random order during weeks 3-4. In weeks 5 and 6, the progression strategy involved using 2x2 dot bricks, starting with a random order of attachment. A screenshot of the training movies presenting how people were instructed to perform these tasks can be found in Fig 13.

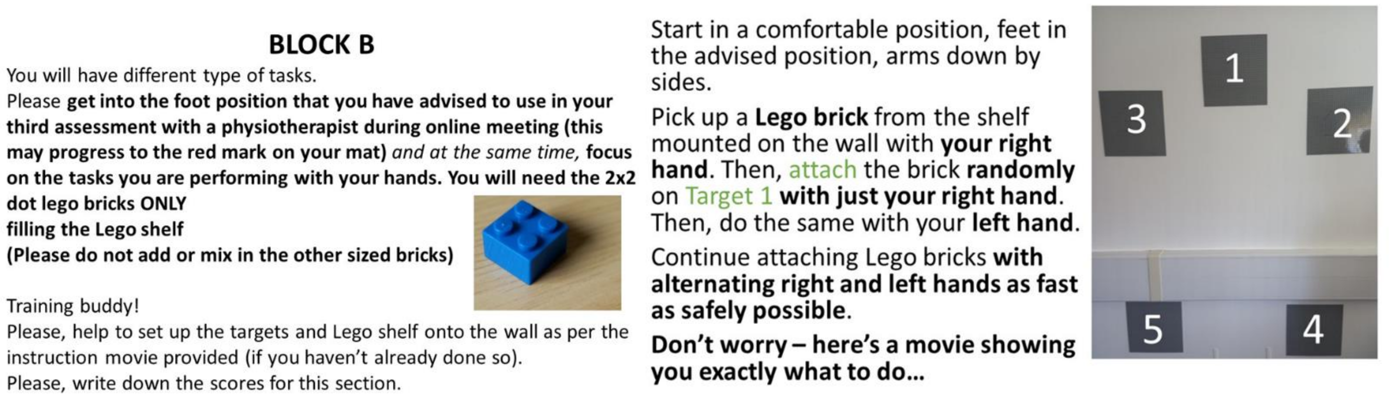


Figure 13: *an example of task instructions for week 5 in M-DTT*

It is important to acknowledge the limitations of the pilot activity, such as the small sample size and the specific conditions of the task. Nevertheless, the findings provided valuable insights for designing the progression strategy in M-DTT.

5.2.6 Assessments/Tests

A standardised form was used to collect demographic and medical information from participants in each intervention group, such as their age and gender, number of years after diagnosis, etc. This included the MDS UPDRS-II self-report scale items, to determine their disability severity as a covariate for group allocation.

Cognitive Status Assessment

Cognitive impairments are common in pwPD (Burdick et al., 2014). To statistically test the correlation between initial cognitive status and the effects of DTTs or the effectiveness of the interventions on cognition was not an objective for this feasibility study. However, it may be interesting to assess how well the study sample represents the target population in terms of cognitive status. It may also help to understand whether there is a relationship between cognitive status and the acceptability of the M-DTT and C-DTT interventions. For these reasons, the participants' cognitive status was assessed only at baseline. The Mini-Mental State Examination (MMSE) test is a recommended screening tool for detecting cognitive impairments in pwPD, despite its low sensitivity when compared to bigger battery neuropsychological tests (Burdick et al., 2014). It should only be used with caution to detect early cognitive deficits or dementia but, the purpose of this study was not to detect such cognitive impairments, and the MMSE is a simple and short test to use in a clinical environment (Zadikoff et al., 2008). As a result, the MMSE (Appendix 19) was utilised to assess baseline cognitive status.

Primary Outcome Measures

Feasibility

Attendance and adherence rates are the main indicative of the feasibility. The study defined 'attendance' to the training movie protocol as the number of views of the sessions, with 'views' indicating that participants both accessed the session link and streamed the associated movies. The number of attendances to training sessions (views) was recorded separately for the warm-up movie, main exercise movies, and cool-down movie for each session using Panopto.

Adherence to the intervention was defined as the 'minutes participants streamed sessions'. Session durations and participant absolute viewing times were recorded for each movie using Panopto. Panopto analytics enabled individual recordings of the participant attendance and adherence and interaction with the sessions. Fig's 14 and 15 shows how Panopto represents analytics belongs to a participant and the interaction.

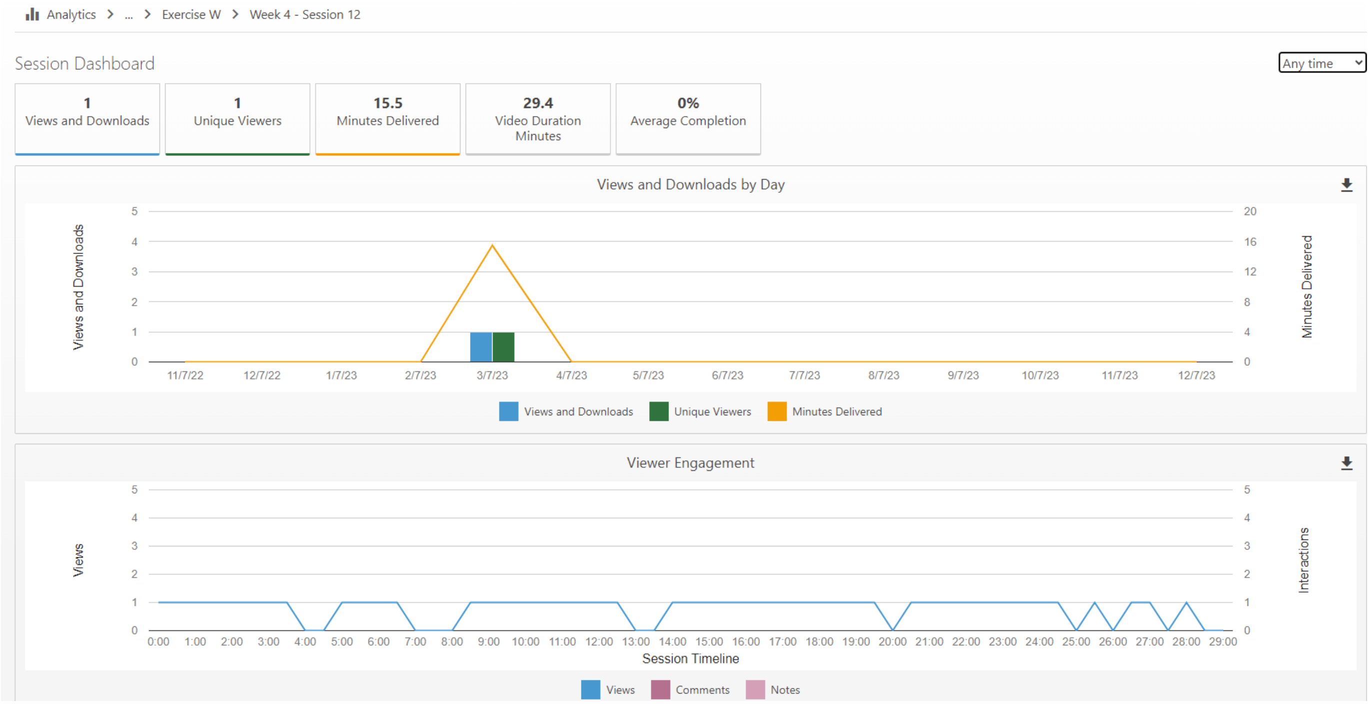


Figure 14: *An example of how Panopto represents a participant's interaction with a specific training session.*

this involves details such as the most-watched segments, skipped portions, and analytics specific to that individual session and participant, such as the number of views and total minutes watched.

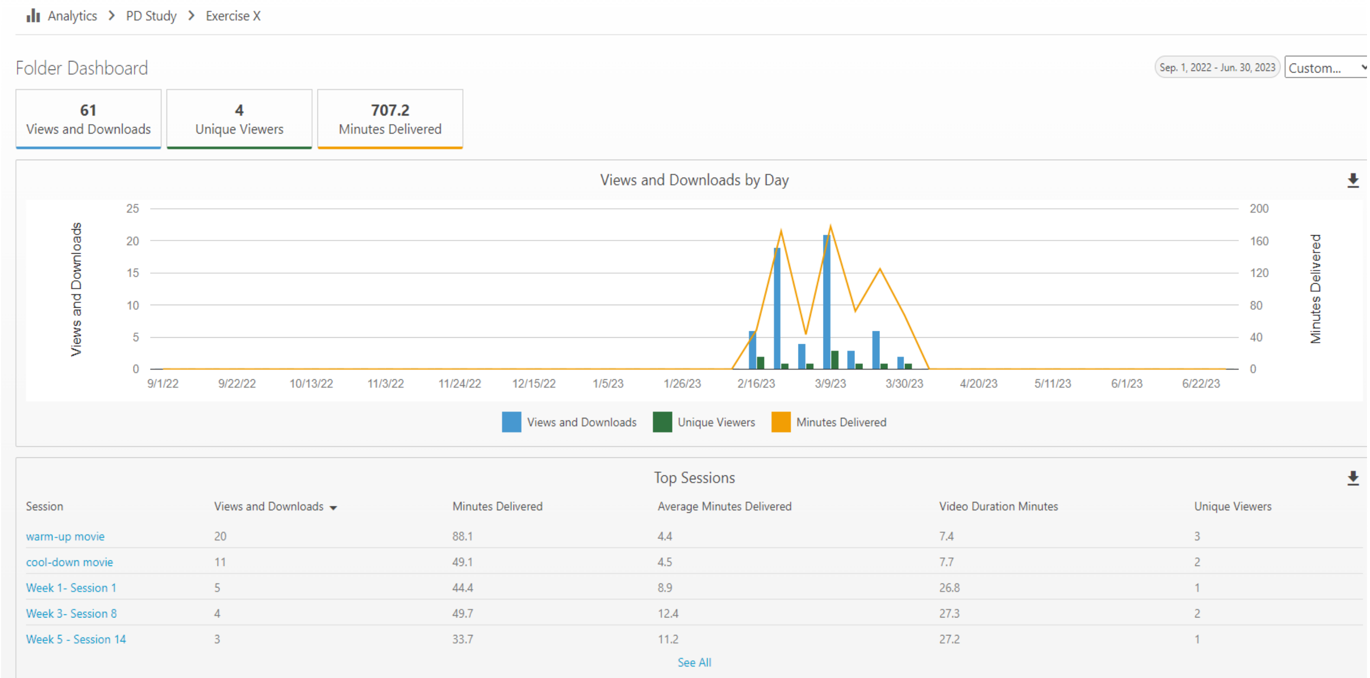


Figure 15: *An illustration of how Panopto represents analytics for a participant during a 6-week training period.*

this includes metrics such as the total number of views, overall minutes watched, and a ranking of top sessions based on individual session view counts.

Safety

There were two methods for recording safety related issues. Participants were signposted to contact the researcher should any incident arise, whereupon a log of adverse events/serious adverse events were recorded. They were also prompted to report any difficulties or adverse/ serious adverse events at the two-week online progress assessment sessions with NC. The training workbook was another tool to record safety. Here participants entered safety issues, such as the number of falls or near falls experienced during training sessions. This was elaborated upon in the semi-structured interviews where participants would be asked to expand on any information shared regarding falls. Participant training workbooks asked participants to contact the researcher as soon as safely possible if they experienced any (i) difficulties (ii) injuries or (iii) negative impacts on health or wellbeing. Whilst these are not all necessarily adverse/serious adverse events, it ensured the researcher could respond to any safety related concerns.

A safety reporting template form (adapted from the HRA standard reporting document) was used to record adverse/serious adverse events (Appendix 20) by the researcher, using the following definitions:

An adverse event: Any untoward medical occurrence in a patient or clinical trial subject administered [an intervention] and which does not necessarily have a causal relationship with this treatment.

A serious adverse event: Any adverse event or adverse reaction that results in death, is life-threatening, requires hospitalisation or prolongation of existing hospitalisation, results in persistent or significant disability or incapacity.

Acceptability

At the end of each two weeks, participants' perceptions of the intervention (individual task difficulty, progression, satisfaction, enjoyment, etc.) were elicited using 5-point Likert scales (Appendix 21) via Jisc online Survey. A variety of participant feedback forms from several feasibility studies influenced the development of these scale questions (Learmonth et al., 2017, McCue et al., 2022).

Participant’s perception regarding outcome measures (e.g. trustworthiness), monitoring (e.g. difficulty, independence), and overall intervention were asked in a semi-structured interview after completion of the training intervention. Immediately following their final face-to-face assessment, each participant was offered an individual interview with NC to minimise issues with recall (for further details refer to the qualitative component section) about their experiences.

The training workbook (Appendix 22) asks to rate enjoyment and difficulty of each session with a 10-point scale, where zero means not enjoyable/difficult at all, and ten represents highly enjoyable/difficult. the training workbook also includes an optional journal to enter their thoughts and comments about the training sessions.

Balance Assessments

Balance-related measures were decided on the basis of the scoping review and qualitative study findings, and with additional evidence from the literature (see Chapter 3 and 4). In brief, participants in the qualitative study agreed with the importance of using standardised and validated assessment tools for research. PwPD also stated that travelling to the researcher site for pre- and post- tests was acceptable. Therefore, participants had a baseline assessment session before randomisation, and another assessment at a maximum of 7 days after the completion of the training intervention. All balance- related assessments were completed in a room at PAHC, UoP. All were completed during the participants' on-medication time and wearing their comfortable shoes.

1. Functional Balance Assessment

Mini Balance Evaluation Scale test (Mini-BESTest) is the shorter version (14 items) of the Balance Evaluation Scale test (BESTest). It is identified as the most comprehensive balance measure for elderly individuals and community-dwelling adults (Di Carlo et al., 2016). It measures different aspects of dynamic balance; movement during gait and transfers, external perturbations and cognitive dual-task performance, with higher scores indicating better balance (Leddy et al., 2011). The Mini-BESTest was highly reliable in terms of test-retest reliability (ICC≥0.88) and inter-rater reliability (ICC≥0.91) in PD (Leddy, Crowner and Earhart, 2011). According to a systematic review evaluating its psychometric qualities, in which most people had PD, it is a reliable and valid balance measure (Di Carlo et al., 2016). The Mini-BESTest was thus utilised to assess the change in static and dynamic balance (Appendix 23).

2. Body Sway Assessment

Force platforms are known as the gold standard for assessing different sway parameters of postural stability (Reynard et al., 2019). Accelerometers are also valid and reliable and can provide similar results to that gained from force platforms (Reynard et al., 2019).

Body sway data was collected using the XSens Awinda motion sensor (XSens Awinda sensor, XSens, Enschede, Netherlands), which is an accelerometer and gyroscope. A recent systematic review showed that lower back (L5) was chosen for the sensor placement in most of the included studies (Ghislieri et al., 2019). This may help to get accurate results for standing balance measurements as the lower back is near the centre of mass. For this PhD study, the sensor was placed on the back of the patient on the C7 vertebra as it allowed easy access and comfort for the participants, rather than the L5 vertebra. Assessments were completed under three standing conditions: (1) comfortable position with eyes open (EO); (2) comfortable position with eyes closed (EC); (3) feet apart within 4cm with EO. All measurements were taken at a sampling frequency of 100Hz over a 45-second duration, consisting of 5 seconds for stabilization, 35 seconds for measurement, and 5 seconds for possible fatigue. 35 seconds of measurement was used for the data analysis as this duration has been found to provide reliable performance (Alsubaie et al., 2019). A 46.1Hz human filter which is already embedded within the motion sensor software was applied to remove potential noise from other human factors. The sway angles and accelerations in medio-lateral (ML) and antero-posterior (AP) directions data were recorded.

The total angular sway velocity, and the angular velocities in the ML and AP directions were calculated, as measuring angular velocity or the acceleration of trunk can accurately quantify the balance during stance tasks (Roetenberg et al., 2019). Higher velocity values indicate poorer balance (Chen et al., 2020b). The following calculation was used for angular sway velocities in ML and AP directions:

$\omega = \Delta\theta / \Delta t$

ω = angular velocity in degree/second

$\Delta\theta = \theta\_final - \theta\_initial$ (change in sway angle in the time interval)

Δt = the time interval

Total angular sway velocity was calculated by applying Pythagoras Theorem with following formula:

$\omega_{total} = \sqrt{(\omega_{ml}^2 + \omega_{ap}^2)}$

ω_{ml}= angular velocity in ML direction in degree/second

ω_{ap}= angular velocity in AP direction in degree/second

The Root Mean Square (RMS) is defined as the square root of the mean of the squares of a sample (Paillard and Noe, 2015, p: 4). RMS values can provide good reliability in discriminating between healthy subjects and those with pathologies (Paillard and Noé, 2015). As a value of RMS is easy to use in clinical practice (Sekine et al., 2013), RMS values of acceleration in AP and ML directions were calculated. Higher RMS values indicate more sway and poorer balance (Alqahtani et al., 2020). RMS of acceleration in both directions were calculated with the following formula:

$$\mathbf{RMS} = \sqrt{\frac{1}{N}}\sum_{i=1}^{N}(a_i\,2)$$

N = the number of data points.

a_i = the squared acceleration values at each data point.

5.2.7 Data Analyses

Acceptability and feasibility related data from the training workbook (enjoyment rate and difficulty rate of the intervention) are reported as the mean for each group.

Attendance is determined by recording the number of exercise sessions attempted for warm-up, cool-down, and main exercise Panopto analytics and is reported as the number of views for the training session movies by participants.

Adherence to movie streaming in the required training week is based on the Panopto system analytics. This was specifically available for each movie streamed but is reported as mean viewing duration time and total watching time for warm-up, cool-down, and Weeks 1-2, Weeks 3-4, and Weeks 5-6 movie watching time in total and as mean for each participant. The responses to each component of the acceptability 5-point Likert scale were recorded. The 5-point Likert scales were completed at the end of Week 2, 4 and 6. The responses to each question are presented in the number for both groups.

The quantitative data derived from (Panopto analytics, XSens sway data, and clinical assessment scores) were entered and analysed in Microsoft Excel (Microsoft Corporation, Version 2208). Participant characteristics and medical data collected at baseline (age, gender, working status, disease duration, and the number of falls in the last 3 months, MDS-UPDRS-II self-report score, and MMSE scores) are presented for each participant from both intervention groups utilising tabulated display methods in Excel.

MiniBESTest scores at baseline and post-intervention, and changes on the scores were calculated for reporting any individual signals of improvement, deterioration or no change in this primary outcome measure.

Changes in angular velocities (deg/s) and RMS of acceleration (m/s^2) in ML and AP directions were descriptively analysed for each participant.

Qualitative data analysis is explained in the “qualitative component” section below (section 5.2.8).

5.2.8 Qualitative Component

The embedded qualitative component of this feasibility study has the potential to give insights into the participant perception of their research experience. In doing so it can provide a better understanding of both the advantageous aspects of the research and any problems with the research processes (Hamilton and Finley, 2019). In this feasibility study a particular goal was to better understand the feasibility and acceptability of the interventions and outcome measures to help to inform a future RCT to investigate the superiority of M-DTT and C-DTT for balance in pwPD. It may also help to understand whether there is consistency with the pre-trial qualitative study findings.

Qualitative data was gathered by conducting semi-structured interviews with pwPD immediately after the final face-to-face post-intervention assessments. To ensure smooth interaction and capture meaningful responses, an interview guide was utilized (Appendix 24). This guide consisted of open-ended questions and prompts designed to probe the participants' experiences with regard to (i) the home-based training, (ii) assessment within site visits, and (iii) the trial as a whole.

The interview guide encompassed specific questions designed to gauge the overall difficulty of the training program and the individual primary and secondary tasks. Participants were asked about their level of enjoyment while engaging in the exercises, as well as the specific challenges they encountered and what they found easiest during their workout sessions. Additionally, participants were asked about their comfort level when performing the exercises at home, their perceptions of the commute to the university for balance testing, their experience with completing the 5-point Likert scale every two weeks, their confidence levels during training, and whether they experienced any falls or dizziness during the training sessions.

Participants were given the option to have their supporters or training buddies present during the interviews. Their presence was encouraged, as it was felt that they could contribute valuable insights to the conversation, could provide assistance with understanding the researcher's questions, expand on responses, or assist with recall of specific experiences. The researcher conducted the interviews using the authorized Zoom account provided by the university to serve as the recording platform. On average, each interview lasted approximately 40 minutes. At the end of the data collection sessions, participants were thanked for their time, and the manual recording process was promptly stopped. To maintain data security, all interviews were securely transferred to the university's licensed OneDrive account for onward analysis.

Analysis of Qualitative Data

The qualitative data gathered from the semi-structured interviews were thematically analysed (Braun and Clarke, 2021). Thematic analysis enables a detailed and nuanced account of the data shaped on the specific questions asked about the participants' experiences, their preferences for future research, and the factors influencing these preferences regarding different aspects of the future RCT (Braun and Clarke, 2006). This approach offered a versatile approach, suitable for critical realist researchers, accommodating various philosophical perspectives and research questions (Nowell et al., 2017).

It was important to gain an understanding of potential facilitators and barriers to participant engagement with the research. To accomplish this, an inductive approach was adopted, allowing for an exploration of participants' real experiences. This inductive approach would aid in refining the research elements prior to conducting the future RCT. Additionally, the findings resulting from a thematic analysis using an inductive approach may offer insights into the design of different types of DTTs in future studies or practical settings. Therefore, a hybrid approach of thematic analysis (Fereday and Muir-Cochrane, 2006) was chosen to achieve the objectives of this qualitative component within the feasibility study. This allows for a comprehensive exploration of the data to generate valuable insights.

In the initial stage of the thematic analysis, the data were transcribed by a competent assistant with a local regional accent (aligning with that of most participants) and prior experience in transcription for research studies (CL). Subsequently, the researcher cross-checked the transcripts with the audio recordings to identify and rectify any errors. All the transcripts were then imported into NVivo 10, a qualitative data analysis software program, and NC followed the stages of thematic analysis outlined by Braun and Clarke (2021): a) familiarization with the data, b) generating initial codes, c) searching for themes, d) reviewing themes, e) defining and naming themes, and f) producing a report.

To familiarize herself with the dataset, the researcher thoroughly read all the transcripts within NVivo and made initial notes for coding ideas. Once familiarization was complete, she proceeded to code the transcripts within NVivo, separately reviewing data from each intervention group as subgroups. To ensure the reliability of the coding process, one member of the research team (LB) independently reviewed one of the transcripts and codes, facilitating discussions and reaching agreement on initial coding. The extracted initial codes were organized in a table format within a Word document, as it proved to be an efficient way to review codes both within subgroups and as a whole.

Following the coding stage, the initial subthemes and themes began to take shape. LB and the researcher reviewed these initial subthemes and themes in relation to the codes, engaging in discussions until reaching a consensus. This collaborative process allowed for the development of coherent and comprehensive subthemes and themes.

5.2.9 Ethical considerations

Consent

In this study, all potential participants were provided with an information sheet outlining the study's purpose, procedures, risks, and benefits prior to expressing their interest to participate. If they expressed interest, they received an invitation to a Zoom interview where they could ask questions and be screened for eligibility. Email invitations were sent to eligible participants inviting them to the Peninsula Allied Health Centre (PAHC), UoP. They were reminded that their participation in the study was voluntary, and they hada right to withdraw at any time. At their initial visit to PAHC, their understanding of the trial was checked before written consent was gained from both the pwPD and their training buddy (Appendix 25).

Data Management and Confidentiality

Data were handled in compliance with the Code of Good Research Practice, which sets out UoP's commitment to research integrity (https://www.plymouth.ac.uk/research/governance/research-ethics-policy). All data will be used only for the purpose of this study by the research team. Written consent and all paper documents (tests and scales, data collection forms) were securely stored in a locked cabinet at the PAHC until they were scanned to electronic files. They were then securely destroyed as per UoP research data policy (https://www.plymouth.ac.uk/research/governance/research-ethics-policy). This electronic data will continue to be securely held within a secure OneDrive repository for 10 years, after which it will be securely destroyed (overseen by LB, JF and University information technologists).

Participant confidentiality was ensured by using unique codes on all documentation to ensure that participant data is not identifiable during the study or when the results are shared.

Audio-records from the qualitative component was stored on a university-licensed OneDrive account folder, accessible only by the research team. Once the audio-recordings were transcribed, participants were no longer be able to withdraw from the study, so their personal contact details were securely deleted. At this point, the transcribed data were anonymous. To ensure confidentiality and anonymity the same codes were used for each participant. All names and personal information were redacted from the transcriptions. Direct quotes were depersonalized and carefully scrutinised to ensure anonymity. Only the research team has had access to personal contact information, raw data (audio recordings, transcripts, and paper documentation.

5.3 Results

The results relevant to study objectives, namely feasibility analysis including consideration of attendance and adherence to the intervention and assessment, online progress assessment, safety, and acceptability of the intervention, exploring signals of effectiveness in outcome measures and will be presented.

Process data relating to feasibility of the trial design will be initially presented using the CONSORT Checklist extension for the pilot and feasibility studies (Schulz et al., 2010). Expanded quantitative data, followed by the qualitative data results will then be presented ahead of a discussion of this data relative to the wider literature.

5.3.1 Recruitment

Two different attempts to recruit participants via the Parkinson's UK email distribution database were made, three months apart, owing to an initial slow response rate. This resulted in 9 interested pwPD. A third attempt involving an in-person visit was made 3 months later achieving a further 3 interested pwPD. Twelve persons initially made contact to show interest in participating in the study. Eleven of these potential participants were screened, and seven participants were enrolled to the study. Three participants were randomly allocated to the M-DTT group, and four to the C-DTT group, utilising the minimisation procedure previously described. One participant withdrew after completing the first two weeks of the training because of an unexpected diagnosis of a pulmonary health condition. The participant initially felt that the respiratory condition (a mild cold) did not preclude her from participating in the trial but at the two-week stage this had increased in severity and was affecting her ability to train. It was therefore mutually agreed that she should withdraw from the study and focus on recovery from this condition. Discussion with the participant at the point of withdrawal confirmed that there was no other reason pertaining to the requirement of the trial which would be a factor in the decision to withdraw. No other participants withdrew from the study. A CONSORT flow diagram (Eldridge et al., 2016) was used to present a summary of recruitment and follow-up stages (Fig 16).

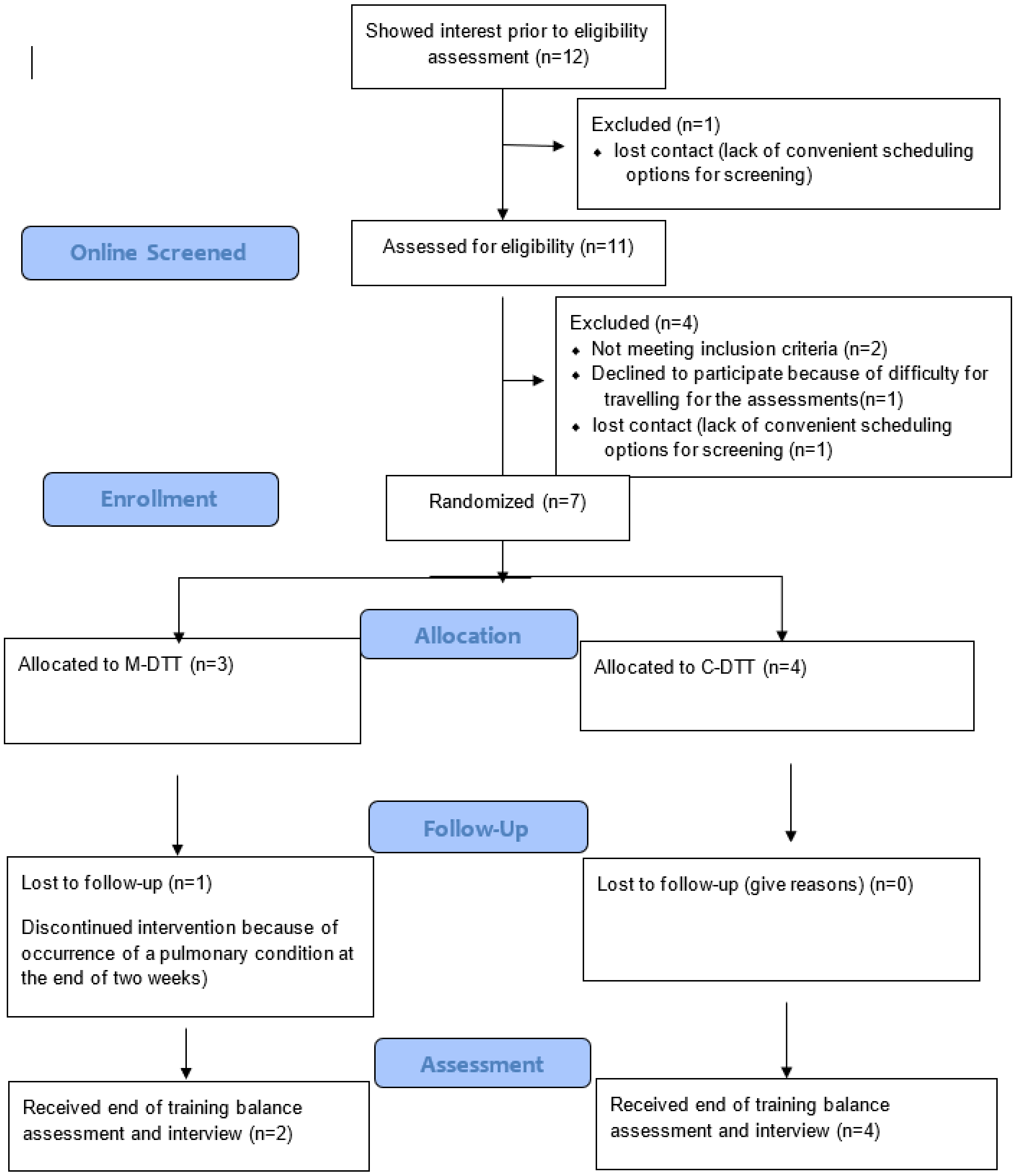


Figure 16: *Adapted CONSORT Flow Diagram*

(Eldridge et al., 2016)

5.3.2 Baseline and Demographic data

At the baseline assessments participants were asked if they want to use their own tablets or requested one from the researcher to use for undertaking the home training sessions. The participants' study IDs were allocated according to that preference; the first participant who chose to use their own tablet was “P1” ID, and the first participant who chose to use a university tablet was “P11” ID. This method was used to follow the borrowing status of the tablets and web links created specifically for each individual participant to access their pre-recorded training movies within Panopto.

Baseline characteristics of participants who attended follow-up assessment are presented individually in Table 10. Two participants were male. All but one participant was retired. The average age was 71 years and average disease duration after diagnosis was 11.42 years. According to the self-report UPDRS-II score, four participants were mild (score <17), and two participants were moderate (scores ≥17) in terms of the effect of the disease on their daily life.

Participants	Allocated Group	Own device /loaned	Gender	Age	Years after diagnosis	Working status	Number of falls in the last 3 months	Health conditions apart from PD	MDS-UPDRS-II Score	MMSE Score	MiniBESTest Score
P3	M-DTT	Loaned	Female	80	10	Retired	None	Osteoarthritis, glaucoma	14	29	18
P11	M-DTT	Own	Male	62	17.5	Retired	None	Not reported	17	30	25
P1	C-DTT	Loaned	Female	63	7	Self-employed	Two times or less	Slightly low blood pressure	11	29	25
P12	C-DTT	Own	Female	76	6	Retired	None	None	8	30	23
P13	C-DTT	Own	Female	71	12	Retired	None	Osteoarthritis	15	29	20
P14	C-DTT	Own	Male	69	14.5	Retired	None	Osteoarthritis	29	29	22

Table 10: *Baseline and Demographic Data*

Legend-‘C-DTT’=Cognitive-motor dual-task training, ‘M-DTT’=Motor-motor dual-task training, ‘MDS-UPDRS II’= Movement Disorder Society Unified Parkinson’s Disease Rating Scale part II (self-reported motor experiences daily living), ‘MiniBESTest’=Mini Balance Evaluation Systems Test, ‘MMSE’=Mini Mental State Examination test, ‘P’=Participants, ‘PD’=Parkinson’s disease.

5.3.3 Attendance

The number of attendances to training sessions (views) was recorded separately for the warm-up movie, main exercise movies, and cool-down movie for each session using Panopto. Participants completed their initial training session incorporating all components (warm-up, training session 1, and cool-down) immediately after their baseline assessment whilst on site and under the supervision of the researcher (NC). Table 11 displays the number of viewed sessions in both intervention groups, where participants in each group was anticipated to attend for 18 total sessions for each component of the full training session (i.e. 18 total warm-ups, 18 total training sessions spread over 6 weeks and 18 total cool downs). Since the training movie links were always accessible, participants could view them as often as they wished. Panopto recorded a total number of views per participant in excess of the anticipated n=18 for all training movies, although total views for warm-ups and cool downs were typically fewer than the anticipated n=18. There are a number of potential explanations for this, which will be revisited in the discussion section.

The Panopto records reveal a trend where most participants repeated the first session at home after having undertaken this on site under supervision. This was contrary to instruction, and it remains unknown as to whether participants were undertaking a second training session, familiarising themselves to their home set up, or showing a friend or family member what they had undertaken.

In the M-DTT group, both participants viewed all main exercise movies, but one participant (P11) watched only 15/18 cool-down movies, and another participant (P3) watched only 9/18 warm-up and only 5/18 cool-down movies.

In the C-DTT group, all participants viewed all of their main exercise sessions, but as per M-DTT group participants, warm-up and cool-down movies were not watched as many times as anticipated. In both groups there were no obvious differences in the viewed number of sessions among each two-weeks of the main exercises. Overall, in both groups, some participants chose not to engage in warm-up and cool-down exercises during each session, despite all of them attempting the main exercises.

Participants	**Allocated Group**	**Warm-up (/18)**	**Main exercises**				**Cool-down (/18)**
			Weeks 1-2 (/6)	Weeks 3-4 (/6)	Weeks 5-6 (/6)	Total (/18)	
P3	M-DTT	9	11	12	9	32	5
P11	M-DTT	19	7	8	6	21	15
P1	C-DTT	3	8	6	7	21	1

P12	C-DTT	8	9	6	6	21	4
P13	C-DTT	17	6	7	6	19	11
P14	C-DTT	20	9	7	6	22	11

Table 11: *The number of viewed sessions of the training components by each participant*

Legend *- 'C-DTT'=Cognitive-motor dual-task training, 'Cool-down (/18)' =the number of viewed cool-down movies (total number of movies is 18), 'M-DTT'= Motor-motor dual-task training, 'Main Exercises-Weeks 1-2 (/6), Weeks 3-4 (/6), Weeks 5-6 (/6), Total (/18)'=the number of viewed sessions of the main exercises (total number of sessions is 18 and each two weeks has 6 sessions), 'P'=participants, 'Warm-up (/18)'= number of viewed warm-up movies (total number of movies is 18).*

5.3.4 Adherence

The aforementioned attendance data could be an indicator of adherence. However, data in this section expands on this, describing adherence to the intervention in terms of the 'minutes participants streamed sessions'. Table 12 presents metrics indicating adherence to the main exercises; including views, completed sessions, total viewing duration, session completeness as a percentage, average viewing time per session, and average of each single-session percentage completeness as an overall session average per person.

	Allocated group	Own device /loaned	No. total views (/18)	No. complete sessions (/18)	No. mins viewed	Average viewed no. mins	% mins (viewed/target x 100)	% mins (viewed/mean per session x 100)
P3	M-DTT	Loaned	32	20	693.5	38.4	112.0	111.63
P11	M-DTT	Own	21	18	510.9	29.45	82.50	82.34
Average for M-DTT			**26.5**	**19**	**602.2**	**33.93**	**97.25**	**96.99**
P1	C-DTT	Loaned	22	16	404.7	22.48	81.43	81.17
P12	C-DTT	Own	21	17	500.4	27.80	100.68	100.35
P13	C-DTT	Own	19	18	456.5	25.4	91.85	91.55
P14	C-DTT	Own	22	18	562.4	31.20	113.16	112.64
Average for C-DTT			**21**	**17.25**	**481**	**26.72**	**96.78**	**96.43**
Grand Average			22.83	17.83	521.4	29.12	96.94	96.61

Table 12: *An overview of movie viewing statistics as an indication of adherence to the main exercises for 6-weeks intervention by each participant.*

Legend- 'Average viewed no. mins'=mean of the total viewed minutes per session (Target: M-DTT n=34.4, C-DTT n=27.7, standard task performing duration is 17 minutes for both group), C-DTT=Cognitive-motor dual-task training, M-DTT=Motor-motor dual-task training, 'No. total views'=The total number of views recorded of all Panopto movies streamed in part or in full by each participant (there is a target of 18 movies to stream so views in excess indicate that some movies may have been stopped and restarted or recapped), 'No. complete sessions'=the number of sessions which are followed from start to finish (including the sessions had pausing and skipping the repetitive instructions to the tasks), 'No. minutes viewed' =number of total minutes viewed of the completed sessions through 6 weeks-intervention (Target: M-DTT n=619, C-DTT n=497.2 (standard task performing duration is 306 minutes for both group)), P=participant, '% minutes (viewed/target x 100)'=percentage of total viewed minutes against the total target movie duration, '% mins (viewed/mean per session x 100)'= percentage of viewed minutes per session against the target mean movie duration (percentage of standard task performing time is 61.37% for per session in C-DTT and 49.42% for per session in M-DTT).

While the number of views exceeded the total number of sessions, through cross-referencing the session completeness data, it is evident that only one participant completed more than 18 sessions (n=20). Only two participants in the C-DTT group (P1 and P12) attempted to watch each session but both did not complete each session. Overall, the completeness rate for all sessions was consistently high, exceeding 80%. Reasons for this will be revisited in the discussion section.

Whilst the completeness rate of all sessions and overall session average per person were higher than 100% for some participants in both groups (P3, P12, and P14), some rates for other participants were lower than 100%. This variability in percentage completion rate will be discussed later in this chapter.

Panopto's recording of engagement within a session was instrumental in understanding participant behaviours, such as pausing, skipping specific segments, and continuing to watch in a single session. Figures 17 and 18 illustrate examples of a participant's (P1) interactions with sessions in the C-DTT group within Panopto.

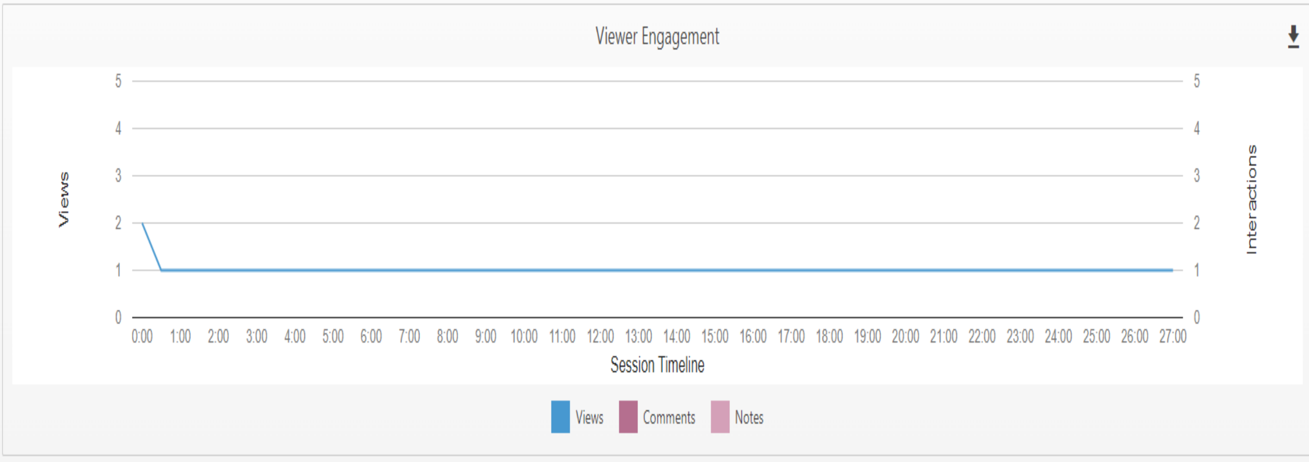


Figure 17: *P1's engagement with Week 1 Session 2 in C-DTT*

The straight line shows that the participant opened the movie two times at the start point, engaged with the whole session and completed it in one viewing.

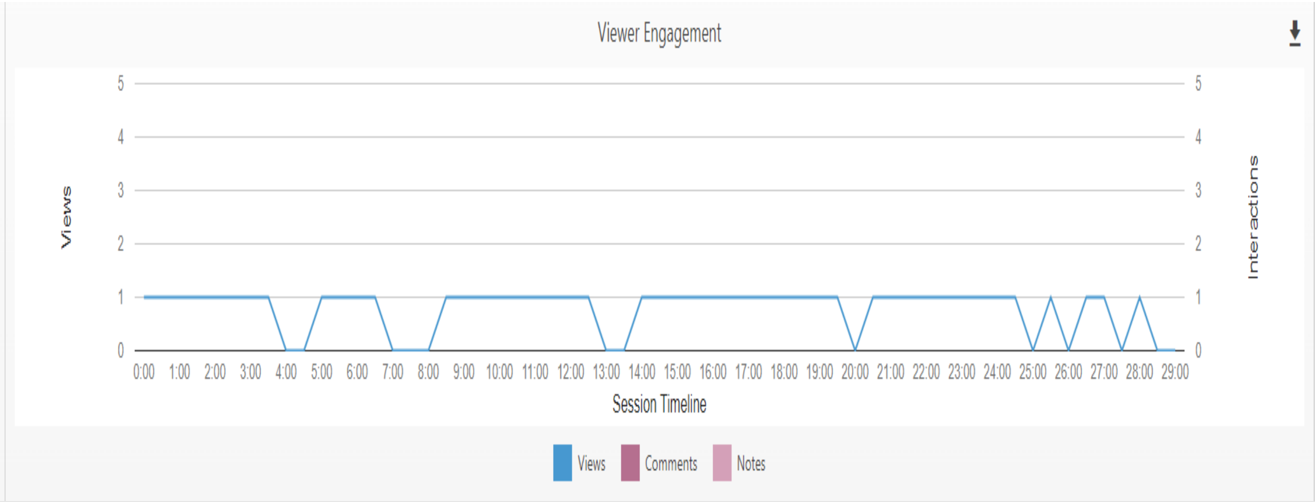


***Figure 18:** P1's engagement with Week 4 Session 11 in C-DTT*

The line shows that the participant viewed that session once, at some points skipped (e.g., minutes 4-5 in session timeline), at some points paused (e.g., the minute 20), and completed the session.

These figures and data in Table 12 suggest that some participants did not view all parts of the movies, possibly including instructional segments. It appears that participants may have engaged in the task itself may be more than once but skipped the instructional portions, contributing to a high overall adherence rate but perhaps indicating a loss of total fidelity.

The number of viewed minutes per session suggests a potentially high adherence rate to the main exercises because the percentage of the viewed minutes per session exceeded the 'active exercise' percentage (the percentage of the non-instructional part of each session; M-DTT: 49.42%, C-DTT: 61.37%).

Table 13 shows data relating to adherence in terms of the number of viewed minutes of completed sessions and percentage of total viewed minutes against the target total duration of sessions for each participant. As before, the data is broken down into the intervention components (warm-up, weeks of main exercises, and cool-down).

The data showed that in both groups the average adherence rate to the main exercise sessions were the highest in Week 1 and 2 (M-DTT [98.29% and 124.49% respectively]; C-DTT [105.33% and 108.26% respectively]). The average adherence rate to the Week 3 main exercises was very high for the M-DTT group (161.2%), influenced by one participant (P3) completing more than the number of sessions required (n=20/18). The average rate of viewed minutes of main exercise sessions for Week 6 was relatively low when compared against other weeks for both M-DTT (67.95%) and C-DTT (84.46%). In the M-DTT group, the average rate of viewed minutes of the main exercise sessions was lowest for Week 4, with one participant (P3) who did not complete all of the required sessions (36.89%). The average adherence rate for sessions in different weeks, both for each group individually and in total, exceeded 100%. Some potential reasons for this may be because (1) participants stopped the movie for some reason and then re-watched it from start, (2) participants did not understand an instruction and re-watched the same part of the movie.

The average adherence rate of warm-up sessions was higher than that of cool-down sessions in both groups. The average adherence rate of cool-down sessions was the lowest amongst the intervention components in both groups (52.34% for M-DTT and 25.56% for C-DTT).

As a summary, the average adherence rate of cool-down component was the lowest in both groups, and the average adherence rate to the main exercises were high in both groups (higher than 95% for the total 6 weeks and higher than 80% for per week).

Participants	Allocated Group	Warm-up (%)	Main exercises							Cool-down (%)
			Week 1 (%)	Week 2 (%)	Week 3 (%)	Week 4 (%)	Week 5 (%)	Week 6 (%)	**Total (%)**	
P3	M-DTT	62.7 (47.07)	100.4 (97.32)	169 (163.75)	250.8 (237.49)	0	114.2 (112.61)	56.2 (60.44)	693.5 (112)	38.2 (27.56)
P11	M-DTT	106.4 (79.88)	102.4 (99.26)	88 (85.23)	89.7 (84.91)	83.2 (73.78)	77.4 (76.34)	70.2 (75.45)	510.9 (82.50)	106.9 (77.13)
Average for M-DTT		**84.55 (63.48)**	**101.4 (98.29)**	**128.5 (124.49)**	**170.25 (161.2)**	**41.6 (36.89)**	**95.8 (94.48)**	**63.2 (67.95)**	**602.2 (97.25)**	**72.55 (52.35)**
P1	C-DTT	14.8 (11.11)	82.7 (102.07)	77.5 (97.10)	81.6 (99.71)	60.5 (66.98)	76.8 (91.80)	25.6 (31.86)	404.7 (81.43)	7.7 (5.56)
P12	C-DTT	51.5 (38.66)	79.9 (98.61)	109.7 (137.51)	54.2 (66.24)	90.0 (99.55)	81.8 (97.78)	84.7 (105.53)	500.4 (100.68)	18.7 (3.49)
P13	C-DTT	71.7 (53.83)	81.5 (100.61)	76.1 (95.41)	75.7 (92.56)	76.3 (84.40)	78.9 (94.27)	67.9 (84.61)	456.5 (91.85)	66.2 (47.76)
P14	C-DTT	88.1 (66.14)	97.2 (120.04)	82.2 (103.00)	92.2 (112.77)	98.5 (108.98)	99.2 (118.49)	93.0 (115.85)	562.4 (113.16)	49.1 (35.43)
Average for C-DTT		**56.53 (42.44)**	**85.33 (105.33)**	**86.38 (108.26)**	**75.93 (92.82)**	**81.33 (89.98)**	**84.18 (100.59)**	**67.8 (84.46)**	**481 (96.78)**	**35.43 (23.06)**
Grand Average		65.87 (49.45)	90.68 (102.99)	100.42 (113.67)	107.37 (115.61)	68.08 (72.28)	88.05 (98.55)	66.27 (78.96)	521.4 (96.94)	47.8 (32.82)

Table 13: *Number of minutes and percentage of completeness for the training components for each intervention group*

Legend - C-DTT=Cognitive-motor dual-task training, M-DTT=Motor-motor dual-task training, 'Warm-up (%)'= total viewed minutes of 18 sessions-warm-up videos and percentage of viewed minutes against the total target video duration (Target:133.2 minutes for both group), 'Cool-down (%)'=total viewed minutes of 18 sessions-cool-down videos and percentage of viewed minutes against the total target video duration (Target:138.6 minutes for both group), 'Main Exercises-Total (%)'=total viewed minutes of the completed sessions of main exercises throughout the training and percentage of total viewed minutes against the total target video duration (Target:619.2 minutes for M-DTT and 429.6 minutes for C-DTT), 'Main Exercises-Week 1 (%)'=total viewed minutes of the completed sessions in Week 1 and percentage of total viewed minutes against the target total duration of sessions in Week 1 (Target:103.2 minutes for M-DTT and 82.7 minutes for C-DTT), 'Main Exercises-Week 2 (%)'=total viewed minutes of the completed sessions in Week 2 and percentage of total viewed minutes against the target total duration of sessions in Week 2 (Target:103.2 minutes for M-DTT and 79.8 minutes for C-DTT), 'Main Exercises-Week 3 (%)'=total viewed minutes of the completed sessions in Week 3 and percentage of total viewed minutes against the target total duration of sessions in Week 3 (Target:105.6 minutes for M-DTT and 81.8 minutes for C-DTT), 'Main Exercises-Week 4 (%)'=total viewed minutes of the completed sessions in Week 4 and percentage of total viewed minutes against the target total duration of sessions in Week 4 (Target:112.8 minutes for M-DTT and 90.4 minutes for C-DTT), 'Main Exercises-Week 5 (%)'=total viewed minutes of the completed sessions in Week 5 and percentage of total viewed minutes against the target total duration of sessions in Week 5 (Target:101.4 minutes for M-DTT and 83.7 minutes for C-DTT), 'Main Exercises-Week 6 (%)'=total viewed minutes of the completed sessions in Week 6 and percentage of total viewed minutes against the target total duration of sessions in Week 6 (Target:93 minutes for M-DTT and 80.3 minutes for C-DTT).

5.3.5 Safety

There was one record of adverse event. That participant from M-DTT group informed the researcher at first online progress assessment meeting at the end of the week 2. It was recorded as a diagnosis of a pulmonary health condition and was not related to the training. After discussion of the situation, mutually agreed that she should withdraw from the study.

There were no reported falls during the training by pwPD in the training workbook. one participant (P14) recorded one wobble during week 1 session 3. Another participant (P1) recorded one wobble during week 5 session 14. Both participants were in the C-DTT group. However, neither felt these constituted a ‘near fall’ as the wobble remained within their control.

Twice weekly an online 5-point Likert scale was completed by participants to score safety of undertaking the home-based DTT interventions. The findings (Fig 19) show that participants in both groups found it ‘completely safe’, with just one participant rating their experience as ‘mostly safe’ during Weeks 5-6 in the C-DTT group. No annotation in the training diary was provided to explain this slight drop in rating for this one participant but in interview data one participant in this group experienced leg pain in the final week, which could be a possible association.

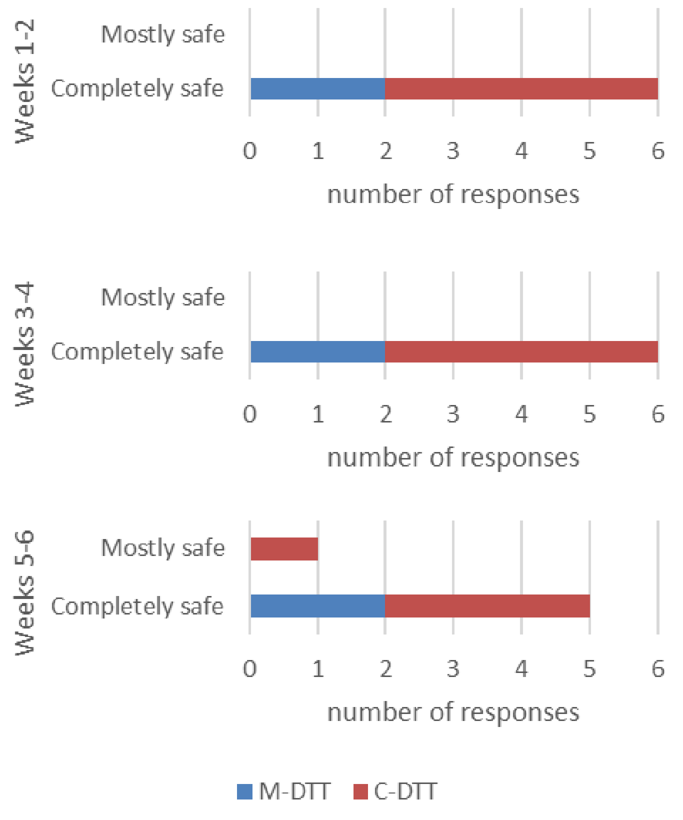


Figure 19: *Responses to question “How safe did you feel training in your own home?” in the twice weekly online 5-point Likert scale.*

the response options were ‘completely safe’, ‘mostly safe’, ‘unsure’, ‘mostly not safe’, and ‘not safe at all’.

5.3.6 Acceptability

Acceptability of the intervention

Acceptability of the intervention was recorded via twice-weekly adapted online 5-point Likert scale questions and open-ended questions which enabled participants to add further comments and suggestions regarding the training at this point. This data is narratively presented below.

Single session ratings of enjoyment and challenge were scored out of 10 by participants immediately post-training within the training workbook's 'week to a page' table of session scores. This provides additional detail relating to acceptability.

Difficulty and enjoyment level recorded via training workbook.

All participants recorded their perceived enjoyment and difficulty level within their training workbook. One participant did not record this for the Week 3 to Week 6 sessions. Table 14 shows the average scores for enjoyment and difficulty level in both groups. Average enjoyment and difficulty scores for the M-DTT sessions were 7.03 and 7.72 respectively. The highest enjoyment score (7.5) was given for Week 5-6. The difficulty level was lowest (6.58) for that week 5-6 sessions. As the number of participants was small, and the scores out of 10 not a continuous measure, a correlation analysis was not undertaken. However, this finding may suggest that as difficulty level increases, the enjoyment level decreases. In contrast, in the C-DTT group the average enjoyment level was low (4.21), gradually decreasing through each progressive two-week block. Here it was more difficult to discern any possible association between enjoyment and difficulty, as difficulty level was highest for Weeks 3-4 (8.13).

The DTT interventions were designed to incorporate progressive training by increasing the level of difficulty of the tasks every two week, following an online remote subjective assessment. However, the scores on the difficulty level showed that the most challenging weeks were Weeks 3 and 4 in both groups, although it was supposed to be Weeks 5-6. While the difficulty level in Weeks 1-2 was higher than in the Week 5-6 in M-DTT group, that was opposite in the C-DTT group. Only one participant (P12) in the C-DTT group gave very low enjoyment scores throughout the training weeks (less than 2/10 for each week), although their difficulty scores were similar with those given by other participants. Reasons for this low rating of enjoyment will be discussed in more detail within the results of the thematic analysis of end exit interviews.

Participant	Allocated group	Own device /loaned	All training weeks		Weeks 1-2		Weeks 3-4		Weeks 5-6	
			Enjoyment score	Difficulty score	Enjoyment score	Difficulty score	Enjoyment score	Difficulty score	Enjoyment score	Difficulty score
P3	M-DTT	Loaned	6.7 (0.89)	7.7 (0.96)	6.8 (0.75)	7.8 (0.41)	6 (0.89)	8.6 (0.52)	7.3 (0.52)	6.6 (0.52)
P11	M-DTT	Own	7.3 (0.89)	6.7 (0.96)	6.7 (1.37)	7.2 (0.75)	7.7 (1.03)	6.5 (0.55)	7.7 (0.52)	6.5 (0.55)
Average for M-DTT			**7.03 (1.03)**	**7.72 (0.94)**	**6.75 (1.06)**	**7.5 (0.67)**	**6.83 (1.27)**	**7.58 (1.24)**	**7.5 (0.52)**	**6.58 (0.51)**
P1	C-DTT	Loaned	6.4 (1.20)	7.8 (1.0)	6.3 (1.21)	6.8 (0.52)	6.3 (1.51)	8.25 (0.96)	6.5 (1.05)	8.5 (0.55)
P12	C-DTT	Own	0.7 (0.84)	8.4 (0.98)	1.2 (0.98)	8.7 (1.03)	0.8 (0.75)	9 (0.63)	0	7.5 (0.55)
P13	C-DTT	Own	6 (0.0)	5 (0.0)	6 (0.0)	5 (0.0)	n/a	n/a	n/a	n/a
P14	C-DTT	Own	5.3 (1.80)	7.5 (1.10)	5.2 (1.72)	7.3 (1.21)	6.3 (1.97)	7.2 (1.33)	4.2 (1.17)	8 (0.63)
Average for C-DTT			**4.28 (2.73)**	**7.60 (1.35)**	**4.67 (2.37)**	**6.96 (1.55)**	**4.5 (3.01)**	**8.13 (1.26)**	**3.56 (2.89)**	**8 (0.69)**
Grand Average			5.4 (2.4)	7.2 (1.2)	5.4 (2.12)	7.1 (1.23)	5.4 (2.67)	7.9 (1.03)	5.1 (3.18)	7.4 (0.87)

Table 14: *Average (mean) and variation (standard deviation) scores per participant concerning enjoyment and difficulty of training.*

Legend - *'Average for C-DTT'= average of the enjoyment and difficulty scores and standard deviation of all given scores for all training sessions and Weeks 1-2, Weeks 3-4, and Weeks 5-6 sessions by the participants in C-DTT group, 'Average for M-DTT'=average of the enjoyment and difficulty scores and standard deviation of all given scores for all training sessions and Weeks 1-2, Weeks 3-4, and Weeks 5-6 sessions by the participants in M-DTT group, 'C-DTT'=Cognitive-motor dual-task training, 'Difficulty score'= the mean of all 18 sessional Likert difficulty ratings per person were presented with the standard deviation to give the central tendency and the variability of the difficulty scores for 'all training weeks', 'Weeks 1-2', 'Weeks 3-4', and 'Weeks 5-6' of the training experience separately (Likert 0=no difficulty, 10=maximum difficulty), 'Enjoyment score'=the mean of all 18 session Likert enjoyment ratings per person were presented with the standard deviation to give the central tendency and the variability of the enjoyment scores for 'all training weeks', 'Weeks 1-2', 'Weeks 3-4', and 'Weeks 5-6' of the training experience separately (Likert 0=no enjoyment, 10=maximum enjoyment), 'Grand Average'= average of the all enjoyment and difficulty scores and standard deviation of all given scores for all training sessions and Weeks 1-2, Weeks 3-4, and Weeks 5-6 sessions by the all participants, 'M-DTT'=Motor-motor dual-task training, 'P'= Participant.*

Perceived challenge level recorded via online 5-point Likert scale.

An online 5-point Likert scale asked participants to rate their perceived level of challenge with three different tasks undertaken during training: (1) maintaining an upright stance position, (2) undertaking a primary-balance task and (3) undertaking a secondary task, at the end of each two weeks. In breaking down the Likert scoring in this way, it is hoped that it may aid better understanding of the effect of progression relative to challenge.

The response to the question concerned with maintaining an upright stance position whilst keeping the feet in correct stance position during the training varied between participants from 'completely challenging' to 'not challenging at all' across the duration of the 6-week intervention (Fig 20).

All participants progressed to a new stance position at the end of each two weeks. Three participants found it was 'mostly challenging' to keep their feet in the correct position in Weeks 1-2, while one person found it 'completely challenging' with the progressed new stance positions in Weeks 3-4 and Weeks 5-6. One participant who found it 'mostly challenging' in Weeks 1-2 and Weeks 3-4, found it 'completely challenging' in Weeks 5-6. Two participants found it mostly 'not challenging' through the whole 6-week training intervention. These findings show that progression in stance position did not affect individuals in the same way; for some participants it did not make any difference while some others felt the challenge with progression. One participant from M-DTT commented about the challenge of keeping the correct feet position during the balance tasks: *"I didn't keep track of my feet position during the exercises, it's nearly impossible for me to step back into the original position when toe tapping or heel digging to front, side, back." (P11, Weeks 1-2)*

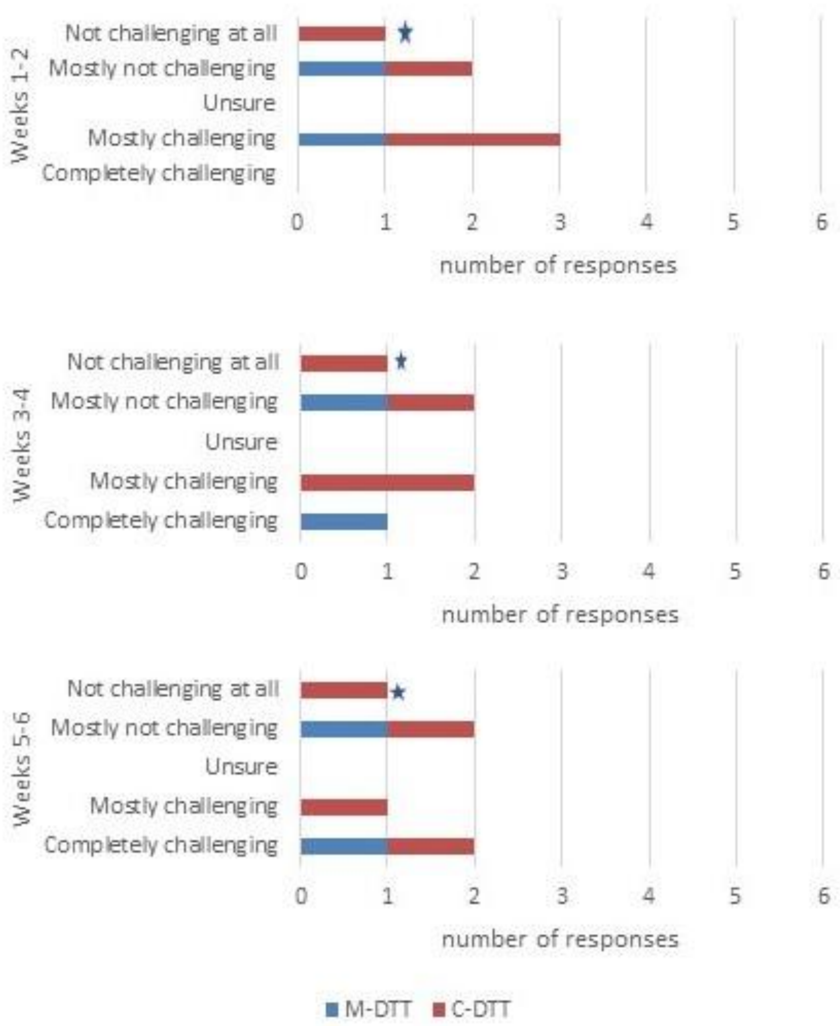


***Figure 20:** Responses to the question "How challenging did you find it to keep your feet in the correct position?" in the twice weekly online 5-point Likert scale.*

★ represents the response of the same participant.

The perceived challenge level of the balance task varied in different progressed weeks. Most of the participants found the balance tasks 'mostly challenging' throughout the 6 weeks (Fig 21). Both participants in the M-DTT group found balance tasks 'mostly challenging' throughout the 6-week training intervention.

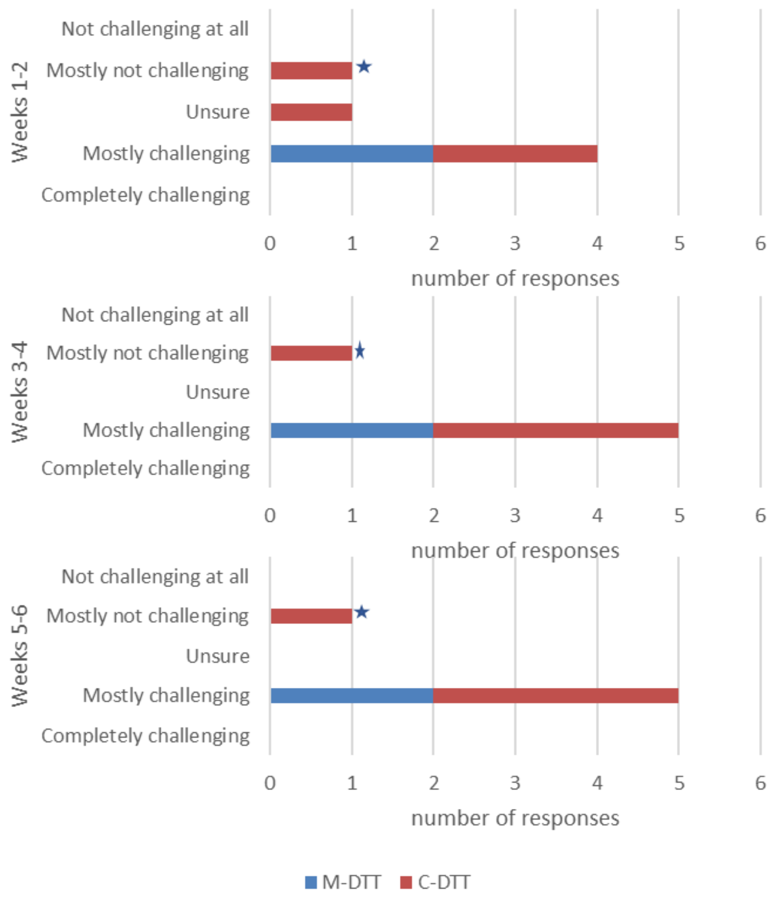


Figure 21: *Responses to question "How challenging were the balance tasks?" in the twice weekly online 5-point Likert scale.*

★ *represents the response of the same participant.*

The perceived challenge level of secondary tasks is important to compare between groups as the secondary cognitive and motor tasks were different. Statistical analysis was not undertaken given the small number of participants. However, exploring this data may help to understand if there is a need to consider standardisation of challenge level between the two DTT approaches in future DTT designs. Fig 22 shows the number of responses in both groups to the question relevant to the challenge level of secondary tasks. It can be seen that the secondary tasks in Weeks 1-2 were 'mostly challenging' for almost all participants in both groups. Cognitive tasks were found 'mostly challenging' (n=3) in Weeks 3-4, although this was not the case for everyone with one participant finding them 'mostly not challenging'. For the last two weeks, cognitive tasks were found 'mostly challenging' (n=3), which was also the case for the motor tasks. These responses show that both motor and secondary tasks were 'mostly challenging' through the 6-

week DTT according to most participants. The data did not show a trend in terms of the perceived challenge level between each two-week block of progression, or between motor and cognitive tasks. One participant (P14) from the C-DTT group commented that the cognitive secondary tasks within Weeks 5-6 were difficult: *"Found the videos very difficult to retain information, made my head spin."* There were no other free text comments about the challenge level of a specific secondary task in the online questionnaires.

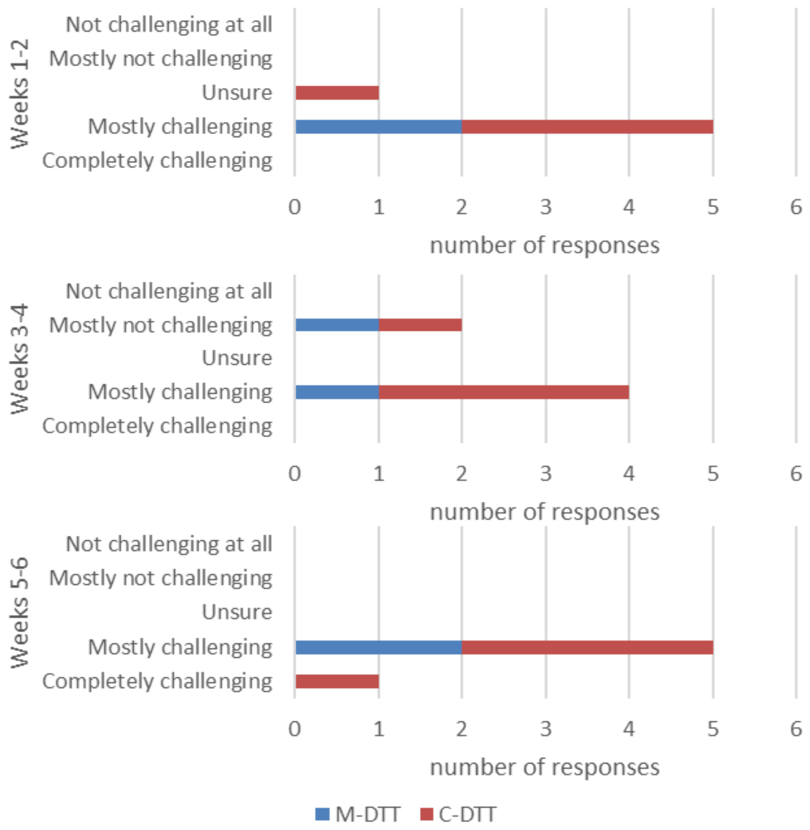


Figure 22: *Responses to the question "How challenging were the secondary tasks?" in the twice weekly online 5-point Likert scale.*

The online Likert scale in Weeks 3-4 and Weeks 5-6 also asked participants to compare the challenge level of the dual-tasks to those in the previous two weeks. The intention here was to understand the participants' opinions about progression (Fig 23). For Weeks 3-4, the perceived comparable challenge level with Week 1-2 varied as follows: 'mostly challenging' (n=2), 'mostly not challenging' (n=2), 'completely challenging' (n=1) and 'unsure' (n=1). For Weeks 5-6, most participants found the comparable challenge level with Week 3-4 ‘mostly challenging’ (n=4), with two participants finding it ‘mostly not challenging’. These responses indicate that most participants were aware of a progression in the challenge level over time, especially in the last two weeks. This was not always the case, with some participants failing to notice a difference in challenge level either in Week 3-4 or Week 5-6. One participant (P1) in the C-DTT group was clear about the difference in challenge between Weeks 1-2 and Weeks 3-4, commenting that *“Weeks 3 & 4 much more difficult.”* In summary, these results show that, the majority of participants experienced a progression in the level of challenge in these activities between the two-week progression blocks, and that this approach generally appeared acceptable to participants.

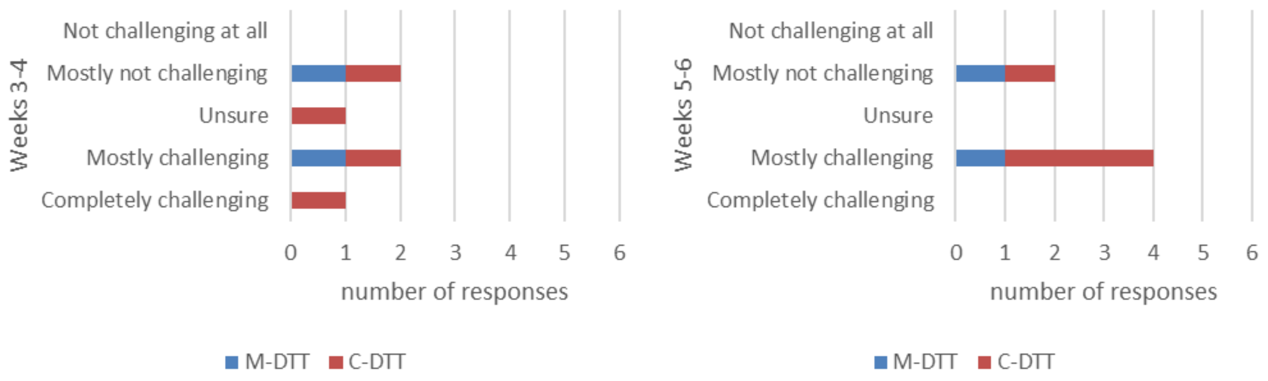


Figure 23: *Responses to the question “How did you find to do the tasks in the past two weeks compared to the previous two weeks?” in the online 5-point Likert scale for Weeks 3-4 and Weeks 5-6*

Perceived enjoyment level recorded via online 5-point Likert scale.

Perceived enjoyment level was asked via the online 5-point Likert scale to understand if improvements are required in the balance task, secondary task, or both to achieve an engaging and acceptable DTT intervention for a future RCT. The responses to the question relevant to enjoyment level is presented (Fig 24) for the two-week periods, as the tasks changed in each two weeks in both the motor and cognitive DTT.

The balance tasks in both groups were found ‘mostly enjoyable’ by most of the participants (n=4/6) for Weeks 1-2. However, while the M-DTT group participants found it ‘mostly enjoyable’ for Weeks1-2, they found it ‘mostly not enjoyable’ for Weeks 3-4. In contrast, the responses were varied for the different weeks of the C-DTT. It was encouraging that, only one participant in the C-DTT group found balance tasks in Week 3-4 and 5-6 ‘not enjoyable at all’. Overall, therefore, the data failed to show a clear pattern with regard to the level of enjoyment of these tasks.

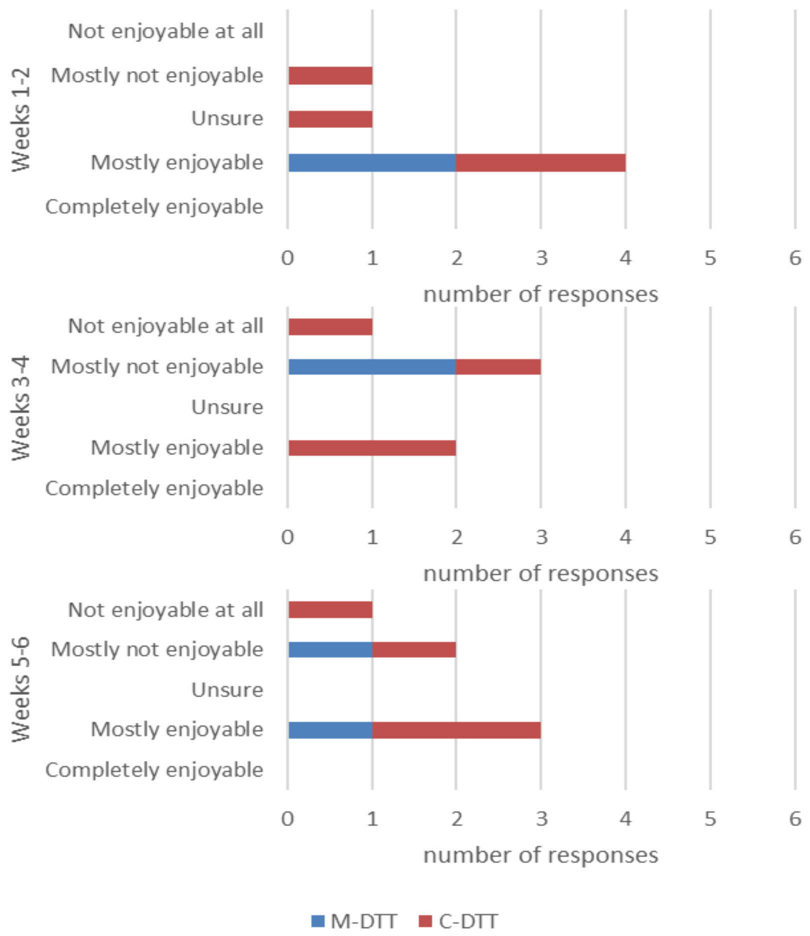


***Figure 24:** Responses to question “How enjoyable were the balance tasks?” in the twice weekly online 5-point Likert scale.*

The responses about perceived level of enjoyment for secondary tasks are presented separately for both groups in Fig 25. Motor secondary tasks were found ‘mostly enjoyable’ for both the first and last two weeks by the two participants. While one participant found the motor tasks within the Week 3-4 in M-DTT ‘mostly enjoyable’, the other participant found them ‘mostly not enjoyable’. Similarly, the cognitive tasks within Weeks 3-4 in the C-DTT were rated as ‘mostly enjoyable’ (n=1), 'mostly not enjoyable' (n=1), and 'not enjoyable at all' (n=1). One participant was 'unsure'. For the first two weeks, two participants rated them as 'mostly not enjoyable', one was 'unsure', and one participant found them 'mostly enjoyable'. For Weeks 5-6, cognitive tasks were found mostly enjoyable (n=2) and mostly not enjoyable (n=2).

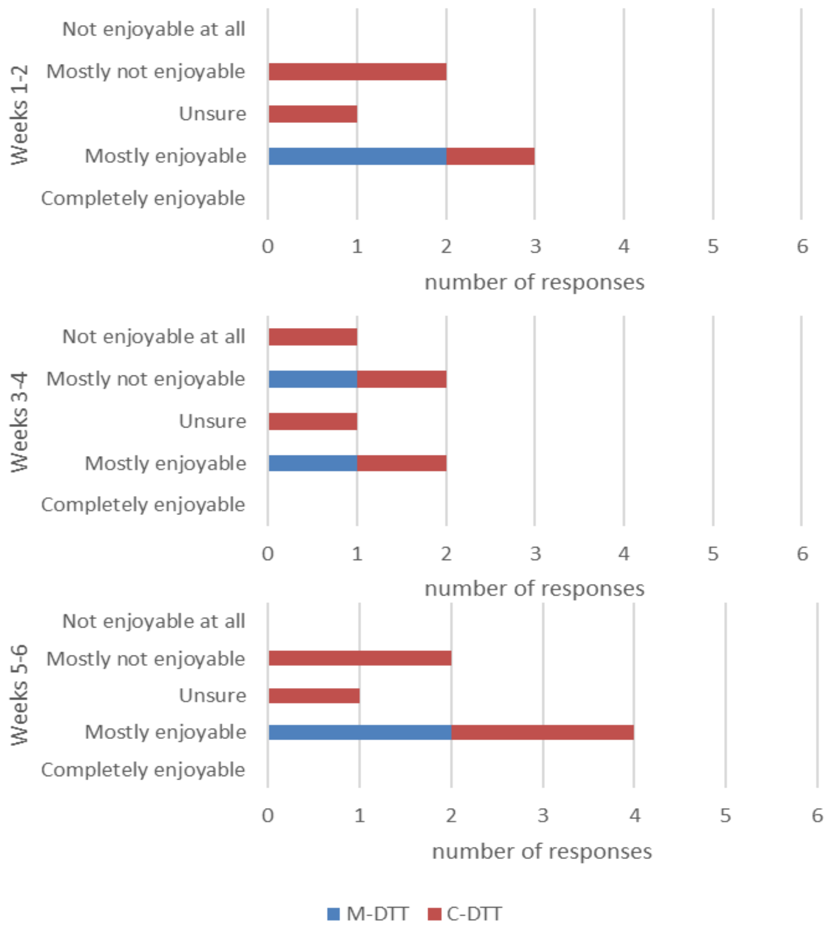


Figure 25: *Responses to the question "How enjoyable were the secondary tasks?" in the twice weekly online 5-point Likert scale.*

Overall, these numbers and responses show that there is no certain trend regarding participants' enjoyment in undertaking the cognitive tasks within C-DTT. For secondary motor tasks within M-DTT it may be stated that they were found mostly enjoyable but there are only two participants, which limits the interpretation of the result.

Tiredness level recorded via online 5-point Likert Scale

Perceived tiredness whilst performing tasks within the DTT was another indicator to test the acceptability of the intervention (Fig 26). Tasks in the M-DTT were found 'mostly tiring' for Weeks 1-4 but 'mostly not tiring' for Weeks 5-6 for both participants. In contrast, variability was seen across responses in relation to this for C-DTT; with some finding it 'mostly tiring' (n=2) and others 'mostly not tiring' participants (n=2) for Weeks 1-4. This perception was similar in Weeks 5-6. Overall, both DTT approaches were found to be 'mostly tiring' but notably the concept of being tired was not raised as a concern during the end exit interviews, which will be discussed in the upcoming section.

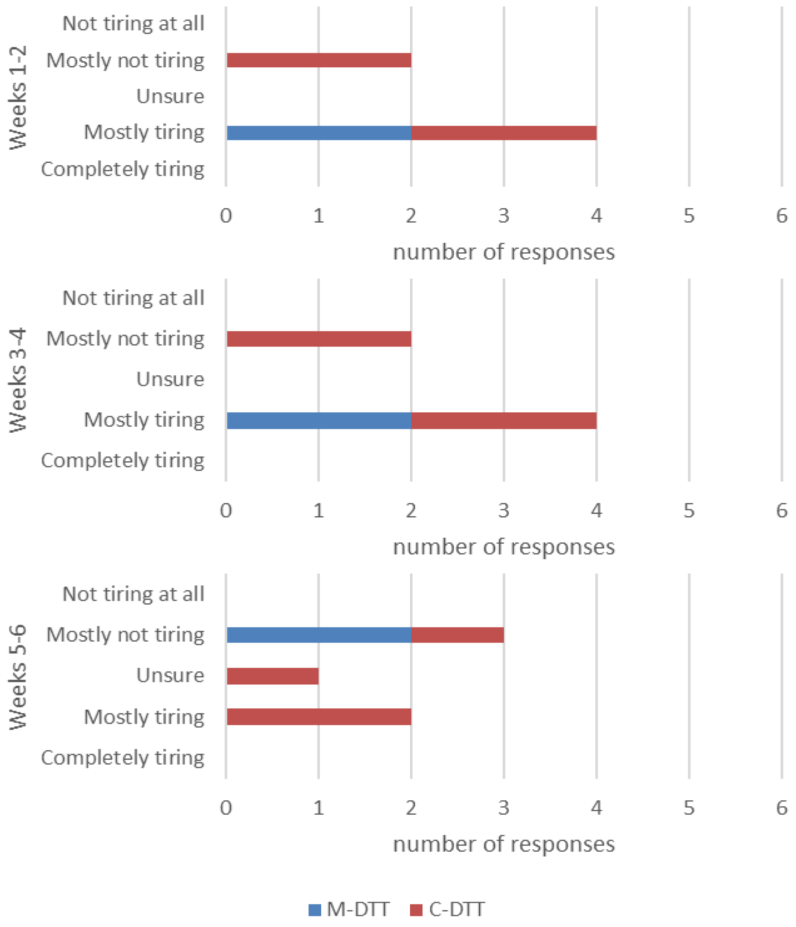


Figure 26: *Responses to the question "How tiring were the tasks?" in the twice weekly online 5-point Likert scale.*

Acceptability of undertaking DTTs at home and without professional supervision

Twice weekly online 5-point Likert scale asked participants about their perception of different aspects of undertaking DTTs in their home: enjoyment and confidence level when training at home, challenge level of using and setting up the technology, and understandability of the training workbooks and training videos.

The Likert scale findings showed that participants in both groups felt ‘completely confident’ or ‘mostly confident’ while they were training at home (Fig 27). Confidence levels increased to ‘completely confident’ for one participant in the M-DTT group during the last two-weeks. For the C-DTT group the number of ‘completely confident’ responses increased for Weeks 3-4 (n=3) and remained at this level for Weeks 5-6.

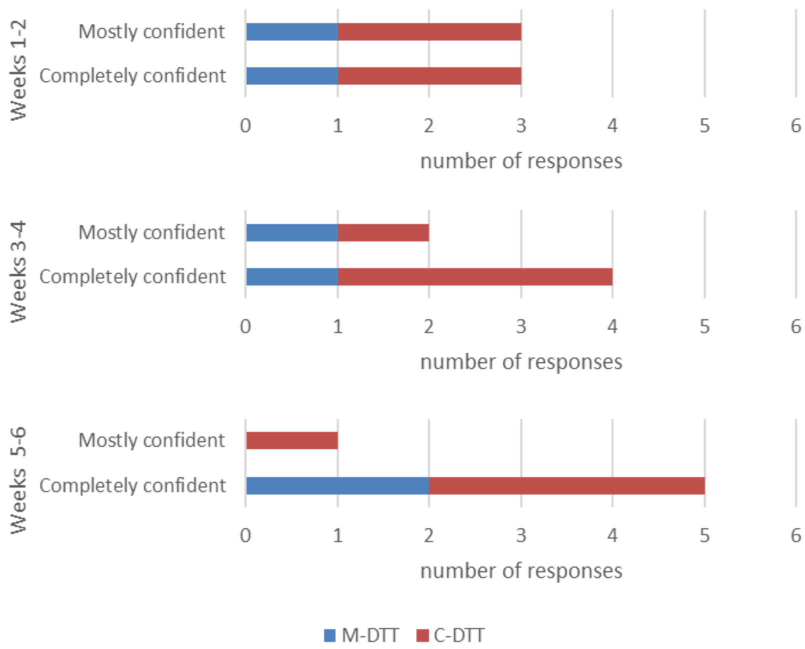


***Figure 27:** Responses to the question “How confident are you to train in your own home?” in the twice weekly online 5-point Likert scale.*

***Legend -** the response options were ‘completely confident, ‘mostly confident’, ‘unsure’, ‘mostly not confident’, and ‘not confident at all’.*

The enjoyment level of the home-based training varied across different weeks (Fig 28). This was found ‘mostly enjoyable’ for Weeks 1-2 and Weeks 5-6 by most participants in both groups. One participant in the C-DTT group, however, found it ‘not enjoyable at all’ throughout the 6-weeks.

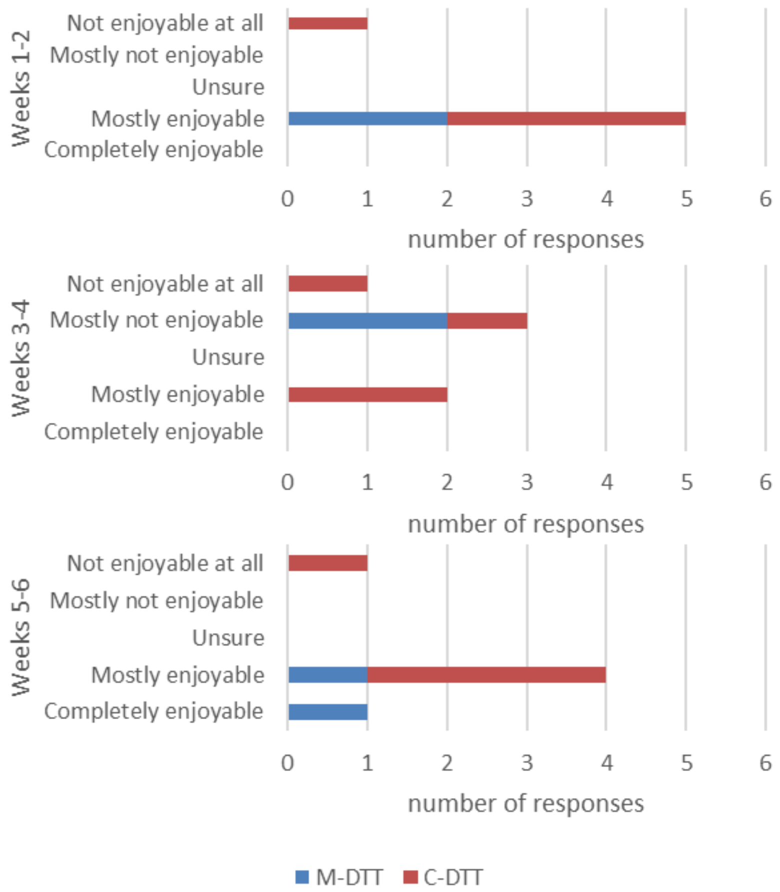


Figure 28: *Responses to the question "How enjoyable did you find training in your home environment?" in the twice weekly online 5-point Likert scale.*

Another component of acceptability of the home-based training was the challenge of setting up and using the tablet on a training wall (and additional equipment for participants in the M-DTT group). Participants were asked: 'How challenging was it to set-up the wall-tablet?'. All participants rated this as 'not challenging at all', or 'mostly not challenging' for all weeks (Fig 29). Only one participant rated it 'mostly challenging' in Weeks 1-2, but their response changed to 'mostly not challenging' for the following weeks.

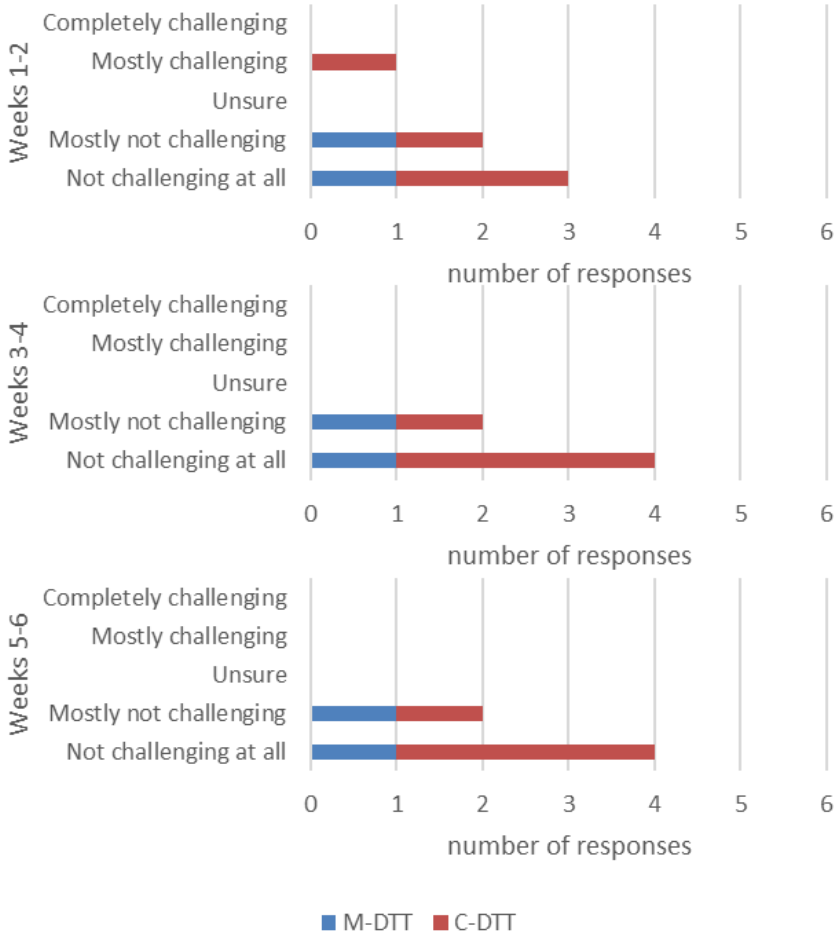


Figure 29: *Responses to the question "How challenging was it to set-up the wall-tablet?" in the twice weekly online 5-point Likert scale.*

Another question was 'How challenging was it to use the technology?'. This sought to gauge the level of challenge in the use of the tablet, accessing Panopto links, and navigating the platform to watch the training movies. All participants rated this as 'not challenging at all' or 'mostly not challenging' for all 6 weeks (Fig 30). Encouragingly, the number of 'not challenging at all' responses increased over each successive two-week period (n=2 for Weeks 1-2, n=3 for Weeks 3-4, and n=4 for Weeks 5-6).

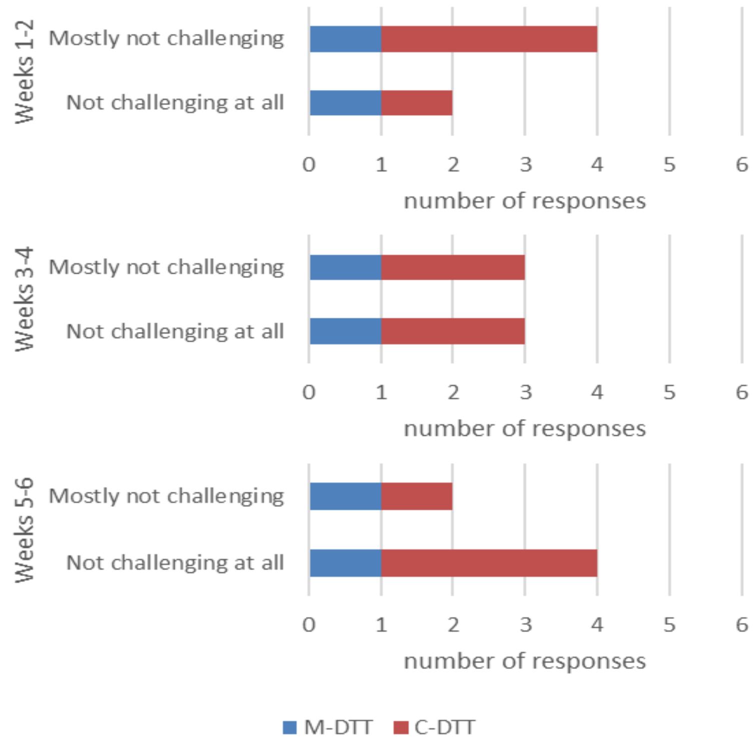


Figure 30: *Responses to the question "How challenging was it to use the technology?" in the twice weekly online 5-point Likert scale.*

Legend - *the response options were 'completely challenging, 'mostly challenging', 'unsure', 'mostly not challenging', and 'not challenging at all'.*

The understandability of the training workbook completion was another indicator to understand the acceptability of the intervention. Its content includes the tool for rating enjoyment/difficulty level of the sessions, and also comprises scoring element for the performance rating of the participants for each session. The responses showed that participants in the M-DTT group found it 'completely understandable' throughout 6 weeks (Fig 31). There were some variations in the responses for the C-DTT group, nevertheless all rated it as either 'completely' or 'mostly' understandable across the study timeline. Overall, participants found completing the training workbook easy to understand and use.

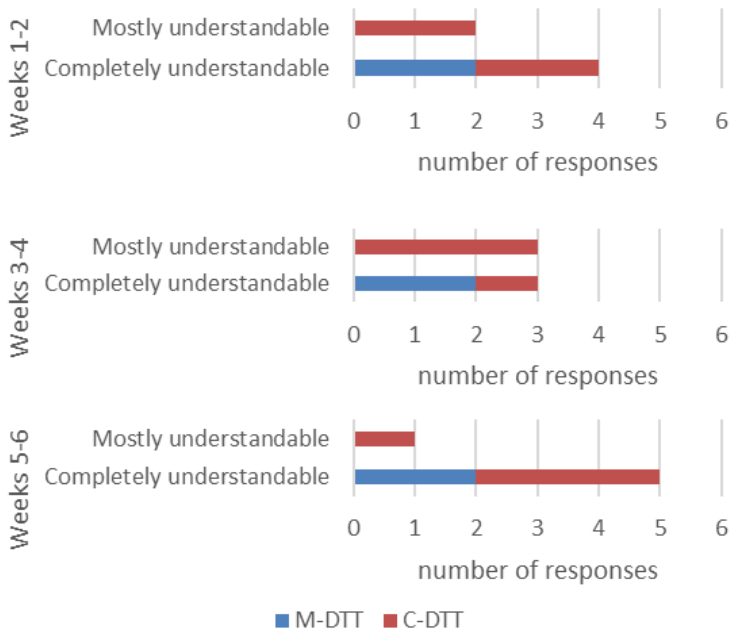


Figure 31: *Responses to the question "How understandable was the training workbook to complete?" in the twice weekly online 5-point Likert scale.*

Legend - *the response options were 'completely understandable', 'mostly understandable', 'unsure', 'mostly not understandable', and 'not understandable at all'.*

The ability to understand the training videos was a key indicator for gauging the acceptability of the non-supervised, home-based DTT. Apart from one participant in the C-DTT at Week 1-2, all other participants found the training videos at this timepoint either 'mostly' or 'completely' understandable. At Weeks 3-4, all participants found it either 'mostly' (n=5) or 'completely 'understandable' (n=1). At Weeks 5-6 the perceived ability to understand the training videos varied among the C-DTT participants, while all participants in the M-DTT group found the videos 'completely understandable' (Fig 32). Overall, over the 6-week training, the videos were mostly understandable. The free text data highlighted that for one C-DTT participant technical issues within the videos were very frustrating, as detailed below: "*The pace of the training session was too slow - too much time wasted, waiting for the correct answer to appear on screen and for the instructions, which were clearly printed on screen, to be read out before every exercise. Video instructions mostly understandable but often inaccurate e.g. visual 'start' and oral 'start' not coordinated or missing altogether. On at least two occasions the answers given for the questions* *in Block A were wrong. Week 1 Block B was a disaster: neither I nor my Buddy could understand the words read out by a non-English speaker. Block B in Week 2 was also difficult: initially, neither of us understood the instructions. It would have been more understandable to have said "Identify the odd one out" rather than "Spot the incorrect piece of the following picture puzzle". The task was more tiresome because it was difficult to see the very small and detailed pictures.*" *(P12)*

So too did one other C- DTT participant find some instructional part of the videos unnecessarily repetitive: *"Some of the instructional videos were over long and didn't need to be repeated in every session" (P13)*

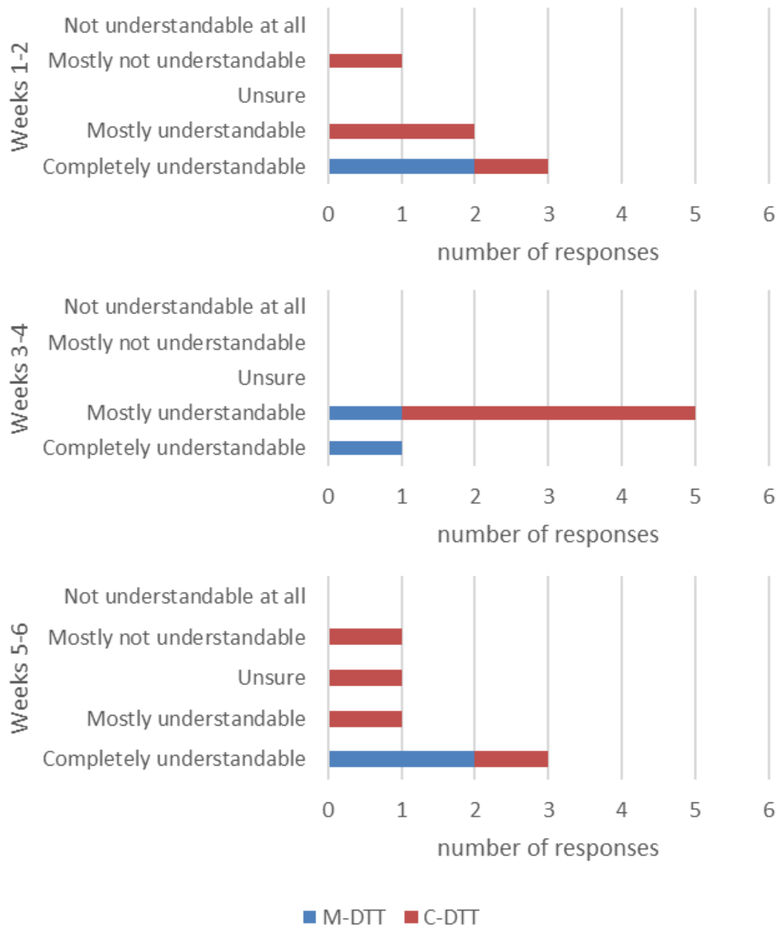


Figure 32: *Responses to the question "How understandable was the training videos?" in the twice weekly online 5-point Likert scale.*

Overall Acceptability of the DTT via the online 5-point Likert scale

An important indicator of acceptability of the DTT was if it would be recommended by participants to other pwPD. The question 'Would you recommend this training intervention for people with PD?' was asked at the end of each two weeks of the training intervention. The responses varied across the weeks and between the groups. Participants in M-DTT group responded 'I would mostly recommend this' for Weeks 1-4 and 'I would completely recommend this' after Weeks 5-6 (Fig 33). For the C-DTT group, the responses were quite varied. One participant (P12) in C-DTT group consistently responded 'I would not recommend this at all' for all weeks, indicating that the C-DTT is unlikely to be acceptable for this participant. In contrast, another participant (P1) responded that they 'would completely recommend' C-DTT throughout the 6 weeks. Overall, these results suggest that whilst the M-DTT has the potential to be an acceptable training option in its current format, the C-DTT may need to be amended to be acceptable.

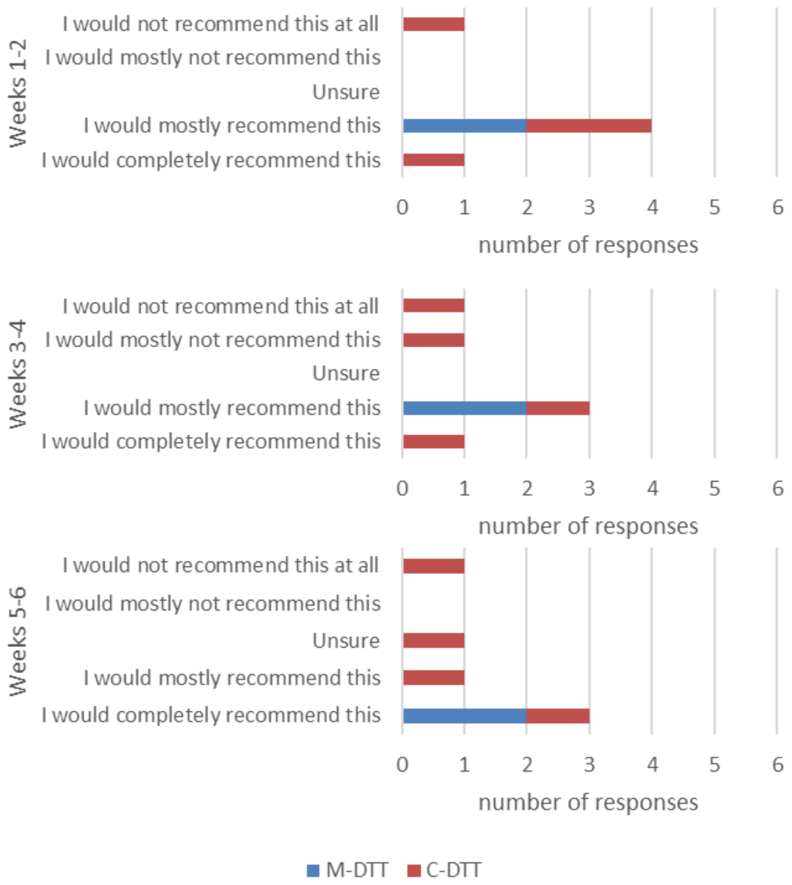


Figure 33: *Responses to question "Would you recommend this training programme for people with PD" in the twice weekly online 5-point Likert scale.*

5.3.7 Effect on Balance Outcomes

Whilst the study aim was on feasibility of (i) the intervention (ii) the assessment and (iii) the trial design, exploratory signals of effectiveness were also explored and contrasted with the participants perceptions of effectiveness. Of note, it is acknowledged that this feasibility study was inherently underpowered and non-generalisable to the wider PD population.

The balance outcome measures used were the MiniBESTest for dynamic balance assessment and body sway values calculated as angular sway velocity in ML and AP directions, total angular sway velocity, RMS of sway acceleration in ML and AP directions. The results from these measures are described below.

MiniBESTest

The MiniBESTest is anticipated as the future primary outcome measure of balance in a future RCT superiority trial design. A widely used and clinically relevant measure, it was applied at baseline and at the end of training to all 6 participants to assess the change in dynamic balance. Individual scores and changes are presented in Table 15. Higher scores (maximum available score = 28) indicate an improvement in dynamic balance. Both the M-DTT participants improved their balance as reflected by higher scores at the end of training. The changes measured in the C-DTT participants varied with balance improving for one participant, worsening for one participant and remaining the same for two participants. The biggest increase (3 scores) was seen in one participant (P3) allocated to M-DTT and one participant (P13) from the C-DTT. It was notable that both of these participants had slightly low scores at baseline than the other participants (18 and 20 consecutively). Overall, these findings may signal that M-DTT could be effective in improving dynamic functional balance.

Participants	Allocated Group	Baseline Scores	End of training scores	Change
P3	M-DTT	18	21	3
P11	M-DTT	25	27	2

P1	C-DTT	25	25	0
P12	C-DTT	23	22	-1
P13	C-DTT	20	23	3
P14	C-DTT	22	22	0

Table 15: *Individual MiniBESTest scores at baseline and at the end of training*

Legend – *'C-DTT'=Cognitive-motor dual-task training, 'M-DTT'=Motor-motor dual-task training, 'P'= Participant.*

Body Sway

Angular velocities

Angular sway velocities in AP and ML directions, and total angular sway velocity, and RMS of acceleration in both directions were calculated to see the change in standing balance after the DTT. The individual data for all three conditions (EO, EC, and feet 4 cm apart) are presented in Appendix 26.

The changes in angular sway velocity in the ML direction did not show any trend for an increase in static balance, as there are both increases and decreases in change for different conditions among participants in both the DTT groups (Fig 34). One participant from the M-DTT group (P3) improved their standing balance in the ML direction in all three conditions (decreases of 0.47 deg/s in EO, 0.58 deg/s for EC, 0.61 deg/s in feet -4 cm apart conditions). In the C-DTT group two participants improved their standing balance in all three conditions. The biggest change in the angular velocity in the ML direction was shown in the feet 4 cm apart condition for three participants (n=1 from M-DTT group, n=2 from C-DTT group). The biggest change was for participant P13 from the C-DTT group with 1.58 deg/s decrease; of note this person had the biggest value at baseline (0.8 deg/s). The angular velocity in the ML direction increased for one participant from M-DTT for all three conditions and two participants from C-DTT for EC and feet 4 cm apart conditions.

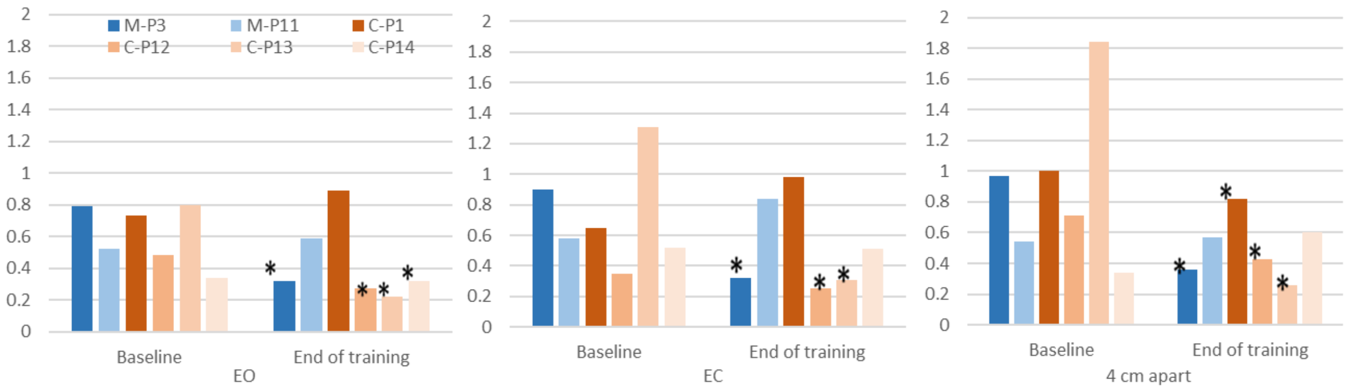


Figure 34: *The angular sway velocity in the mediolateral direction at baseline and end of training assessments.*

Legend *- C=C-DTT group, EC= eyes closed, EO= eyes open, M=M-DTT group, P=participant, 4 cm apart= feet are placed 4 cm apart. *=decrease in change, reflecting an improvement in balance.*

The angular sway velocity in the AP direction was higher than in the ML direction for some participants (n=2) in all three conditions, and for most participants (n=5) in the feet 4 cm apart condition at the baseline assessment. Fig 35 shows the angular sway velocity in the AP direction. The values decreased for one participant (P3) in the M-DTT group in all conditions, whilst for the other M-DTT participant the angular velocity was improved in the AP direction for EC and the feet 4 cm apart conditions. Participant P13 had the biggest change (decrease in all conditions) among the participants in the C-DTT group.

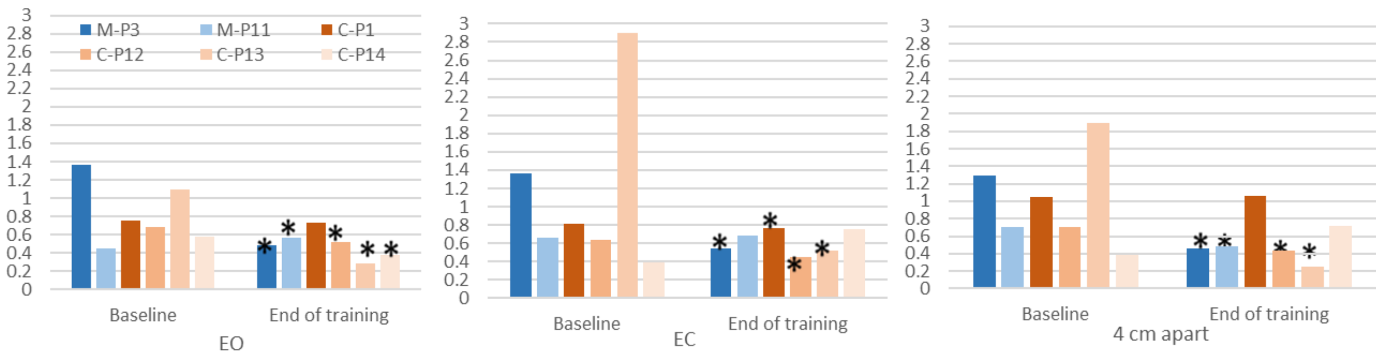


Figure 35: *The angular sway velocity in anteroposterior direction at baseline and end of training assessments.*

Legend *- C=C-DTT group, EC= eyes closed, EO= eyes open, M=M-DTT group, P=participant, 4 cm apart= feet are placed 4 cm apart. *=decrease in change, means improvement in balance.*

The changes in total angular sway velocity varied (Fig 36). For most participants (n=5) this improved for the feet 4 cm apart condition. P3 from the M-DTT and P13 from the C-DTT group improved in terms of total angular sway velocity for all conditions, because they improved angular velocities in both the AP and ML directions.

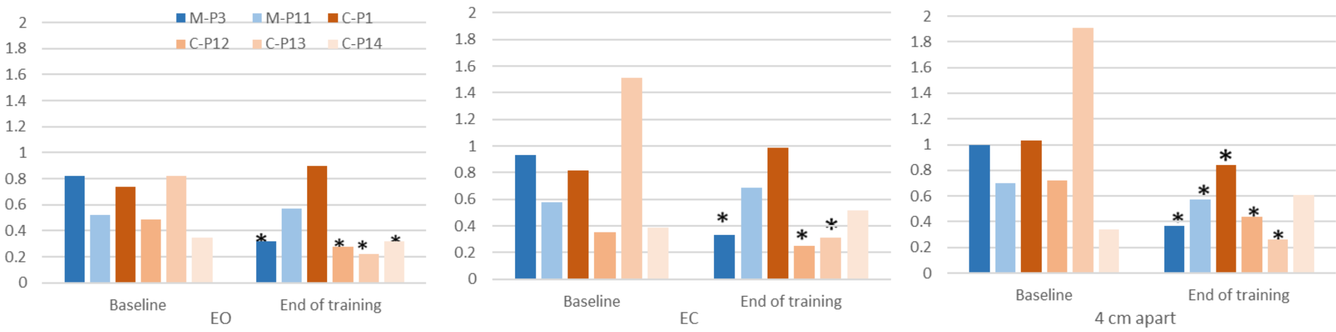


Figure 36: *The total angular sway velocity at baseline and end of training assessments.*

Legend - *C=C-DTT group, EC= eyes closed, EO= eyes open, M=M-DTT group, P=participant, 4 cm apart= feet are placed 4 cm apart. *=decrease in change, means improvement in balance.*

The results showed that, in the main, where the improvements are in both direction, there is also an improvement in total sway velocity. This was not always the case, for example this pattern was not seen in one participant from the C-DTT group (P1) where the angular velocity improved in the AP direction but not the ML direction for the EC condition. In contrast in the feet 4 cm apart condition the improvements were seen in the ML direction, but not in the AP direction, and total sway velocity improved. Thus, a promising correlation between the angular velocity in different conditions and different directions was not apparent. Neither was this the case between the sway velocities in different directions and the total sway velocity in these study participants.

In terms of group comparison, it was not appropriate to analyse the data using inferential statistics with this small sample. However, one participant from the M-DTT group and two participants from the C-DTT group improved angular velocities in all directions for every condition and in total angular velocity, demonstrating that 50% of both groups improved in respect to this at the end of the training.

In terms of the comparison of conditions, there is no specific pattern to the observed improvements in terms of either the number of participants who improved or the value of the change.

Root Mean Square of Sway Acceleration Values

The change in root mean square (RMS) values of sway acceleration in the ML direction varied for different conditions (Fig 37). Small improvements were shown for P1 from the C-DTT group for all conditions, for P12 from the C-DTT group in EC and feet 4cm apart conditions (0.02 m/s^2 and 0.26 m/s^2 respectively) and for P14 from the C-DTT group (0.27 m/s^2 and 0.06 m/s^2 respectively). At the end of training the RMS values increased for all conditions in the M-DTT participants, reflecting poorer balance.

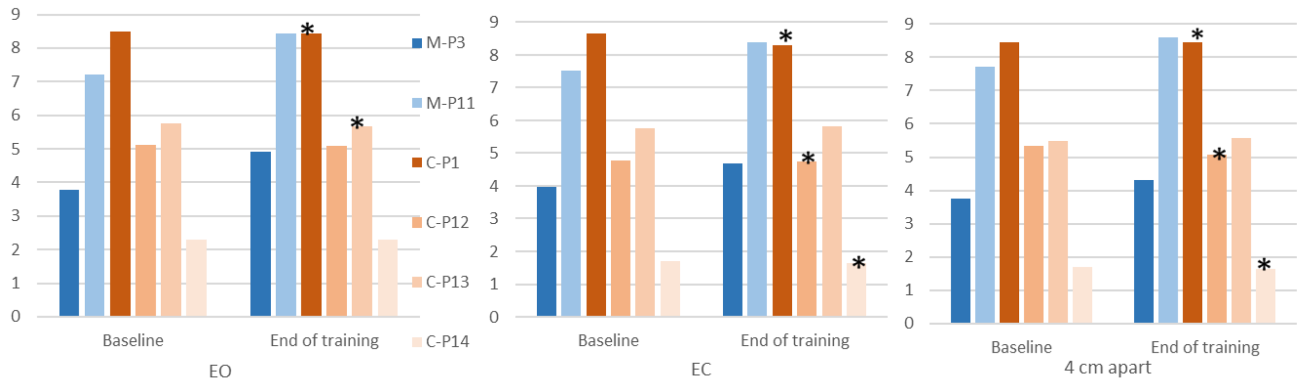


Figure 37: *The root mean square of acceleration in mediolateral direction at baseline and end of training assessments.*

Legend - *C=C-DTT group, EC= eyes closed, EO= eyes open, M=M-DTT group, P=participant, 4 cm apart= feet are placed 4 cm apart. *=decrease in change, reflecting improvement in balance.*

At the baseline assessment, the values of RMS of sway acceleration were smaller in the AP direction than those in the ML direction (Fig 38). The acceleration decreased in the AP direction at the end of training for all directions for both participants in the M-DTT group, especially for P11 (1.17 m/s^2, 0.87 m/s^2 and 1.33 m/s^2). P13 in the C-DTT group had a decrease in values for all conditions, while the RMS values increased for all conditions for P14 and P1.

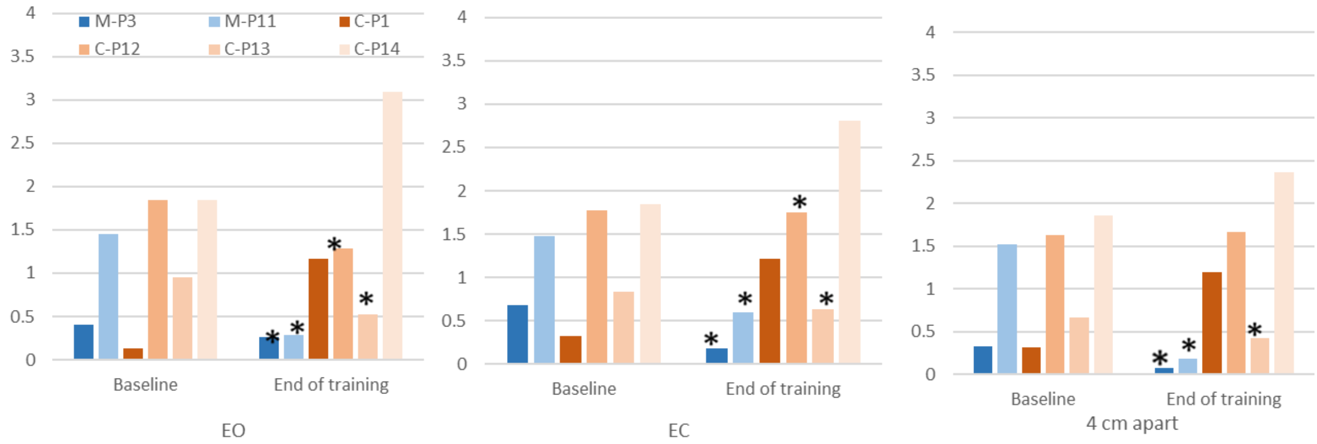


__Figure 38:__ The root mean square of acceleration in anteroposterior direction at baseline and end of training assessments.

Legend - *C=C-DTT group, EC= eyes closed, EO= eyes open, M=M-DTT group, P=participant, 4 cm apart= feet are placed 4 cm apart. *=decrease in change, means improvement in balance.*

5.3.8 Summary of Quantitative Data

P12 from C-DTT group improved balance in angular velocities as well as in accelerations for both directions and all conditions. Similarly, P3 from the M-DTT group improved balance in angular velocities. However, interestingly, this participant improved acceleration only in the AP direction. Another participant from the C-DTT (P13) similarly had improvements in angular velocities, but an improvement was seen in acceleration in the AP direction for all conditions and only for the EO condition in the ML direction. These results show that there may not be an association between the effect of DTT on angular velocity and the RMS of acceleration for these study participants.

The total angular sway velocity was improved for all conditions for P3 (M-DTT) and P13 (C-DTT). The MiniBESTest score of these participants also improved. So, this result may show that M-DTT and C-DTT was effective improving both standing and dynamic balance in these individuals. However, it is difficult to summarize the relationship between total angular sway velocity and dynamic balance.

A change in sway velocity in the ML direction is generally a reliable indicator to assess standing balance (Alsubaie et al., 2019). The changes in ML direction were observed to improve for one participant in the M-DTT group. In the C-DTT group the response in sway parameters differed amongst participants, with some improving and others not improving in different conditions. Overall, therefore there is no clear indication as to whether either the M-DTT or C-DTT have potential as effective interventions to improve standing balance.

In summary, the postural sway data shows no specific trends within the group or between the groups in terms of the potential effectiveness of the M-DTT and C-DTT on standing balance. The MiniBESTest scores indicate that M-DTT may be effective in improving the dynamic balance in pwPD, although there should be significant caution with this interpretation given that there were only two participants in this M-DTT group.

A tabulation of the overall findings of the acceptability parameters and potential effectiveness of DTT interventions (Table 16) provides an overview of the variables measured which may influence acceptability and effectiveness of the DTT. This will help to inform the design of DTT interventions which could be evaluated in a potential future randomised control trial.

Participants	Allocated Group	Mean of self-reported perceived challenge in training workbook (/10)	Mean of self-reported perceived enjoyment in training workbook (/10)	Number of total views of the main exercise sessions (/18)	Number of complete main exercise sessions (/18)	Overall percentage of viewed minutes of the completed main exercise sessions	Change in MiniBESTest score	Change in total angular sway velocity	Change in angular sway velocity in ML direction
P3	M-DTT	7.7	6.7	32	21	112.0	3	EO: ↑ EC: ↑ Feet 4 cm apart: ↑	EO: ↑ EC: ↑ Feet 4 cm apart: ↑
P11	M-DTT	6.7	7.3	21	18	82.50	2	EO: ↓ EC: ↓ Feet 4 cm apart: ↑	EO: ↓ EC: ↓ Feet 4 cm apart: ↓
P1	C-DTT	7.8	6.4	22	16	81.43	0	EO: ↓ EC: ↓ Feet 4 cm apart: ↑	EO: ↓ EC: ↓ Feet 4 cm apart: ↑
P12	C-DTT	8.4	0.7	21	17	100.68	-1	EO: ↑ EC: ↑ Feet 4 cm apart: ↑	EO: ↑ EC: ↑ Feet 4 cm apart: ↑
P13	C-DTT	5	6	19	18	91.85	3	EO: ↑ EC: ↑ Feet 4 cm apart: ↑	EO: ↑ EC: ↑ Feet 4 cm apart: ↑
P14	C-DTT	7.5	5.3	22	18	113.16	0	EO: ↑ EC: ↓ Feet 4 cm apart: ↓	EO: ↓ EC: ↑ Feet 4 cm apart: ↓

Table 16: *Overall synopsis of the acceptability and balance outcome results*

Legend *- 'C-DTT'=Cognitive-motor dual-task training, 'EO'=Eyes open, 'EC'=Eyes closed, 'M-DTT'=Motor-motor dual-task training, 'MiniBESTest'=Mini Balance Evaluation Systems Test, 'P'=Participants, ↑=decrease in velocity, means improvement, ↓=increase in velocity.*

The perceived challenge level is higher than the perceived enjoyment level for most of the participants (except for P11 and P13). This is particularly relevant to participants in the C-DTT group (P12 and P14). This suggests that there may be a potential negative correlation between enjoyment and challenge level. Further studies, using larger sample sizes would be needed to confirm this.

The high perceived challenge level did not appear to limit the attendance and adherence to the DTT interventions, as the number of views of the training movies is higher than the number of sessions, and the adherence rate to the main exercises is higher than 80% in both groups. Adherence rates to the main exercise sessions appeared to have an influence on the effectiveness of the training in improving balance outcomes. For example, those participants who improved their dynamic balance and standing balance (P3 and P13) had very high adherence rates (112% and 91.35% respectively). Although this was not always the case; for example, P14, who had the highest adherence rate (113.16%), did not improve in dynamic balance, and standing balance improved for only one condition (total angular sway velocity for only EO condition, angular sway velocity in ML direction for only EC closed condition). Another participant from the C-DTT group (P13), also with high adherence rates (100.68%), improved in the standing balance but worsened in dynamic balance. This indicates that the relationship between adherence rate and the change in balance outcomes is not clear cut.

5.3.9 Findings of the Qualitative Component

All participants (n=6) who completed their training were interviewed, face-to-face, at the end of the balance assessment. Four of the participant's supporters contributed to the interviews. After analysis of the data, seven themes with some sub-themes emerged. These themes/sub-themes and relevant quotations are presented in Appendix 27.

Theme 1: An acceptable DTT balances challenge and enjoyment.

This theme explains the importance of keeping the challenge of the DTT tasks at an achievable level, the importance of keeping the tasks enjoyable and interesting with an enough amount of variability, and potential effects of individual needs or situations on the perception.

Sub-theme 1: Dual-task training is challenging because it includes coordination and multi-tasking.

Dual-task training requires dividing attention to different activities. M-DTT in this study required focus on both the feet and hands. According to participants from the M-DTT group, although doing those tasks as an individual task would be achievable, combining both of them creates a challenge. Performing those tasks required coordination between feet and hand exercises, which was perceived as challenging by the participants.

> *"I didn't have any problem with balance to be perfectly honest, it's just the coordination of different tasks that I find hard." (P11)*
>
> *"It is easy if I don't have to do anything else….it is not too difficult. I need to concentrate on it. Yeah, but I do it easier but if I have to use the hands that's when it gets difficult." (P11)*

“It was challenging, but yeah, that’s all I can say it was …It helps with co-ordination, I think.” (P3)

Participants in the C-DTT group had a similar perception, that concentrating on different things at the same time made the training challenging.

“The actual physical thing seemed like a very easy thing to do. But in fact, it's not as soon as you had a cognitive test as well.” (P1)

Some task combinations made the dual-tasking particularly challenging:

“The marching actually help you do things. The lunges make it a lot worse…Well, it does when it counts thing. I mean, it can do. But unluckily the marching was with the tongue twisters... It's like two separate things.” (P1)

“…it was a complete surprise when we started to do the exercises, which you outlined because they became mind bogglingly difficult, physically very demanding. I found that I either had to do something, I had to concentrate on moving my feet, clock pattern.” (P14)

Level of challenge may be an important indicator of an acceptable DTT (Conradsson *et al.,* 2014). In this study, although the DTT activities were perceived as challenging, they appeared acceptable to participants because they were generally achievable.

“*…all I can say it was challenging but I managed to do them. Yeah, that was okay.” (P3, M-DTT).*

“No, it was fine. I mean. It's just that right really, I mean, if it was, I think we'd put off doing it or it would take longer…We had a bit of a challenge, and it was footwork, but it was fine. It was okay to me.” (P13, C-DTT)

Sub-theme 2: Dual-task training is challenging but it is interesting and enjoyable.

The idea of doing two things at the same time intentionally was found interesting by most of the participants. The challenge of the dual-task activities enabled participants to reflect on their limitations. This was especially experienced by the C-DTT participants where the variety of cognitive tasks required different types of cognitive functioning, including for example executive function (counting backwards), memory and attention (remembering audio-story details), challenged them and maintained their interest and enjoyment throughout the training.

> *"It was very challenging, absolutely very, very, very much so…the balance exercises, no problem. They were easy. But when I hit the challenges, you gave me then it opened all the cracks, all the weaknesses." (P14)*

> *"I enjoyed the challenge of it. Yeah. I mean, when I didn't have much time and it was frustrating, apart from that I enjoyed it. And. Yeah, and it's just quite interesting to see that it suddenly got a lot harder when you have something that backwards and that was like wow, counting forward was quite easy and that they were not very easy, but you know it's much easier and then suddenly counting backwards." (P1)*

The variety of tasks may be an important factor which can affect the enjoyment level needed to maintain engagement throughout the training intervention (Chua et al., 2021). Although a couple of participants perceived the DTT as mostly enjoyable and interesting, one participant from C-DTT group found the tasks very similar and repetitive.

> *"a lot of the exercises seem to be repetitive. You're doing the same at the end as you'd been doing at the beginning. So frustrating, tedious and boring. "(P12, C-DTT)*

> *"…in a way because the sessions were very similar, they got a little bit boring…" (SoP12)*

However, this was not the experience for other participants, who were found the training challenging, interesting and fun.

> *"Some of the exercises I have found extremely challenging although quite simple…I mean positively hard. I mean, that was just a personal frustration that takes away the enjoyment. So, it was fine, well it was a challenge, but you know, what are they cooking up the week, what are the challenges next week? it was all well-designed and engaging." (P11, M-DTT)*

> *"It was an interesting approach to doing it…it's definitely a challenge." (P12, C-DTT)*

Sub-theme 3: Sustaining motivation and challenge is needed to gain benefit.

Most of the participants in this study believed that sustained exercise is beneficial for them to improve their PD symptoms.

> *"So, I would have thought that was about the only thing you could do to improve your balance, is to keep practising." (P12, C-DTT)*

Sustaining motivation was perceived by participants as key to keep going and to see the potential benefit of the DTT but was recognised as being difficult and potentially affected by different external factors. It was recognised by some participants that intrinsic motivation was necessary to gain benefit from a training intervention even if the training is perceived as being too challenging or boring:

> *"…but I think to benefit from it, you've got to get your mind in the right mindset to do things that you don't really enjoy doing if you're going to have benefit from it afterwards." (P3, M-DTT)*

Different intrinsic factors may work for different individuals (Geller et al., 2018). For example, one participant from the M-DTT group stated that her fear regarding the deterioration of her symptoms kept her motivated to continue exercising.

> *"Well, a lot of people say, oh, you're very good you do this and do that. And my answer is, it's not being very good it's fear of what will happen if I don't do it. If I don't do it, I'm going to deteriorate. But if I make the effort, I can feel the benefit. So, it's fear driven, fear of what will happen if I don't exercise." (P3, M-DTT)*

For some participants, challenging themselves with the tasks given in the DTT helped them to see improvements in both their performance for undertaking the DTT and their balance. Although they did not always feel comfortable with the level of challenge, and did not find the tasks particularly enjoyable, they reported that challenging themselves at the edge of their limit contributed to their engagement throughout the intervention, and the ultimate benefits gained from the DTT.

> *"it's constantly building up. So, I mean, six weeks, you can tell that how much did you know, it does help you, but it is the sort of thing that would be very*

good to build and, you know, have something that you'd be able to keep doing. But definitely it can help." (P1, C-DTT)

"I hate to feel that I couldn't do it. So maybe it might encourage me to think harder because the day before that I hadn't done very well. And I was determined then to look at it more closely and concentrate more to see if I could improve on it." (P13, C-DTT)

Participants developed their own strategies to complete the DTT tasks, gaining a sense of achievement on completing the tasks, And seeing the subsequent benefits. Sometimes the benefits were directly related to their everyday balance, but at other times the benefit was he improved performance and ability to undertake the next task, the next challenge:

"…I decided that what was the thing that was causing me the most problem. The most problem at any one time was always moving my feet while watching the clock's sequence. But I decided that it was a no brainer I was not going to do that. So, I threw that away, that gave me two things to look at. The two things I did much better. I felt I did better." (P14, C-DTT)

"…people with PD tend to for the cognitive and not the physical thing. And I tried to let go of the cognitive and think, it doesn't matter if you don't get it right, you are testing yourself. So, I try and concentrate on the movement…I was actually really concentrating on them on the physical." (P1, C-DTT)

Subtheme 4: Individual situations and interests can affect the level of acceptability.

The data showed that each pwPD experience their condition differently. For example, some had good balance but found the cognitive tasks of remembering things and keeping attention more difficult. The different responses to medication, and how it affected their "on" and "off" time also affects their training performance, perceived level of challenge, and enjoyment.

"I was just heading towards my off phase, and it gets more difficult and very slow." (P11, M-DTT)

Some individuals may have co-morbidities alongside PD, and this may affect their ability to engage with the training intervention. For example, one participant from the C-DTT group (P14) had anxiety which was triggered by certain exercises:

> *” When I was trying to do that sums cognitive stuff. I'm not, I knew I wasn't very good at that anyway. “(P14, C-DTT)*
>
> *“I think your anxiety about doing cognitive testing with clinical cognitive testing waylaid your thinking…you came to take them away and all we were doing was counting back. Okay, so there are some exercises that caused anxiety.” (SoP14)*

For others, health issues required them to have a break in their training:

> “*The only thing I would say is with Parkinson's is this so many of the things that you would tell…And then if there's a week when I haven't done so much, like, you know, in the time that since I last saw you, you know, I've had, like, a bad shoulder. Yeah, I had a really bad cold, flu thing, for like a week. And that means that all my things come back, like. I mean, all my symptoms are like 100% worse.” (P1, C-DTT)*

Family dynamics can also affect their perspectives about their experience with the training (Smith and Shaw, 2017).For example, for one participant (P1), whose children were not aware of the participant’s PD diagnosis, there was considered pressure not to fail while performing exercises. For this participant the timing of training had to be organised for when the children were not around. These factors can affect the engagement with training:

> *“…my kids don't really know about Parkinson’s, they don't. And so, I like for example, I had two weeks was the Easter holiday. And so, I can't because I get upset if you do anything that shows weakness. Uh, yeah, it's a problem with the children. And so, I didn't really do it when they were around.” (P1, C-DTT)*

Individual interests or previous exercise routines appeared to affect participants perception regarding challenge and enjoyment level. For example, one participant from the M-DTT group described herself as an outdoor person, preferring to undertake her exercises outside where it is possible:

> *"Well, I can't say I enjoyed them, but they're not particularly unpleasant, but it isn't the sort of thing I would choose to do by choice…I've always been a very outdoor person, so I don't. Things that are indoors have never interested me very much…" (P3, M-DTT)*

One other participant with a special interest in photographs found the tasks which involved looking at different pictures enjoyable, despite finding them challenging. This highlights the importance of including a variety of task types to reach a wide range of interest to optimise acceptability of the intervention:

> *"The most amazing thing for me was the photos, it was like a sanctuary because there I was, I could stare at something. And I couldn't say goodbye. Right, so I enjoyed looking at them. So, this comforted me...." (P14, C-DTT)*

> *"There are certain things I found easier than others I found pictures and I enjoyed that…The math side completely go to pieces, and I couldn't really concentrate on the numbers or keeping my balance and moving very difficult…But yes, generally it was, it was good fun." (P13, C-DTT)*

Overall, these statements show the importance of individually designed DTT activities to enhance the acceptability of the intervention and adherence to it. Important to participants was the challenge level of the DTT, so that activities were challenging enough to push their limits to create the potential benefit, but still achievable so that they can feel their progress and remain motivated to keep going.

Theme 2: A home-based intervention has both advantages and disadvantages.

This theme explains the importance of a DTT intervention fitting into the persons daily life. It considers elements such as time constraints, having a suitable area at home, and feeling safe.

Sub-theme 1: A safe environment offering flexibility.

Feeling safe and comfortable can contribute to the acceptability of DTT.

> *"…Making people comfortable, that's made a huge difference." (P14)*

In terms of safety, home environment was perceived as an acceptable training place, and provided some opportunities to minimise potential safety risks. For example, one participant found the wall in her home as a help in preventing falls during lunging/ Others found the indoor setting of the training reassuring, enabling training to continue without worrying about potential negative events.

> *"The thing is you can do like something in an outside like fast walking stuff like this, but, you know, like this time of the year, Well, so muddy everywhere if you were doing it, there will be consequences." (P1, C-DTT)*

> *"The lunges were all right because I have the security of the wall on that side although I wasn't touching it, but I knew it was there." (P3, M-DTT)*

> *"I stumbled a few times, but I didn't fall…I feel perfectly comfortable doing the exercises in my own home it wasn't a problem." (P12, C-DTT)*

DTT within the home environment gives some flexibility to allow people to fit it into their daily routine. Although the frequency and duration of the training sessions are standard for each participant, they can pick the time to perform the training according to their mood, medication status, and availability; potentially optimising their performance during training.

> *"It was easier to choose a time of day without the reliance on someone." (P11)*

> *"You could fit that in any time of the day. Really. It didn't have any strict timescale. That was good. I like doing them at my own time, my own place, it was good, wasn't it? Don't have to go anywhere. It suited that lifestyle because you could fit it in, and it didn't do impeding anything all." (P13, C-DTT)*

> *"I think you're more relaxed in your own home …you can do it when you feel it best. So, you do a better job than if you were made to do it at a different time." (P3, M-DTT)*

However, one participant and a supporter highlighted that this flexibility may mean some people are less likely to take responsibility for continuing the training. suggesting that supervised training or a group work may help prevent this for some pwPD.

> *"I don't know if some people might not put the effort in if they're home, if they're not being watched. You know, you can say I've done it when I haven't." (P3, M-DTT)*

> *"You can choose when to do it but it's also very easy to choose not to do it. So, if you were doing like group exercise then you would feel more obliged…So, I think group exercises gives you a sense of teamwork and depending on other people as well and not letting them down but working at home gives you the choice. So, there's a balance there, I think." (SoP14, C-DTT)*

Overall, the home-based DTT was perceived as safe and flexible training interventions by the participants.

Sub-theme 2: Finding an available training area can be difficult.

Although the home environment offers flexibility, finding a safe and functional space to perform DTT at home may be difficult for some pwPD. Requirements like proximity to a clear wall, and sufficient space for a non-slip exercise mat may limit DTT feasibility for those without an ideal setup at home. This may make it unacceptable or unfeasible to undertake home-based DTT for some people. Whilst the inclusion criteria required all participants in this study to have such an area, it was highlighted as an important factor to consider for a wider group of pwPD.

> *"Fortunately, we have a spare bedroom, so I had enough space and the right sort of place to put the iPad. It could be difficult for some people I would have thought. You need quite a big space, don't you, to do those exercises." (P12, C-DTT)*

> *"You would want an empty room. So, for me, it was fine, but for somebody with balance problems it might be difficult to find a safe place in the house." (P11, M-DTT)*

> *"I only say about that the mat was quite big. Yeah. Quite Hard to find a space." (P1, C-DTT)*

Although all participants could find an available space, for some people the need of such a large space during the 6-week training intervention caused some restrictions in the use of their home and affected their routine:

"I think one problem I found was the mat was very large and if we left it down it caused me a trip hazard. So, we had to roll it up afterwards… "(SoP14, C-DTT)

"That was all right because we just moved the table up the end and used that space. So, we didn't play table tennis for six weeks." (P3, M-DTT)

Sub-theme 3: Finding a suitable time can be difficult.

Choosing the time for the training based on both the participant's and training buddies availability required flexibility by participant's:

"I just sort of fitted it in when my supporter was there and you know, there was nothing else happening. We would do it to say, should we go and do the exercises now?" (P3, M-DTT)

Others found it more challenging to find an available time for their training due to life routines which often included work, spending time with their children, and coordinating with training buddies who had different schedules.

"It's surprisingly difficult to find the time to do it. When you're busy. I mean it needs both of us to be available." (P12, C-DTT)

"The biggest problem was finding a run of time where we weren't trying to do other things at the same time… So, our days structured around what we have to do and sometimes it was oh we have got to do this as well." (SoP14, C-DTT)

As a summary, the home-based DTT was generally perceived as a safe and flexible approach. These data suggest it may be acceptable by pwPD who have an appropriate home environment and can be flexible with their schedule.

Theme 3: Dealing with the technology.

This theme explains the perception of participants regarding how acceptable technology was to undertake the DTT, to complete the online 5-point Likert scale, and the online meetings with the researcher for progress assessments. It also describes how technical issues affected engagement with the DTT.

Sub-theme 1: Accessing and streaming the movies whilst training.

The ability to access training sessions without professional supervision can serve as an important initial indicator of technology acceptance. This may depend on the participant's skills and prior experience with technological tools such as tablets and emails. Most participants reported being able to access the training movie links, although some encountered minor challenges.

> *"Once I found the right email it was easy because we've got quite a list of emails between us. I couldn't always find the right one, but when I picked the right email, it wasn't any trouble." (P12, C-DTT)*

> *"I'm rubbish with computers anyway. It's a bit of a lottery whether I'm pressing the right things or not. I don't know what I did, it must be something I pressed but it's all right because I had it on my other tablet anyway, so I could have used that if I couldn't find it. But it did start by fumbling a bit, but we got it sorted come the end." (P3, M-DTT)*

After accessing the training videos, the next step involves navigating to locate the correct session video and streaming it on the tablet, which includes functions like playing, pausing, and restarting. Most participants successfully managed this, commenting on the benefits that functions such as the pause feature provided, enabling them to stop and start when required. The extent to which individuals can benefit from this flexibility is likely to depend on their technical skills.

> *"It is fine I am used to working with a tablet and navigating windows. So yeah, it is fine." (P11, M-DTT)*

> *".. being able to pause the program if somebody came to the door or a postman or a delivery man and this sort of thing.... sort of come up and we do the warmup and then we go press done. And we go back to the link..." (SoP13, C-DTT)*

> *"…some people seem to have quite a bit of difficulty getting to the right place like am I there and pressing buttons and things. It just depends on how much skill people have." (P13, C-DTT)*

However, not everyone found this easy. One participant encountered difficulties with navigation, which affected the choice of training time, and potentially affected performance, and caused them some concern. Despite these challenges, this participant was able to complete the entire training intervention with the assistance of the training buddy.

> *"It's not smooth it's very clunky. when I was pressing, I expected it to do what it was supposed to do. We spent a long time losing you, losing those videos, hunting around they weren't even in the right order. So, it was a cumulative effect. This was supposed to be a very simple thing to just push a button and it works, so that worry is taken away. That was a real problem because we all argued about what time we were getting ready to go and do these things because it took us so long to log on." (P14, C-DTT)*

> *"Using iPad was smoother P14. I found it better to take over that bit because otherwise we would have been ages and with frustration probably have not got to the exercises." (SoP14)*

Overall, accessing and streaming were found manageable by the participants.

Sub-theme 2: Interacting with the movies.

Being able to follow the content within the movies is very important for engagement, and another important indicator to understand the acceptability of the technology use for delivering DTTs. There were some difficulties in understanding when the task performance started, since there was a time gap between the written and audio instruction.

> *"There are actually a few errors in the instructions…there's a difference between when the screen comes says go. Yes. And then what? And then when it said go. And so, I got very confused. And so sometimes I started when the go came up and carried on the way through. And then then and then I go. I mean, there are tiny things but generally they were good." (P1, C-DTT)*

> *"The 'Go' sign came up quite a while before the voice said Go. So, there's a bit of confusion about when you should have started. But apart from that, it was great." (P3, M-DTT)*

There were other issues regarding the content of the session in C-DTT that could impact the perceived challenge and enjoyment level. These included inconsistency between written and audio instructions, clarity of the instructions, and difficulty in hearing or understanding the accents of non-native English speakers who provided the audio instructions and audio stories as cognitive tasks.

> *"The voiceover was saying the same instructions, but the written instructions were three and seven. So, we followed the written instructions." (P13, C-DTT)*

> *"The instructions were clear enough, sometimes they didn't coincide with what was written on the screen, so the narrator would be saying something different." (P12)*

Whilst one C-DTT participant found it acceptable:

> *"Really apart from the sort of technical glitches, it's gone very well." (SoP13, C-DTT)*

Others found the instructions and some of the content of the training sessions difficult and tedious to understand. Suggestions were made from the participants as to how this could be improved:

> *"I didn't know what I was doing. I didn't know what to expect. Brain training exercises is how I interpret the first bits. I'd never seen anything like that. I didn't realise that's what they were. I needed more examples. I couldn't work the rules out. When someone said, take something away from a hundred that just, alarm bells went off because I've got to do that, and I couldn't prepare myself or anything for that." (P14)*

Hearing and understanding the task instructions, as well as the videos that are a specific part of the cognitive tasks, were considered difficult and presented a challenge to another participant (P12):

> *"I have difficulty with the video. It has a lot of mistakes in it. So sometimes it was, I didn't really know what it was asking me to do, or I couldn't hear what was being said. That was the difficulty, the level of difficulty of the tasks given were not too bad. I mean, even the later ones where we had the chap walking on Dartmoor, he was an English speaker, but he didn't speak very clearly, and my hearing is going anyway. So, it was sometimes quite difficult to hear what he said so then I couldn't answer the questions because I hadn't*

heard what was said. So that is where the difficulty came in…I couldn't understand what you were saying. I'm sorry. I just find your accent difficult to comprehend. So, it was things like that that was tedious. So frustrating, tedious and boring." (P12, C-DTT)

"I mean, we actually almost gave up on some of the similar practice stories where it was different because we couldn't actually understand enough, and we were really concentrating." (SoP12)

One M-DTT participant pointed out that having the task instructions throughout the entire training is repetitive and not always necessary, as they are almost the same for each task in M-DTT.

"At the end, you don't need all the information you can fast forward through that so that's not a problem". (P11)

Overall, the technical elements of the training package were found acceptable for those in the M-DTT group but needs improvements for the C-DTT to be considered as an acceptable approach by all participants.

Sub-theme 3: Using an online approach as an assessment method.

The use of online 5-point Likert scales as a data collection method is common among researchers (Maeda, 2015). The usability of these scales by participants in this study serves as an indicator for the acceptability of an online approach for this assessment. Encouragingly, most of the participants found it clear and easy to fill out:

"It (online 5-point Likert scale) was clear from the start. Yeah, I didn't have any difficulty with it at all." (P11, M-DTT)

"Yes, that (online 5-point Likert scale) was easy." (P12, C-DTT)

In contrast, one participant noted that the structure and clarity of the questionnaires needed improvement:

"It (the online 5-point Likert scale) was completely too vague. Every question it had I could write much more because it needed a specific answer itself. So, it was something needs to be another thing. It wasn't well-structured, and you

didn't have anything to put in at the beginning to know what the correct thing was." (P14, C-DTT)

Another assessment component in this study was the use of video conferencing through Zoom with the researcher. Here the purpose was to monitor participant's progress. This approach was perceived as necessary and useful, allowing the participants to connect with the researcher, seek advice, and feel supported; which they felt contributed to their motivation and overall DTT success.

"I think it's a necessary thing to do when two people are coping to work has together." (P14, C-DTT)

"it's nice to catch up. You don't actually always write down or remember things. When you do that, it's nice to go over and you were asking questions and giving our response. I think it's a good idea, the meeting, because we wouldn't surprise that in one episode." (P13, C-DTT)

"I think it's good to keep face to face contact because you get more feel for what's happening don't you. Yeah, that's good." (P3, M-DTT)

As a summary, in general the use of technology for exploring participant's views on the acceptability of the DTT, and monitoring their progress, was acceptable for most participants. It does, however, need improvement in terms of some of the technical issues within the content of the training movies.

Theme 4: There are advantages and disadvantages to training with a buddy.

Training with a buddy can offer valuable support to participants (Rackow et al., 2015). The participants in our study conveyed that this approach helped them feel less isolated and more supported, and provided a sense of security for the person with PD.

"I mean, used to find, we need somebody there just to give hand, really. Training buddy is a really important point." (P13, C-DTT)

"I'm happy to have somebody there, but I'll still do them with nobody there." (P3, M-DTT)

"He was entirely supportive. What else can I say." (P12)

Due to the scoring component of the DTT, having a training buddy was essential to count and document scores:

> *"My supporter was always there when I did those exercises because he had the scores, so I think I could do them by myself, but you can't because you can't count and do it." (P3, M-DTT)*

Participants described how training buddies provided feedback, motivation, and potentially improved their performance over the course of the training program, leading to potential benefits for some pwPD.

> *"you've got to have somebody there to actually see if you're improving or not." (P3)*

> *"I know that some people go to my class, and they have a partner who says 'come on, come on, stand up straight. Now, you're not doing that very well.' Then, maybe it's quite often it's because they've got to the point where they have some problem, so they really benefit from what someone says to them. But I haven't got to that point yet. And I push myself. Not anyone. I don't need someone to push, and I push myself. So, I think it's always good to have the option you know. If they had someone who they could relate to I mean to get feedback how they are doing that thing okay." (P1, C-DTT)*

Training with a buddy was felt by some to enhance enjoyment through friendly competition and mutual motivation.

> *"It was a bit of a competition to my husband myself as to how he got right. And I said, good competition." (P13, C-DTT)*

Whilst others found this type of competition to be a negative experience:

> *"I felt the whole thing was set up to be competitive. My supporter said do the best you can, go as fast as you can, keep going. Very, very competitive. I don't like that particularly, it's not my style. I do it because I can do it and have been successful doing it when I choose to." (P14, C-DTT)*

Working alone with buddies was sometimes challenging for a participant (P14) during task performance. The clarity of the buddy's role was highlighted as being important as they may act as a coach/supervisor or participate in the exercises alongside the participant. Confusion about the buddy's role presented an additional challenge for some, impacting negatively on the performance of pwPD.

> *“Having my supporter to take records was quite interesting because I assumed she would take records and be completely neutral but there was scope within the work that you gave us to have a different interpretation to one another in the same room, looking at the same things, and it brought some discussion.” (P14)*

Training buddies were the participants’ partner/spouse in this study. While most of the participants found training with their own partner as a training buddy acceptable, some expressed that they would have preferred to train with strangers as buddies, believing it could provide a shared sense of experience, and be less burdensome for their partners.

> *“I don't need any more social interactions with my supporter. I have plenty thank you. Stranger (as a training buddy) because they're both going through the same exercise. You haven’t got the baggage.” (P14)*

Overall, training with a buddy was found to be acceptable and, at times, even essential for engaging with DTTs. However, the data suggests that these buddies do not necessarily need to be partners of pwPD.

Theme 5: Training characteristics are manageable.

This theme explains the participants perceptions regarding the duration and frequency of the individual sessions and the training intervention, and the progression of training over the weeks. It also explains the extent to which the participants felt they benefitted from the DTT.

Sub-theme 1: Duration and frequency of the sessions

Some participants found the duration of the training, including warm-up and cool-down sessions, to be somewhat lengthy. This made it challenging to fit in their schedules at times.

> *“When you're busy. I mean it needs both of us to be available. And it's a good half an hour, it’s more than half an hour actually by the time you've done the*

cool down it's a good forty-five minutes three times a week for the two of you" (P12)

"So sometimes I had conflicts of interest or pressure to do your stuff on top of the other things that couldn't be moved. That was very difficult." (P14)

Consequently, some participants chose to skip the warm-up and cool-down sessions, which enabled them to manage the DTT more effectively.

"The warmups and the cool downs, I know you're supposed to do it, most of the time I felt warm enough, so I didn't do it. I was so fed up come the end I never did any cool downs. So that was cut off either side." (P14)

"Like being able to do it in, say, 20 minutes. I mean, if I could do it, it tended to take over half an hour. If it was taking 20 minutes, I'd probably be doing it more. Yeah. Sometimes what I did was exercising, and I moved straight on to the next slide, so I did not do the warm-up. That made it easier to do." (P1)

However, one participant found the overall duration of the M-DTT acceptable:

"It was perfect to warm up and warm down." (P11)

Some participants found the time for individual tasks within the C-DTT to be acceptable, but they observed gaps between tasks, and noticed that certain task instructions were repetitive. One participant suggested that the instructions could be shortened to address this issue. Some participants chose to skip certain instructions to speed up the process, allowing them to engage more with the C-DTT while avoiding unnecessary repetition.

"The actual length of time for each of the exercises was okay. There seemed to be a big gap between the end of the exercise and having to do the next one. So, there was a lot of downtime because there was a space between the two. It could have been speeded up." (P12, C-DTT)

"I'm listening to something; I struggle to focus on that very much anyway. So, I don't really listen to the instructions properly. So, I quite like to review instructions maybe once a week or something." (P1, C-DTT)

"We tended to skip past them a little bit because we knew it was just instructions, so we shouldn't lose it when we did that. And it took half an hour to get through. Which is fine." (P13, C-DTT)

The frequency of the sessions was generally acceptable, although one participant suggested that conducting them once a week would be easier.

"That (frequency of the sessions) was fine." (P1, C-DTT)

"Once or twice a week would be easier than three times, but probably once a week wouldn't be enough to have reasonable results." (P12, C-DTT)

Overall, the duration and frequency of the sessions was mostly acceptable.

Sub-theme 2: Seeing the benefits of it in 6 weeks is difficult.

It may be important for participants to understand the potential benefits of participating in a training intervention at the start to optimise their engagement with it. One participant noted, however, that he was unclear about the training's objectives and what to expect over the six weeks at the beginning. This lack of clarity could make it difficult to recognize the program's potential, and consequently, impact their engagement with DTT.

"I'm not sure what's the goal, yeah. Is it because I'm supposed to improve balance? Am I trying to improve coordination between the balance task and the hand task? Or am I looking for improvement in my general health? It's hard to see from here, where we start, where are we heading for, what is the purpose of the trial, what are you trying to achieve here." (P11, M-DTT)

Although the participants found it manageable to keep doing DTT at home over six weeks, most agreed that practicing more frequently or over a longer period would be more effective to experience a change in their balance.

"For six weeks it's very easy to know that you can keep going, keep going, whereas maybe for 12 weeks people might struggle a bit more. But on the other hand, with anything that way, you can see the improvement. I mean, like, for example, my classes I get into in person and usually ten weeks, by the end of it it's very different than beginning." (P1, C-DTT)

“Sometimes you have good days and sometimes you have bad, and you don't know if it's the exercise or not... I think you'd have to do it (the DTT intervention) for a long time to see if you’re stable with it. Yeah. I think it does help you. I think to improve it you'd have to be doing them every day or over a longer time.” (P3)

Most of the participants stated that they could not perceive any change in their balance after the 6-week DTT. One participant noted that this lack of change might be relevant to their baseline performance and suggested that pwPD with more sever balance issues would benefit more (P11). The supporter (SoP11) emphasized that there could be an improvement in their functional level, but pwPD may need to challenge themselves to notice a change.

“I can't determine any particular change with balance. It’s still not good.” (P12, C-DTT)

“I personally can't see any change, but then again, I wasn't so bad at the beginning. You might want somebody who has major balance problems and a faller on this. But yeah, I can see the principle of the exercise model.” (P11, M-DTT)

Discussions between the pwPD and their supporter highlighted that their perceptions sometimes differed as to whether changes in balance had occurred:

“Mind you we didn’t challenge your balance either. So, was it easier to put the Christmas presents up in the loft before or after?” (SoP11)

“After.” (P11)

“You felt better going up the ladder after than you did before?” (SoP11)

“Yes.” (P11)

“That’s an improvement.” (SoP11)

Overall, the six-week DTT was manageable, but many participants did not perceive any change in their balance. A longer period of DTTs may be more beneficial for noticing an improvement in balance.

Sub-theme 3: Progression may work in different ways.

The DTT was designed as a progressive training program, with the expectation of experiencing a higher level of challenge every two weeks. The progression between weeks was noticeable, especially with specific tasks and task combinations for most of the participants. Only one participant mentioned that she did not notice the difference between the weeks.

> *"But it was very noticeable in the last two weeks with the patterns left, right, equal, counting the different words that got progressively hard. But the harder, the harder the brain tasks, the more I had to think about keeping my feet. the early ones, I could probably do anything with it, you know, just concentrate on the brain." (P13, C-DTT)*

> *"For example, the foot tapping wasn't too bad. Some of the lunges I found really difficult, especially in week five and six. You carried on looking at screen. And that made it easier for lunging to the side… And. Yeah, and it's just quite interesting to see what it suddenly got a lot harder when you have something that backwards and that was like wow, counting forward was quite easy," (P1, C-DTT)*

However, the perceived level of challenge differed from the designed progression in each two-week period for some participants. For instance, one participant found the tasks in the weeks 3-4 to be more challenging than those in weeks 5-6.

> *"Weeks one and two were probably easier. Week 3, then introduce the round clock. And that I found hard yeah. And then it got easier again. There was a fidget toys that was difficult with one hand. I'd say probably weeks three and four were the trickiest ones…Yeah, I guess I felt the best during the last couple of weeks or maybe because the exercises were less challenging." (P11, M-DTT)*

Overall, while most participants were aware of the progression in challenge level over the 6 weeks and found it acceptable, some did not notice any difference in progression between specific weeks.

Theme 6: Research assessments are familiar but are they acceptable?

This theme explains how prior experience with being a research participant may affect people's perception about research assessments and face-to-face assessments. Also, this theme explains the participant perceptions about the use of the training workbook.

Sub-theme 1: Face-to-face assessments are acceptable, but travel may be a burden.

All participants travelled to the university twice for their assessments, both before and after undertaking their DTT at home. Some participants had prior research experience and were familiar with the assessments, finding them acceptable.

> *"The assessments are fine. I have had most of them done before. The various neurologists I've seen have done exercises with me or I've taken part in several other studies and so I've had that kind of procedure before so it's quite familiar to me." (P12, C-DTT)*

> *"It's alright. I have been part of other tests before and they all do something similar. So, I was really familiar with it. It was fine." (P11, M-DTT)*

Although all participants were able to travel for both assessments, some pointed out that travelling could be burdensome for some pwPD and their supporters.

> *"It was alright. It's an easy enough drive for us, just three quarters of an hour for us. So, it's fine." (P11, M-DTT)*

> *"…and travelling down here. It depends on where you live. If you live down here it is not so difficult." (P12, C-DTT)*

> *"I just hate travelling around Derriford because of the traffic." (P3, M-DTT)*

It was suggested that having these assessments conducted at home or being assessed using online approaches would be desirable to overcome any challenges associated with travel.

> *"The assessments that we do here are easy to do it is only the process of coming here and I don't quite see what the difference between doing it at home and doing it here. People have now begun to accept video conferencing and I don't think it's ever going to go back to face to face. Nearly for everyone it's too expensive, time and that sort of thing. It (face-to-face assessment) is lovely because you can see a person but functionally (shaking head)." (P14, C-DTT)*

"Well, yeah. I mean, you got no choice, really. Unless you want to come to us?" (P3, M-DTT)

Sub-theme 2: Training workbook is acceptable.

The training workbook was completed by training buddies to record the scores achieved by participants during the training sessions, as well as any falls or near-falls, and to rate the enjoyment and challenge level of the sessions. Most participants found completing it to be easy, but one participant and their training buddy found it unclear when rating the enjoyment and challenge levels.

"It's (completing the training workbook) quite straightforward, actually." (P3, M-DTT)

"I did that (completed the training workbook). That was easy." (SoP12, C-DTT)

"Filling in the scores were fine but there were only two things to write and how many times did P14 fall over and that was zero. But P14 had to score enjoyment and initially we couldn't decide how to score that, so we just picked a number and stuck to that consistently. So, enjoyment was a high number if he enjoyed it. So, there were other things as well, so maybe a bit of guidance on the scale." (SoP14, C-DTT)

Overall, face-to-face assessments and completion of training workbook was perceived acceptable by the pwPD and their training buddies.

Theme 7: Suggestions from pwPD and supporters

Lastly, suggestions and comments of pwPD and their supporters were made to improve the interventions and research design during the interviews. This theme explains their suggestions regarding the content and characteristics of the DTT and assessments.

Sub-theme 1: DTT content and delivery

PwPD tend to prioritize one task (Bloem et al., 2006). One participant pointed out that giving a cue to prioritize the primary task and secondary task in other sessions would be a good strategy to ensure both tasks were performed properly throughout the entire DTT. This method may help them to successfully perform each individual task and benefit from both the primary and secondary tasks. So, the participant suggested that if they have someone with them, they can provide that cue.

> *"Say to people sometimes this time maybe put your emphasis on physical. Yeah. Because it makes quite a lot of difference…When you are multi-tasking, you don't really multitask properly. And so, what happens is you always prioritise one. I'm trying to say for this one time, prioritise the physical…. So, what I realised that it's possible if you had someone with you, they tell you to come on, put more effort into it." (P1, C-DTT)*

One supporter commented that clear guidance for the training buddies about their role would be helpful. They were unsure if they were allowed to coach the person with pwPD to perform the tasks correctly.

> *"I mean I could see where he was going wrong, but if it had been left up to him, he would not have seen it. So, I didn't know if I was allowed to coach him (the person with PD) or to point out what the instructions meant. So that would have been helpful for the coaching." (SoP14)*

Another participant suggested instructing participants to emphasize performing tasks without focusing on perfection but rather doing their best, especially for tasks involving their feet. *"It (instruction) gives you focus to know what you shouldn't just step here; it should be somewhere close. Yeah, but don't expect that somebody can distinguish between this way and this way." (P11, C-DTT).* This highlights the importance of researchers clearly explaining their expectations to the participants.

The researcher also plays an important role in the first session with the participants. One participant suggested having a variety of tasks in the first session to assess the participants' needs. This approach would allow participants to undertake an individually designed DTT program and benefit more from it. Introducing different types of tasks that address various components of balance could also provide an opportunity for participants to choose tasks according to their interests. These comments indicate that building this this type of flexibility into the training may enhance engagement with DTT and subsequently improvements in the balance outcomes.

“What would be very good is to have something with a few variations in it and then work with a therapist to go through it. Start with just so that we set it up for each individual person. I mean, so that you could try different things. And, you know, that may be slightly different that someone with you if you didn't have someone with you.” (P1, C-DTT)

“I think you have to do targeted exercises like you’ve got in the program. But I still think you need to get outside. I mean to walk and stuff like that. Because those things don't demand precise movements… maybe if the weather's not very good when you're in the indoor activity. If you're home, you can tailor that to the conditions on the day. You know, if it's like this then if it's something you can do outside then I would be outside.” (P3, M-DTT)

One participant suggested that showing how to perform the tasks using small videos of the researcher in front of a tablet placed on the wall would be clearer for the participants to understand what they should expect to see in the training area.

“When you were demonstrating the lunges like that way you tell where you have to do, you didn't have a screen there and it would have been good to have the screen.” (P1, C-DTT)

Sub-theme 2: Assessments and scoring

Only one participant had a suggestion regarding recording scores in the training workbook. It was suggested that it would be clearer to track progress and improvement throughout the DTT programmes if the scores were recorded for each individual task, rather than recording total scores for a session.

“Would it be better to itemise (the scores) them because you don't know which ones that you've improved on and which you haven’t rather than the whole total. So, he's put the daily things that we did on the back as I was doing them. With the individual score on as well.” (P3, M-DTT)

As a summary of the findings from the qualitative component of this study, both C-DTT and M-DTT were perceived as manageable for continued performance over six weeks with a training buddy at home. Some technical improvements in the content of DTTs are needed to enhance engagement and increase the level of acceptance, with helpful suggestions from the participants as to what these improvements might comprise.

Chapter 6: Discussion

This chapter discusses how the findings of this PhD study can inform future clinical trials which investigate the superiority of the M-DTT and C-DTT on balance in people with mild to moderate PD. The key findings of each work package (scoping review, the pre-trial qualitative study, and the feasibility study with embedded qualitative component) are synthesised and discussed around the study objectives and in light of the literature.

The overarching aim of this PhD study is to firstly design home-based M-DTT and C-DTT interventions and then, to test their acceptability and feasibility to inform the design of an anticipated powered RCT. The chosen data collection methods and tools to achieve this aim is also discussed.

6.1 Recruitment and sample size

The target sample for each group was five, totalling 10 for the feasibility study, as informed by a feasibility study conducted for investigating the effectiveness of a highly challenging (involving dual-tasking) balance training for mild to moderate PD (Conradsson *et al.,* 2012). The actual recruitment was below this, with seven participants recruited over the four-month recruitment period. However, a single participant withdrew from the study, leaving a final cohort of six individuals who completed both the training and the subsequent assessment and interview upon its conclusion.

Successful recruitment of patients is known to be one of the most challenging aspects in conduct of RCTs (Kadam et al., 2016). Recruitment was not specifically assessed in the feasibility study, as the key focus was on determining the acceptability and feasibility. However, this is recognised as being crucial to ascertain the effectiveness of the participant recruitment strategy in securing a suitable and adequate sample for informing future RCTs (Teare et al., 2014). On reflection, it would have been helpful to add this as a specific objective to enable this to be more fully explored. The timing of recruitment, especially considering its initiation in mid-November nearing the winter season, may have introduced potential challenges. Conducting initial assessments and subsequent training during special occasions such as Thanksgiving and Christmas has been recognised by other researchers as adversely impacting participants' willingness to participate to the study (Thoma et al., 2010).

Additionally, the burden of traveling for assessments may deter potential participants (Patel et al., 2003), as exemplified by an interested individual who, due to the considerable distance between home and the PAHC for assessments, found participation unfeasible. While this instance involved only one person, it underscores a point highlighted by pwPD in the pre-trial qualitative study. To mitigate the potential decline in trial participation due to travel-related challenges, participants were provided the option to have their travel and parking expenses covered up to a specified limit. This measure aimed to reduce the financial burden associated with travel; however, due to limited resources, it does not address the broader issue of expanding the geographical reach of the trial. The constrained geographical scope, limited to the South-West area, represents an additional limitation in achieving a more extensive sample. Expanding the target location might seem like a plausible solution, but it introduces a similar constraint—namely, the challenge of travel (Patel et al., 2003). Thus, a balance must be struck between enlarging the study area and mitigating the potential impact of increased travel demands on participant recruitment.

The allocated four-month timeframe and going through outside of care pathways like National Health Services for the recruitment process, dictated by the constrained timeline of the PhD, further compounds the challenge (Briel et al., 2021). For example, an RCT has achieved to reach the estimated sample size (total 540 pwPD) from different National Health Services hospitals, clinics, community services in eight regions in England in a year time period (Chivers Seymour et al., 2019). The limited timeframe of this feasibility trial likely contributed to the shortfall in achieving the planned sample size. Addressing these factors and estimating realistic timescale by using gathered data from previous studies and comparing them against the planned sample size may enhance the feasibility and success of future recruitment endeavours (Huang et al., 2018).

Key parameters to be considered in the sample size estimation include the effect size, statistical power, and statistical significance level (An et al., 2020). Unfortunately, due to the limited number of participants, specifically two in the M-

DTT group and four in the C-DTT group, conducting meaningful statistical analyses within and between groups was not feasible. Consequently, as a limitation of the feasibility study, the calculation of the effect size and the sample size for any future study was not possible.

Although a formal sample size estimation was not conducted in this feasibility study, there is a recognition of the importance of such an estimation for informing a future RCT that will assess the superiority of the effectiveness of both DTTs (An et al., 2020). The current data provides an initial starting point for calculating the sample size for a future RCT, although because of the limited number of participants on which this is based, it is suggested that it would be advisable to next undertake a pilot study to collect further data with a larger sample before moving on for the definitive trial to perform a sample size calculation (Teare et al., 2014).

Broad estimates of sample sizes can also be informed by previous relevant studies. For example, Conradsson and colleagues (2012) previously estimated a sample size of 24 participants for a two-arm study (intervention and control groups) involving the MiniBESTest. Their goal was to detect a 3-point difference at the group level, assuming an effect size of 0.83 with 80% power. Given that a future RCT is anticipated to involve two intervention groups and one control group, it is likely that it a sample size greater than 24 participants will be needed. This adjustment is crucial for ensuring adequate statistical power and precision in evaluating the effectiveness of the DTTs.

6.2 Attendance and Adherence

Adherence to the intervention is a critical component in assessing the feasibility of the intervention and it was a primary outcome for this feasibility study. This aspect is highly significant, particularly in the context of an unsupervised intervention (El-Kotob and Giangregorio, 2018). When adherence to an unsupervised intervention is a primary outcome, it is important to meticulously select assessment methods. Additionally, efforts should be made to explore potential factors that might influence adherence, such as the setting and delivery method of the intervention, and whether it is administered in a group or individual format (El-Kotob and Giangregorio, 2018, Suttanon et al., 2013).

Total sessions attended can be regarded as a common measure of adherence (Rivera-Torres et al., 2019). Attendance at the main exercise session (excluding warm-up and cool-down) demonstrated a notably high rate, evidenced by the session views surpassing the session numbers for the majority of participants. This observation potentially indicates a high level of adherence to the DTT sessions.

In this feasibility study, adherence to the home-based DTT was primarily assessed by monitoring the minutes of watched training videos through Panopto. Additionally, participants used a training workbook to self-report their scores in sessions, although these self-reported scores were not included in the analysis. Self-report diaries are widely recommended for assessing adherence to home-based interventions as they help mitigate recall bias (Pickering et al., 2013). However, it is essential to acknowledge that they also carry a risk of non-response bias (El-kotob and Giangregorio, 2018). Online progress assessment meetings with the researcher helped to minimise this risk by ensuring the regular communication with the participants and reminding them to fill the training workbook.

An objective measure of adherence involves considering the time spent on online sessions, the number of completed sessions and activities (Donkin et al., 2011). Use of Panopto enabled the recording of metrics for adherence, including the number of minutes participants spent watching sessions, the frequency of accessing each session, and overall engagement. Consequently, platforms like Panopto have the potential to yield accurate results and offer an opportunity to monitor participants' exercise behaviour throughout the entire training program.

While measuring the usability of Panopto was not a primary objective, insights from interviews revealed its potential utility as a measurement tool for assessing adherence rates. Exploring the usability of Panopto as both a delivery and assessment tool for adherence and attendance rates could be valuable for future research. It is needed to explore internal resources within our university to gain a comprehensive understanding of how Panopto can be effectively utilized, ensuring confidentiality and preserving individuality, especially with a larger sample size for upcoming studies.

It has been hypothesised that a supervised exercise program exhibits higher adherence among older adults (Rivera-Torres et al., 2019), although increasing age has also shown to be a barrier in pwPD (Pickering et al., 2013). Despite the DTT in this feasibility study being unsupervised, several participants showed a high number of viewed minutes for certain sessions. Overall adherence to the main exercises (excluding warm-up and cool-down) reached 96.94%, surpassing the 70% adherence rate, which typically denotes high adherence (Nagpal et al., 2021). This high adherence for the intervention is very promising, and contrasts with adherence rates for other home-based programmes where low adherence rates can be experienced (Okezue et al., 2019) and adherence rates are recognised as being a common challenge (Mahmood et al., 2023).

The setting and delivery type of intervention are also factors influencing the adherence to the intervention (Suttanon et al., 2013). The data gathered within the qualitative component of this feasibility study suggested that individual DTT at home may enhance adherence by providing flexibility to pwPD, allowing them to integrate the program into their daily routines. This is supported by evidence from the literature pertaining in a range of other chronic health conditions (Argent et al., 2018).

However, Panopto analytics revealed that engagement throughout the entire session was not consistently steady, with some participants skipping parts of the sessions or pausing and resuming later. Delivering DTTs as training movies through the Panopto link granted participants this flexibility, impacting adherence in various ways. For instance, the number of minutes watched indicated that some participants revisited certain sessions, potentially due to environmental disruptions. One participant cited the intrusion of a dog into the training area, while another mentioned the possibility of a postman arriving at the door, necessitating a pause in the training. The flexibility to control such situations may increase adherence, as participants can manage interruptions rather than missing parts of the session.

Another reason for re-watching sessions may be participants' desire to ensure they comprehended the tasks, particularly for success in cognitive tasks. A participant from the C-DTT group mentioned re-watching sessions to attempt answering cognitive task questions. This trend was more apparent in the C-DTT group, aligning with studies indicating that individuals with PD tend to focus more on cognitive tasks than motor tasks during dual-tasking (Yogev-Seligmann et al., 2012b). Some participants in this study echoed this sentiment, noting that when they realized they were not performing motor tasks correctly, they strategically refocused on the motor task rather than the cognitive task answers.

However, some participants revisited certain questions in cognitive tasks upon realizing difficulties in answering them initially. The scoring component of the training program served as feedback, potentially prompting participants to watch the sessions more than once. This feedback mechanism might encourage the creation of strategies to better focus on cognitive tasks, as participants were tasked solely with scoring secondary tasks. This situation has the potential to impact both adherence and the extent of improvement in outcomes. There is a possibility that participants might solely concentrate on and master the secondary task, making it challenging to differentiate the effects of C-DTT and the secondary task itself on balance outcomes.

Participants also had the option to skip tasks they were not comfortable or successful at performing, potentially resulting in a lower adherence rate. In the meantime, this flexibility can allow pwPD to choose their most efficient time for performing each session, which can provide engagement with the sessions and result with high adherence. Although the feasibility study showed high adherence rate to the intervention, given the small sample size (n=6), it is challenging to conclusively determine how the flexibility in the delivery of DTTs affects adherence rates.

In the pre-trial qualitative study, a physiotherapist emphasised the significance of explaining the expectations and benefits of training, stating, *'I would see that as really beneficial, and I think what I do with most of my patients, I try to educate them as to why we're doing this' (PT1)*. There is evidence to show that enhancing self-efficacy is an important factor in optimising adherence to home-based programmes (Bachmann et al., 2018). Clearly informing participants about the mechanism of focusing on both tasks and providing regular reminders throughout the training program at various points may help to enhance participants' understanding and equip them with strategies and skills relevant to DTT. This may also help to improve adherence rates by providing professional's advocate and increasing their self-efficacy (Okwose et al., 2020).

It has been shown that the provision of simple and less-demanding instructions to the participants, and including reminders, can promote adherence (Flegal et al., 2007). Buddy-style home-based exercise intervention have also shown to improve adherence to exercise in disabled older adults (Takeda and Takatori, 2022). This reflects the view expressed by some participants in the feasibility study who suggested incorporating cueing or coaching provided by training buddies, as a supportive reminder, helping participants stay focused on the tasks during DTT. So, integrating both informative sessions and guidance about external cues are aspects which should be considered for future DTT designs. This may help to minimise the potential negative effects of a flexible, unsupervised delivery method on adherence.

Social support provided by family members or friends is associated with higher exercise adherence, as they can offer motivation and gentle reminders to adhere to the training program (Jin et al., 2008). In this PhD feasibility study, participants' training buddies were their partners who not only played a role in scoring the participants but could also in potentially motivating them to improve performance during training. The data showed that participants valued this support that their partners offered. This additional support may have contributed to the overall high adherence to the DTT, considering that motivation is identified as one of the prognostic factors for increased adherence in individuals with chronic conditions (Ricke et al., 2023).

The use of technology, such as training movies within Panopto and the gamified style of tasks with a scoring element, may have also contributed to the generally high adherence rate. A systematic review revealed that technology-based exercise interventions demonstrate higher adherence rates compared to traditional exercise interventions, irrespective of the intervention setting, delivery mode, and level of supervision in older adults (Valenzuela et al., 2018). Although the DTT was not delivered as a gamification app, the DTT tasks incorporated certain gaming elements like scoring and challenges, attempting to create an adventurous atmosphere (Ozdamli and Milrich, 2023). For example, participants actively participated in the DTTs, experiencing a sense of accomplishment through self-scoring, which was designed to motivate them to challenge themselves and surpass their previous scores recorded in the training workbook. It is postulated that this engagement and motivation likely played a role in the high adherence to the DTTs.

Adherence may be a factor associated with the acceptability of DTTs due to considerations such as the delivery method, tools employed, and training setting. The adherence rate is also crucial for interpreting the results concerning balance outcomes, a discussion that will follow later in this chapter. Encouragingly, the overall adherence rate was high for both the M-DTT and C-DTT. Although the interview data suggests there are additional relevant refinements to the intervention design that might be further considered in a future RCT.

6.3 Safety

Safety considerations were important in evaluating the feasibility of the intervention during the trial. This evaluation involved monitoring the occurrence of falls and near falls through participant-recorded entries in the training workbook. Additionally, adverse events were probed during post-training interviews to comprehensively assess safety.

Examining the safety of implementing DTT interventions is particularly crucial, given findings from prior studies indicating that dual-tasking can exacerbate gait and balance issues, especially in pwPD (Fishel et al., 2018). This aggravation might be attributed to the posture-second strategy, wherein prioritizing secondary tasks in dual-task conditions can heighten the risk of falling (Bloem et al., 2006).

Moreover, potential safety concerns were compounded by the delivery of interventions in a home setting without supervision. The scoping review showed that only one study conducted the intervention at home (Vallabhajosula et al., 2017), and this was limited to a case study. While case studies offer valuable insights, they may lack the generalizability needed to draw robust conclusions about the safety and feasibility of administering DTT interventions without supervision in a home environment (Walker and Carr, 2021).

Contrasting this, recent systematic reviews have provided more optimistic perspectives (García-López et al., 2023, Flynn et al., 2019). One such review demonstrated that DTT is safe for gait and balance rehabilitation in pwPD (Garcia-

Lopez et al., 2023), and another affirmed the safety of home-based exercise interventions for pwPD (Flynn et al., 2019). In line with the feasibility study reported no adverse events, with only two participants experiencing a momentary wobble over the six weeks, and importantly, these incidents did not culminate in falls. Together, this evidence from the literature and feasibility study, suggests that home-based, unsupervised DTT interventions can be safe.

6.4 Acceptability

The assessment of the acceptability of DTT interventions was a key focus in this feasibility study, aligning with best practices recommended by the Medical Research Council (MRC) (Skivington et al., 2021). This evaluation holds particular significance as an integral component in the preliminary stages of conducting large-scale RCTs with powered sample sizes.

In line with the framework proposed by Sekhon and colleagues (2017), the feasibility study evaluated acceptability of the intervention through use of a range of measures including, number of dropouts, discontinuation of intervention, satisfaction, uptake rates, and side effects. Additionally, it is likely that the participants engagement with the intervention, the content of the intervention, and the actual or perceived effectiveness of the intervention can significantly impact its acceptability (Sekhon et al., 2017).

The assessment of acceptability in the feasibility study was contingent on participants' perceptions. The evaluation tools included adapted 5-point Likert scale administered online twice weekly, along with end-of-training interviews gauging participants' views on various aspects of the DTTs. These components encompassed delivery methods, technology usage, incorporation of training buddies, DTT content, task variety, challenge levels, and enjoyment of tasks. Both interviews and the scales addressed identical issues but provided complementary information.

While the 5-point Likert scales allowed participants to self-rate their perceptions, the interviews provided valuable insights into the reasons and rationales behind these perceptions. The combined use of these instruments, fortified the measure of acceptability by ensuring it was more comprehensive, thereby better informing the proposed future research.

The questionnaires/scales were developed by adapting feedback forms from various studies exploring the feasibility of interventions (Learmonth et al., 2017, McCue et al., 2022). Upon the completion of the questionnaire design phase, it is important to undertake a pilot test. This preliminary testing process is essential for assessing the questionnaire's functionality, identifying potential issues, and refining its structure and content before its widespread deployment in the actual research study (Setia, 2017). Incorporating usability testing into the pilot not only enhances the accessibility and user-friendliness of the questionnaires but also contributes to the quality of data collected (da Costa et al., 2013). Given the unique challenges faced by pwPD, it is crucial to acknowledge that the methodological gaps identified, particularly the absence of usability testing, may impact the overall user experience.

While the 5-point Likert scale utilized in this study were thoughtfully designed to pragmatically align with the specific issues relevant to the feasibility study's objectives, it is essential to note that the absence of validity, reliability, and usability testing presents a potential risk to the reliability of the study's findings (Ishtiaq and Sundas, 2021). Unfortunately, due to the time constraints associated with the completion of the PhD, these critical assessments were not conducted, which is an acknowledged limitation.

The significance of evaluating the construct validity of the questionnaires cannot be overstated. The lack of such testing raises concerns about the potential challenges; pwPD may encounter in comprehending and accurately responding to the questionnaire items (Tsang et al., 2017). This oversight may have implications for the overall understandability of the questionnaires and may influence the responses provided by participants.

In summary, despite the time constraints of a PhD, it is crucial to highlight the need for careful validation of the questionnaires in future research to make findings more trustworthy and relevant.

Acceptability of the interventions

Enjoyment and challenge levels emerged as focal points in the feasibility study, reflecting their significance as influencing factors on DTT acceptability, as highlighted in feedback from pwPD and physiotherapists in the pre-trial qualitative study. These parameters were assessed using average scores on a 10-point scale over two-week intervals and for overall training within each participant and intervention group, complemented by questionnaires and interviews.

Analysis of enjoyment scores revealed that sessions of M-DTT were notably enjoyable, with scores exceeding 7 points for the primary exercises. Simultaneously, the challenge level was high, registering an average score of 7.72 points. While the average challenge level score slightly surpassed the enjoyment level score, the proximity of these values suggests a balanced perception. Examining scores on an individual basis, consistency emerged within the M-DTT group across the same two-week intervals, indicating a uniform perception of challenge levels throughout the overall training duration.

The 5-point Likert scale assessed individual task challenge and enjoyment levels to gauge their impact on the overall perceived challenge and enjoyment of DTT sessions. In the M-DTT group, participants consistently reported secondary motor tasks and balance tasks as 'mostly challenging.' Participants' experience of the level of challenge of tasks varied. Whilst one explanation for this discrepancy could be that individual's interpretation of instructions and task prioritization strategies differed. Another explanation could be the different types of balance problems experienced by the individuals, dependent upon their underlying impairments, and the differing strategies used by individuals to accommodate those impairments incomprehension (Yogev-Seligmann et al., 2012).

Secondary task prioritization, a posture-second strategy observed in pwPD during cognitive resource competition, may influence dual-task performance. Studies suggest that explicit instructions to prioritize the primary task can improve some gait parameters (Yogev-Seligmann et al., 2012). To maintain balanced challenge levels, external cues provided by a training buddy or integrating coaching into DTT design may be viable approaches. These strategies, besides potentially enhancing adherence, contribute to the development of a well-received (acceptable) DTT intervention.

Typically, participants rated the level of challenge as high but acceptable, perceiving it as a contributor to motivation, and so, engagement. Similarly, Leavy and colleagues (2017) highlighted the positive effects of challenge; pwPD in their study found that challenge of dual-tasking is motivating and rewarding. DTT allows pwPD to challenge the limits of their balance capacity and helps to increase their confidence and self-efficacy for participation in physical activity (Leavy et al., 2017). Motivational effect of enjoyment and challenge of the DTT was main indicators of its acceptability, despite one participant highlighted that she maintained motivation due to the fear of symptom deterioration if she did not embrace the challenges. This aligns with a systematic review suggesting that personal desires of pwPD to maintain independence and slow symptom deterioration enhance motivation and shape their perception of physical activity and participation (Hunter et al., 2019).

Perceived challenge level varied among the individual aspect of DTT, for example, whilst most participants found secondary cognitive tasks mostly challenging, opinions on the challenge of balance tasks, including maintaining correct foot position, differed. This diversity in perceived challenge may stem from personal factors such as training expectations, self-efficacy levels, and emotional responses to encountered challenges. Outcome expectancies, including affective expectations linked to emotional states during or after physical activity, play a role in this variability (Klusmann et al., 2016, Gellert et al., 2012). The fulfilment of positive emotional outcome expectancies, correlated with a positive physical activity experience, proves crucial for successful adoption of physical activity (Klusmann et al., 2016). This was reflected by the comments from (P12) who noted during the interview that she perceived her balance as poor and observed no improvement throughout C-DTT. Despite consistently rating the challenge level as 'not challenging at all' in 5-point Likert scale, her scores for challenge varied from 7.5 to 9 out of 10 over the 6-week C-DTT. This inconsistency may be attributed to the lack of positive emotional outcome expectancies due to negative experiences during each session. Failing to complete cognitive tasks correctly could generate a negative emotional state, affecting overall outcome expectancies and influencing the perception of the training's overall challenge.

Participants in both groups generally perceived the training as challenging yet enjoyable. This phenomenon may be linked to the participants' level of self-efficacy in exercising. Higher exercise self-efficacy can cultivate positive feelings when facing challenges (Ahern et al., 2022), leading individuals to enjoy these challenges because they believe in their ability to achieve higher scores in the tasks. Ultimately, this can influence perceptions of challenge and enjoyment, impacting adherence to DTT interventions and their overall acceptability. Hunter and colleagues (2019) identified that pwPD prefer engaging in activities that are fun and enjoyable. This inclination toward enjoyable activities fosters positive exercise experiences, elevates outcome expectations, and ultimately enhances adherence and acceptability. The feasibility of DTT is also influenced by the attainable level of challenge, as it contributes to enjoyment, motivation, and overall adherence and acceptability (Buckinx et al., 2021). Interview findings align with these concepts, reflecting participants' perceptions as mirrored in their scores and questionnaire responses. For some individuals, DTT was embraced as an interesting approach, considered positively challenging, and the progressively increasing difficulty was welcomed. This provides an indication of how beneficial it was to undertake the pre-trial qualitative study, as it was these findings that emphasized the importance of crafting a DTT that strikes a balance between being challenging yet achievable and enjoyable for participants to actively engage with the training. Keeping this principle in mind, both the M-DTT and C-DTT interventions were meticulously designed. However, the feasibility study revealed nuanced findings regarding the enjoyment and challenge levels of the DTT. This highlighted differences between the two training approaches. M-DTT successfully achieved a balance, providing an achievable challenge level that participants found enjoyable. In contrast, C-DTT exhibited variations and inconsistencies among participants and across different data collection tools, suggesting the need for further considerations in its design.

The significance of a home environment for exercise training has grown, particularly since the Covid-19 lockdowns (Kaur et al., 2020). For pwPD, cultivating exercise behaviour is crucial to deter a sedentary lifestyle (Bhalsing et al., 2018). Home settings not only offer a solution during exceptional situations like the Covid-19 pandemic but also provide a continuous opportunity for physical activity, especially in adverse weather conditions or when supporters are unavailable to facilitate group classes. This home-based approach can support independence, allowing individuals to seamlessly integrate training into their daily lives, fostering consistent practice, and averting potential deterioration. This aligns with a personal desire among pwPD to maintain their functional levels (Hunter et al., 2019). Considering these factors collectively, they serve as indicators of the acceptability and viability of home-based training for pwPD.

Telecommunication-based neurological rehabilitation, proven effective in health services (Mantovani et al., 2020), may serve as a home-based approach for DTT. Menengic and colleagues demonstrated the feasibility of cognitive-motor DTT through telerehabilitation for Alzheimer's patients, emphasizing the impact of peer support and real-time supervision (Menengiç et al., 2022). While social interaction during home training enhances acceptability and effectiveness, this method's flexibility is constrained by therapists' and peers' availability, potentially making it unsuitable for some pwPD. In the pre-trial qualitative study, pwPD expressed acceptance of telerehabilitation for DTT, but physiotherapists highlighted challenges, such as difficulty monitoring participants in online group sessions and certain tasks being impractical online. This aligned with the findings of the feasibility study, where most participants favoured the unsupervised home-based method, citing its flexibility and convenience in fitting into their schedules without the need to travel.

Tuena and colleagues demonstrated that tech-assisted cognitive DTT, utilizing virtual reality or exergames in various environments, is feasible for older adults with chronic conditions (Tuena et al., 2023). However, these methods, while effective, can be less flexible, often depending on the availability of therapists and requiring a dedicated training area and equipment. Home-based DTTs, though flexible, share a similar drawback regarding the need for a suitable training area at home which may not be feasible for all pwPD.

As discussed in the adherence section, flexibility in DTTs is facilitated by technology. In recent years, especially during the Covid-19 pandemic, the use of video streaming platforms and applications on tablets or smartphones has been tailored for the health and well-being of older adults (Sixsmith et al., 2022). The pre-trial qualitative study highlighted pwPD' familiarity with exercise video streaming platforms like YouTube, making the integration of these videos into their training acceptable, especially given that there was the opportunity to see the research therapist throughout the programme. Based on this finding, DTTs were structured with an initial in-person session with the physiotherapist, followed by training videos for subsequent sessions at home. This lends further support to the benefits of having undertaken a pre-trial qualitative study to inform the feasibility study.

The acceptability of technology as an intervention delivery method may be tied to individuals' digital health literacy, reflecting their ability to use digital technologies, understand health symptoms and treatment options, and engage in exercise behaviours (Neter and Brainin, 2012, Hsu et al., 2014). Therefore, the prior experiences and skills of pwPD might influence the acceptability of technology in delivering interventions. It may therefore be important to investigate which participant profiles can effectively use and derive benefits from a technology-assisted delivery approach. The feasibility study did not employ a scale like the Digital Health Technology Literacy Assessment Questionnaire (Yoon et al., 2022) to assess participants' technology skills, hindering the establishment of a clear relationship between their skills and perceptions of acceptability. While a connection between digital health literacy skills and health behaviours exists across various populations, exploring this relationship in the context of DTT acceptability for pwPD could be valuable for future studies.

In the execution of the DTT within the home settings, the involvement of training buddies appeared to play a pivotal role. These individuals closely monitored participants' performance, diligently recorded their scores, and provided essential assistance in navigating between and during sessions, as well as setting up the required equipment. This emerged as a valuable source of support for offering motivation, highlighting progress, and occasionally fostering positive competition; leading to an enjoyable training environment. The findings of this feasibility study are in line with the literature, where studies have emphasized the significance of motivation and perceived support as crucial factors contributing to higher adherence rates and the overall acceptability of training programmes (Schootemeijer et al., 2020).

A crucial aspect to emphasize is the potential impact of Covid-19 lockdowns, particularly on older individuals with long-term conditions in the UK, leading to challenges such as isolation, limited access to health services, and changes in physical well-being (AgeUK, 2021). Reports from various countries have indicated that pwPD experienced heightened feelings of loneliness during the pandemic, contributing to adverse outcomes and a diminished quality of life (Soilemezi et al., 2022). The effects of Covid-19 also extended to the interactions between pwPD and healthcare professionals, with perceptions varying between professionals and individuals with Parkinson's disease. For instance, a study revealed a reduction in healthcare service access and interactions with health professionals among pwPD during the pandemic. While professionals interpreted this as a sign of improved independence and self-management, pwPD expressed feelings of being unsupported and vulnerable (Soilemezi et al., 2022). This circumstance may influence a preference for outdoor exercises, community exercise classes, and face-to-face sessions with professionals to alleviate the sense of loneliness and vulnerability when feasible. However, the newly adopted practice of individual home exercises or participation in online group classes may prove engaging and become integrated into people's exercise routines even after the pandemic. Several studies have demonstrated that online exercise classes are effective and that the adoption of home-based exercises, coupled with available support, correlated with improved outcomes for pwPD during Covid-19 (Kumar et al., 2020, Langer et al., 2021).

Overall, participants in this feasibility study found the home-setting of DTT interventions acceptable. However, it is important to consider that their perspectives were influenced by their experiences during the Covid-19 lockdowns.

Another potential factor impacting the participants views about DTT is their exercise routine prior to the onset of Covid-19. For example, pwPD who were accustomed to outdoor activities may perceive home-based DTTs as more limiting, particularly if the transition to home-based exercise training does not align with their previous routines (Kumar et al., 2020). Many of the pwPD in both the pre-trial qualitative study and the feasibility study had engaged in regular exercise classes before the pandemic and made efforts to stay engaged with the online version of their exercise program. This familiarity with a type of home exercise program might have contributed to the perception that the home-based DTT program was feasible and acceptable. Nonetheless, it could be valuable to investigate how prior experiences with home-setting exercise training impact the feasibility of DTT interventions and their outcomes. A future study could specifically explore this relationship to optimize results for the appropriate group of pwPD.

Acceptability of the outcome measures and monitoring

Exploring the acceptability of the assessments was another objective of the feasibility study. This was asked at the interviews at the end of the training. The frequency of assessments can impact acceptability, with less frequent assessments being more manageable and less burdensome, especially if they involve travel or time commitment (Vaswani et al., 2020). The participants in the feasibility study found the two face-to-face assessments acceptable in terms of cost and time, but this acceptability was contingent on the frequency—only twice. There are questionnaires available to rate the perceived burden of research on participants, but these were not used in this study (Lingler et al., 2014). However, the qualitative approach used has provided valuable data to inform decisions about the frequency of a future RCT.

While in-person assessments were deemed acceptable, the feasibility study should explore the acceptability of remote assessment options further. Understanding participant preferences and comfort with remote assessments can inform the design of future trials and interventions. For example, one participant noted that video conferencing at home for assessments are accepted at this new era and could not see any differences between the clinical and home setting. Similarly, most of the pwPD did not mind the change in the approach to remote consultations, and other pwPD found that it was not ideal; which is line with the literature (Soulemazi et al., 2022).

Despite not being a physical assessment, the progress evaluations, which took place through video conferences via Zoom at the conclusion of each two-week training period, were considered acceptable by participants. They further emphasized this by commenting that they felt them to be an essential component. This positive reception could be attributed to the awareness that they were under observation and receiving tangible support by the researcher; this support is acknowledged as a perceived benefit of participating in research (Bachmann et al., 2018). Furthermore, the collaborative nature of balance rehabilitation, seen as a collective effort akin to teamwork, likely contributed to the participants' favourable perception of the remote progress assessments. As a result, the blended approach of in-person and online assessments for different purposes were acceptable as they offered safe, reliable results and support without being very burdensome (van der Kolk et al., 2018).

6.5 Potential Effect of DTTs on Balance

The evaluation of the effectiveness of DTTs is crucial to identify promising evidence before embarking on a definitive RCT investigating superiority. To achieve this goal, participants' standing, and dynamic balance were assessed using the MiniBESTest, and sway data were analysed under different conditions at baseline and the end of training.

Additionally, it was essential to assess the feasibility of the tools employed for these evaluations before conducting a definitive RCT. According to the participants' perceptions, these assessments were deemed acceptable. However, the careful selection of tools needs to align with the specific assessment objectives. One previous study investigating the superiority between the effectiveness of M-DTT, C-DTT, and single-task training on balance in pwPD exclusively utilized the Timed Up and Go test (Pourkhani et al., 2019). In comparison, the MiniBESTest offers a more comprehensive evaluation, addressing various aspects of balance. The inclusion of body sway assessment has the potential to further enhance overall balance evaluation, enabling the detection of minor changes and facilitating a comparison of effectiveness on dynamic and standing balance. This information can guide future applications of different DTT approaches which aim to improve specific aspects of balance in pwPD.

The findings of this feasibility study showed that the changes in standing and dynamic balance were diverse, with no specific trend observed within or between groups in the descriptive analysis of the data. The small sample size means that no conclusions can be drawn about the effectiveness of these two interventions on the basis of these findings.

6.5.1 Potential impact of adherence on balance outcomes

Understanding the adherence rate is important when interpreting the results of the balance outcomes, with various scenarios to consider. A high adherence rate, as was seen in this feasibility study, suggests that the results are likely to accurately reflect the impact on outcomes (Nagpal et al., 2021), indicating that participants practised the given DTT intervention throughout the training programme. The intention of practising the DTT tasks is to create neuroplastic changes in the cerebellum, which is a key brain area responsible for balance function in humans (Surgent et al., 2019, Li et al., 2022).

Adherence versus fidelity

There may be a potential discrepancy between adherence and intervention fidelity, as adherent participants do not necessarily consistently perform tasks as described (Trutschel et al., 2023). As an example in this study, one participant, who was highly adherent, highlighted difficulties in correctly executing stepping tasks when focusing on his hands. Others in the C-DTT group, acknowledged using a posture-second strategy at some point and adapted by focusing more on balance tasks. It is possible that intervention fidelity may play a more significant role in explaining variations in the change in standing and dynamic balance among participants in both groups than adherence rates in this feasibility study (Trutschel et al., 2023).

Although Panopto successfully recorded adherence and monitored session engagement, it fell short in evaluating fidelity. The feasibility study did not aim to assess intervention fidelity, and this could be an important limitation in exploring the feasibility of non-supervised DTTs. Future research should consider incorporating fidelity assessments to provide a more comprehensive understanding of the impact and effectiveness of non-supervised DTT interventions.

6.5.2 The potential influence of demographic and disease characteristics on balance outcomes

Certain baseline characteristics among participants may influence adherence rates and variations in the balance outcomes after training. For instance, gender might play a role in both high adherence rates and balance-related improvements. A study discovered that a lack of enjoyment in physical activity acts as a deterrent for female pwPD (Urell et al., 2021). Interestingly, all participants who showed enhancement in both standing and dynamic balance were female. The perceived enjoyment level in these female participants was notably high, correlating with their strong adherence to the intervention, and potentially contributing to the observed improvements in balance.

The symptoms of PD experienced individually by pwPD may significantly impact their performance during training and, consequently, influence balance outcomes. For instance, certain participants may be grappling with freezing of gait. Research has shown a correlation between freezing of gait and a diminished ability to voluntarily lean in anterior and posterior directions, as well as a reduction in the amplitude and onset of anticipatory postural adjustments (Bekkers et al., 2020). As a result, freezing of gait has the potential to elevate the perceived challenge level of primary balance tasks in DTT, such as stepping and lunging forward and laterally within specific timeframes. This heightened challenge may, in turn, impact adherence to the training regimen and influence balance outcomes. Understanding the nuanced effects of symptoms like FoG on task-specific challenges can provide valuable insights for tailoring DTT interventions to address the diverse needs of individuals with PD, ultimately contributing to more effective therapeutic approaches.

Certain symptoms of PD can directly impact the execution of secondary tasks. Tremor, a prevalent symptom affecting approximately 60% of pwPD during movement (Heusinkveld et al., 2018), exemplifies this challenge. In the context of the M-DTT, the secondary motor tasks relied on hand control and dexterity. For participants with hand tremors, performing these hand tasks can pose challenges due to the associated reduction in fine motor skills and upper extremity function (Norman and Héroux, 2013). Consequently, individuals experiencing hand tremors may find themselves directing more attention to the secondary task (hand tasks) than the primary balance tasks. This shift in focus could hinder the practice of balance tasks as intended, potentially affecting the anticipated changes in balance after training. Recognizing the impact of specific symptoms on task performance is therefore crucial for tailoring interventions to accommodate the unique needs and challenges faced by individuals with PD, optimise adherence to the intervention, and in doing so potentially enhance the effectiveness of the DTT.

Mild cognitive impairments are prevalent non-motor symptoms experienced by some pwPD (Litvan et al., 2012). These impairments can influence the perceived challenge level of various secondary cognitive tasks that demand distinct aspects of cognitive function, including verbal fluency, memory, and calculation, particularly within the C-DTT group. During the baseline assessment, participants exhibited similar, relatively high MMSE scores, all exceeding 24/30, indicative of mild cognitive impairment (Folstein et al., 1975). Despite comparable MMSE scores, participants faced diverse challenges in cognitive tasks. For instance, two participants found tasks involving calculation highly demanding, while another struggled with memorizing details within mini-videos. These discrepancies may be attributed to individual variations in cognitive function.

This diversity in cognitive task challenges could prompt participants to adopt a posture-second strategy, wherein their attention is primarily directed towards cognitive tasks (Bloem et al., 2006), potentially impacting changes in balance performance by the end of the training. Recognizing these individual differences in cognitive challenges would appear important for refining the C-DTT interventions and tailoring them to the unique cognitive needs of participants.

Comparing the impact of participants' cognitive status on balance outcomes between the M-DTT and C-DTT groups poses challenges. Both DTTs inherently demand the utilization of cognitive functions by dividing attention. It is conceivable that the cognitive tasks within C-DTT may necessitate a higher allocation of cognitive resources, potentially resulting in a distinct overall perceived challenge level between M-DTT and C-DTT. This discrepancy may not solely arise from participants' cognitive status at baseline but could be attributed to variations in cognitive load between the two training approaches. Moreover, this feasibility study included only pwPD exhibiting mild to moderate motor symptoms and either no cognitive deficits or only mild cognitive impairments. Consequently, none of the participants presented severe motor or cognitive symptoms, and so it is impossible to generalise the findings to those with moderate to severe cognitive difficulties.

Level of balance confidence is another factor to consider. This has been found to be correlated not only with static balance but particularly with dynamic balance in individuals in the moderate stage of PD (Lee et al., 2016). In this feasibility study, participants in both groups reported feeling confident about undertaking DTTs at home, however this may not represent their overall balance confidence. Since participants were not specifically questioned about their balance confidence as part of a formal assessment, interpreting the results in relation to their balance confidence is not feasible. To address this limitation, it is recommended that future studies incorporate the measurement of balance confidence, as suggested by Lee et al. (2016). Including a balance confidence assessment as part of the overall evaluation, alongside measures such as body sway and dynamic balance assessments, would provide a more comprehensive understanding of the participants' balance performance. This enhancement in assessment protocols can contribute valuable insights to the development of targeted interventions and strategies for managing balance-related challenges in pwPD.

In summary, comparing the effects of each DTT intervention on balance in relation to baseline demographic and disease characteristics like cognitive status, tremor, and gender was constrained in this feasibility study. Such a comparison might be undertaken through a cross-over study design, wherein each participant undergoes both interventions in a different sequence after a sufficient washing-out period, as suggested by Nair (2019). This holds particularly true for studies with a limited sample size, akin to the conditions in our feasibility study (Nair, 2019).

A future fully powered RCT should also consider representation of a diverse population of individuals with mild to moderate PD. This will allow confident interpretation of the result, including the generalisability of the findings, thereby providing more conclusive insights into the comparative effectiveness of these DTT interventions.

6.5.3 Effects of method to use of balance measures on interpretation of outcomes

One of the conditions during sway assessment involved placing the feet 4 cm apart, ensuring standardized test conditions for each participant. This standardization enhances the ability to make individual comparisons among participants regarding changes in standing balance. During both eyes open and closed conditions, participants selected their comfortable standing positions. However, providing them with a specific base of support to maintain their body's centre of mass can enhance our ability to comprehend the true change in balance following the training (Park et al., 2015). However, it is important to note a limitation in the study: the assessment did not measure the participants' preferred standing conditions during both eyes open and closed conditions. Assessing changes in their preferred base of support could serve as an additional indicator of improvement in balance, as it reflects the participants' stability limit, (Conraddson et al., 2012). To address this limitation and gain a more comprehensive understanding of participants' balance improvement, future assessments could include the measurement of changes in their preferred base of support during sway assessments.

Total angular sway velocity improved when participants stood with their feet 4 cm apart, showcasing positive changes for both M-DTT participants and three out of four participants in the C-DTT group. While reaching a conclusive result about overall standing balance improvement poses challenges, examining the change in the ML direction for this condition provides an indicator of the effectiveness of DTT on standing balance. The choice of ML sway measures, proven to be more sensitive than AP sway measures in detecting differences in moderate PD (Mancini et al., 2012), further supports this assessment. Notably, angular sway velocity in the ML direction improved for one participant from the M-DTT group and two participants from the C-DTT group. This outcome suggests that both M-DTT and C-DTT hold potential effectiveness in enhancing standing balance, with positive improvements observed in half of the participants from each group.

Conversely, the RMS of acceleration improved solely in the AP direction within the M-DTT group. Notably, no participants exhibited improvement in acceleration for both ML and AP directions at the same time across both groups. While certain participants demonstrated enhancements in sway velocity or acceleration in ML directions, others showed improvements in the AP direction under different conditions. Consequently, changes in each direction and condition were highly individual, complicating the interpretation of results regarding the potential effectiveness of the different DTT approaches.

6.5.4 Effect of training characteristics on balance outcomes

A systematic review has demonstrated that home-based exercise programs enhance balance-related activities in pwPD, with effects comparable to those observed in centre-based exercise programs that share equivalent intensity and duration (Flynn et al., 2019). Findings from the pre-trial qualitative study indicated that the home environment may be preferable to some participants due to its potential to offer flexibility. Consequently, the decision was made to base predominately the DTT in the home setting, and it was anticipated that this had the potential so positively impact balance outcomes in participants, in part by fostering high adherence to the interventions. The results showed that although adherence to both DTTs was high, balance outcome results varied, making it difficult to be drawn conclusions as to whether there was a signal of effectiveness. One possible explanation for this variability could be attributed to the DTT duration and intensity as current research suggests that a minimum of 150 minutes per week for at least six weeks is needed for a home-based exercise intervention to improve balance-related activities (Khuzema et al., 2020). The DTTs in the feasibility study did not meet this intensity requirement, even though the duration was six weeks.

A systematic review highlighted the absence of a standardized DTT protocol concerning duration and intensity (García-López et al., 2023). Studies included in the review examining the effects of DTT on functional and dynamic balance, indicated that DTT is an effective training method compared to usual care and single-task training for improving balance outcomes in pwPD. Notably, the studies demonstrating statistically significant improvement had higher intensity and duration (e.g., 1 hour/session, three times/week over 10 weeks) than those employed in the feasibility study. Consequently, DTT sessions lasting 30 minutes, three times a week over six weeks may not provide sufficient time for the completion of neurophysiological processes necessary to observe significant improvements in balance (Abbruzzese et al., 2016). Therefore, while the DTTs show promise for balance improvement, future research with a home-based design should carefully consider intensity and duration.

other characteristics of the DTT includes task repetition. Motor learning is anticipated through the repetition of tasks (Nieuwboer et al., 2009), suggesting that reliance on visual inputs may diminish as individuals practice, leading to the automaticity of balance task performance. Notably, in the M-DTT group, one participant, and in the C-DTT group, two participants demonstrated improved total angular sway velocity in eyes closed conditions. However, a noteworthy observation was that five out of six participants exhibited improvement in eyes open conditions. This outcome suggests that the benefits of motor learning may not seamlessly translate to enhanced standing balance performance.

However, both DTT interventions were progressively advanced, with different balance and secondary tasks introduced every two weeks. Given that motor learning progresses more slowly in pwPD (Nieuwboer et al., 2009), the structure of these DTTs may not afford participants sufficient time to fully learn the tasks due to the limited number of repetitions, thereby potentially hindering the transfer of DTT effects on balance outcomes.

The progressive nature of DTT is another characteristic and it is thought to play a pivotal role in improving balance performance through the facilitation of motor learning (Conradsson et al., 2012). Notably, challenging and progressive balance training, incorporating dual-task activities, has demonstrated effectiveness in enhancing balance among pwPD (Smania et al., 2010; Conradsson et al., 2015). While the feasibility study could not establish the specific effectiveness of individual DTTs, it is worth highlighting that these studies incorporated both motor-motor and motor-cognitive dual-tasks within a unified training protocol. This approach ensured that participants engaged in practice with both types of dual-tasks, potentially contributing to superior balance outcomes. The design of integrating diverse sensory inputs and applying progressive loads within a single training program is noteworthy and may be a key factor in achieving enhanced balance results.

6.5.5 Effect of training content on balance outcomes

Maintaining balance depends on visual, somatosensory, and motor controls (Silsupadol et al., 2006, Barbosa et al., 2016). The sensory adaptation mechanism of motor learning necessitates exposure to diverse inputs, allowing these systems to process information and achieve effective balance control (Leech et al., 2022). In the C-DTT, the cognitive tasks aimed to provide visual and auditory stimuli, while the M-DTT involved secondary motor tasks offering stimuli related to spatial orientation and motion. Additionally, delivering the training in a video format may also provide a certain level of visual stimuli for both groups.

Although the training itself does not immerse participants in environments with enhanced stimuli, such as exergaming or virtual reality setups, it was anticipated that the stimuli incorporated into both DTTs—whether through cognitive tasks, secondary motor tasks, or the visual aspect of the training as a movie—would contribute to motor learning and improvements in balance control for both groups. This expectation aligns with the effectiveness of virtual reality approaches in balance training for pwPD, as they offer a multisensory environment and augmented feedback (Wu et al., 2022).

While one might anticipate greater improvement in the C-DTT group due to the diverse inputs provided by cognitive-motor dual-tasking, no specific trend favouring either group emerged in terms of overall standing balance improvement. This lack of distinction may be attributed to the absence of tactile stimulation at the foot during balance tasks in both groups, such as standing on varied surfaces, which could contribute to somatosensory control and, consequently, balance control (Park et al., 2023). Additionally, the absence of real-time feedback, as seen in virtual reality approaches, may have impacted participants' performance and motivation throughout the sessions, as immediate feedback is known to enhance these factors.

In the context of DTT, certain task combinations may limit the visual field available to individuals, impacting their ability to naturally maintain balance. For instance, in the feasibility study, participants faced visual restrictions when combining lunging forward with following mini videos as a cognitive task. This limitation arose from the change in the angle of the eyes required to view a tablet placed on the wall. A similar issue occurred in the M-DTT, where participants' visual field was constrained as they focused on a popping toy in their hands rather than looking at their feet for stepping. In instances where participants cannot visually attend to their feet during balance tasks, maintaining the centre of mass within the base of support becomes challenging due to reduced visual control (Rinalduzzi et al., 2015). The dilemma intensifies when participants prioritise secondary tasks over balance tasks, especially when cognitive tasks demand visual attention. Consequently, individuals may concentrate more on secondary tasks, potentially compromising the proper execution of balance tasks. This, in turn, could impede the optimal progress and improvement achievable through DTTs. The relevance of this was underlined by the results of the sway data. The total angular sway velocity was higher in eyes-closed conditions than in eyes-open conditions for the majority of participants (n=5/6) during the baseline assessment. This situation can be attributed to the significance of visual control as a crucial mechanism for balance control. PwPD tend to overly rely on visual information to sustain balance (Bronstein et al., 1990).

While both interventions target primary balance tasks, the motor secondary tasks in the M-DTT may enhance the performance of balance tasks themselves. For instance, executing a secondary motor task like reaching a target on the wall while lunging to the same side engages the 'stability limit' aspect of balance (Conraddson et al., 2012). Practicing these secondary motor tasks over six weeks could contribute to an overall improvement in balance tasks within the M-DTT. This potential impact on balance outcomes was observed in dynamic balance scores, where MiniBESTest scores increased for participants in the M-DTT group after training, while only one out of four participants showed an increase in the C-DTT group. The dual-tasking nature of M-DTT, involving upper extremities, may facilitate interlimb coordination- an essential aspect of dynamic balance (Lin and Wagenaar, 2018). This coordination aspect aligns with the effectiveness of dance therapy, which involves coordination between upper and lower limbs and has been found to improve dynamic and functional balance in individuals with mild to moderate Parkinson's disease (Carapellotti et al., 2020).

Nevertheless, M-DTT did not yield a consistent effect on standing balance, as changes varied across participants and test conditions. This suggests that practicing coordination between extremities may not seamlessly transfer as an outcome to standing balance. This discrepancy could be attributed to the fact that coordination practice likely enhances the ability to control movements and adjust to changing positions, tasks that align with components of the MiniBESTest such as walking and turning. However, standing balance necessitates control without the support of dynamic movements, requiring specific training to address this distinct aspect of stability. Similarly, it is suggested that a comprehensive DTT program that integrates various tasks targeting specific components pivotal to balance, such as flexibility and lower limb muscle strength, as well as functional activities relevant to daily life, may be a strategic approach for enhancing both standing and dynamic balance (Wong-Yu and Mak, 2015).

It is challenging to fully distinguish between motor and cognitive secondary tasks, given that dividing attention introduces cognitive load during dual-tasking for both groups. It is crucial to note that the design of the DTTs did not intend to entirely separate the two approaches but aimed to create two training programs—one emphasising motor tasks and the other focusing on cognitive tasks as secondary tasks. To my knowledge, only one study has explored the effectiveness of these distinct training programs (Pourkhani et al., 2019). This study concluded that both motor-motor and motor-cognitive dual-task trainings effectively improve balance (as measured by the TUG) in pwPD. However, they found no statistically significant differences compared to single-task training in their intervention groups or the control group. Standing balance effects were not assessed.

Directly comparing their results to the feasibility study is not possible due to their larger sample size (ten participants per group) and the absence of statistical analysis in the feasibility study. Additionally, it is not possible to directly compare the MiniBESTest results with the TUG since the TUG assesses mobility, while the MiniBESTest focuses on different aspects of dynamic balance. Notably, individual variations in both standing and dynamic balance results for both groups in the feasibility study diverged from Pourkhani et al.'s findings. Possible reasons for this disparity include the duration of individual sessions and the entire training program. Pourkhani et al.'s dual-task training sessions, lasting 45 minutes, were delivered over ten weeks, potentially allowing for a more substantial contribution to neurophysiological processes independent of the training context (motor-motor versus motor-cognitive) compared to the DTT designs in the feasibility study. The impact of supervision could also be a significant factor, as individual supervised training has shown to be more effective than unsupervised, home-based training (King et al., 2015).

While the M-DTT data suggests that it may be effective, and the C-DTT holds potential for enhancing dynamic balance, it is important to investigate the extent to which these improvements translate into clinical outcomes. The minimal clinically important difference for the MiniBESTest in pwPD is reported as 4.0 points for individual change and 3.4 to 4.0 points for group-level interpretation (Godi et al., 2020). In the feasibility study, the observed maximum change for the individuals was 3.0 points, falling short of the reported minimal clinically important difference. This suggests the possibility that DTT interventions may not exhibit a readily transferable effect on clinical improvement at the individual level. So, further studies are needed to understand how DTT interventions affect meaningful changes for pwPD.

6.6 Strengths and limitations of the PhD study

The scoping review revealed that the majority of studies investigating the impact of DTT interventions have primarily concentrated on functional balance and gait parameters. This emphasis on functional and dynamic balance was also observed in the studies included in the recent systematic review-meta-analysis conducted by

Garcia-Lopez and colleagues (2023). As a notable strength of the feasibility study, sway assessments were conducted under various test conditions to detect subtle changes in balance control. The results were promising, indicating the potential effectiveness of both DTTs, with a number of the participants showing improvements in total angular sway velocity in eyes-open conditions and angular sway velocity in the medial-lateral direction in the standard test condition (feet positioned 4 cm apart). It is important to highlight that these assessments were exclusively conducted during the participants' 'ON' medication status. As a result, the insights gained from the study may be particularly relevant and informative for studies employing a similar assessment procedure under similar medication conditions.

One potential limitation of the feasibility study may arise from conducting both baseline and end of training assessments during the participants' 'ON' stage. Therefore, the findings of the balance assessments should be carefully considered for generalizing overall balance performance.

One other important point to consider is the placement of the inertial sensor for standing balance assessments. The placement of sensors is mostly on the trunk (Ghislieri et al., 2019). Although neck (C7) is one of the trunk position (Rucco et al., 2018), it is suggested that lower back (L3/L5) is the most effective to determine the most posture measure (Patel et al., 2020). Therefore, use of lower back as a sensor placement point may be considered to strengthen the accuracy of the data for future research.

Another potential limitation may be the use of MMSE to test cognitive function at baseline rather than Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005). It is suggested that MoCA may be more sensitive than MMSE to depict the cognitive impairments in pwPD (Zadikoff et al., 2008). Although assessing the impact of DTT intervention on pwPD's cognitive function was not an objective of the feasibility trial, it becomes crucial to investigate the cognitive status of participants at baseline. This exploration is essential for comprehending balance outcomes and interpreting findings. For a fully-powered RCT, it can be suggested to consider using more sensitive tool like MoCA to assess the level of cognitive status of the participants, and potentially, to explore whether there is a correlation between MoCA scores and the changes in balance outcomes following M-DTT and C-DTT interventions.

A limitation of the feasibility study lies in the fact that the psychometric properties of the questionnaire utilised were not evaluated, casting doubt on the reliability of the findings derived from it. Additionally, the use of a 5-point Likert scale limits the range of responses and may not sufficiently capture participants' nuanced perceptions. However, individual interviews proved invaluable in addressing potential gaps and gaining a deeper understanding of participants' perspectives. This aspect is a strength of the feasibility study, providing valuable insights to inform a future RCT.

The frequency of administration of 5-point Likert scale, twice weekly, presented an opportunity to understand whether participants' perceptions evolved with changes in individual tasks over each two-week period, particularly regarding enjoyment and challenge levels. The concurrent use of individual interviews helped gain understanding of some of the reasons for these changes in perception. Another strength is the use of both quantitative and qualitative methods to explore participants' perspectives on acceptability; this enhanced the rigour of the study findings by ensuring consistency in the results.

A potential limitation of the feasibility study arises is that participants were not restricted to solely engaging in the provided DTT interventions. Therefore, there should be some caution when interpreting the results of balance outcomes, as the effectiveness of the DTT may have been influenced by participants' engaging in other regular exercise routines. For a future study, it is suggested that participants assigned to an intervention group should be requested to only undertake the designated study intervention. This approach would enable a more accurate assessment of the actual effects of DTTs.

The limited sample size in both the pre-trial qualitative study and the feasibility study is a limitation, as the findings may not be generalisable to a larger population. While the feasibility study does not aim to establish statistical significance, it falls short in providing an adequate estimate of the sample size to inform future RCTs. Additionally, the qualitative study was constrained to only two physiotherapists and two supporters, thereby limiting the diversity of perspectives gained.

6.7 Future Research and Recommendations

The findings of the pre-trial qualitative study and the feasibility study with the earlier discussion highlighted potential factors that could influence outcomes related to balance and limitations of the trial design. Prior to embarking on a powered RCT to investigate the superiority of the effectiveness of both the M-DTT and C-DTT interventions, it is important to consider enhancements or modifications across various aspects of the DTT interventions and trial procedures. The recommended adjustments are outlined below:

1. Training characteristics:

(1) session duration; in line with the literature, extending each session duration within an acceptable limit,

(2) overall training duration; in line with the literature prolonging the training programme.

2. Training contents:

(1) Diversifying the secondary tasks to enhance enjoyment and adherence,

(2) Redesigning task combinations for some individual tasks to make them more applicable by considering the pwPD' visual area.

3. Use of technology; Collaborating with an expert in application design/content creation to improve technical aspects of the training session movies such as the time gap between oral and written instructions, delaying the time that tasks appear on the screen.

4. Recruitment strategy; allocating more time to recruitment process and considering a wider range of recruitment avenues (e.g. NHS clinics).

5. Acceptability of the 5-point Likert Scale; revising the items and piloting its application with pwPD.

Other areas for future research

The discussions and findings offer insights for future research on pwPD in an array of areas. For example, one potential avenue is exploring the use of technology, possibly Panopto, both as a delivery method for DTT interventions and as an assessment tool for adherence. This exploration could delve into the influence of factors such as age, gender, disease duration, previous experiences, researchers' familiarity with technology, and clinical expertise in managing pwPD.

Additionally, future research could focus on the more robust development of the Likert scale for evaluating the acceptability of DTT, including reliability and validity testing. This would contribute to a deeper understanding of the DTT interventions' acceptability among pwPD.

In summary, refining the trial design and intervention components, leveraging technology, and investing time in recruitment and outcome measures will contribute to the overall success of a future RCT. Future research avenues could further expand our understanding and refine interventions for pwPD.

6.8 Contributions of the PhD Project

To the best of my knowledge, there are not thoroughly documented DTT protocols specifically designed to focus solely on motor-motor dual-task training for pwPD, apart from a study conducted by Pourkhani et al. (2019). In their work, they developed two distinct motor-motor and motor-cognitive DTT protocols for pwPD, but these were implemented in clinical settings under the supervision of physiotherapists. Thus, the interventions in the feasibility study represent the first design of home-based, unsupervised DTT programs, using two distinct motor-motor and motor-cognitive components, aimed at improving balance in individuals with mild to moderate PD.

Both the scoping review and existing literature have revealed a dearth of qualitative studies pertaining to DTT interventions for pwPD, particularly during the pre-trial stage. This PhD project has made a valuable contribution to the field by introducing a pre-trial stage design for a qualitative study. Moreover, the project has advanced our understanding of acceptable DTT interventions for balance rehabilitation in pwPD. It not only offers insights for researchers, specifically in the context of the feasibility study within this PhD project, but also extends its impact to a broader audience of clinicians through the dissemination of findings at a conference and potentially with future publications.

The literature also showed the lack of feasibility studies that evaluate the effectiveness of M-DTT and C-DTT interventions from the participant perspective. Consequently, the design of this feasibility study, which includes an embedded qualitative component, has made a significant contribution to our understanding of potential factors influencing the acceptability and feasibility of DTT interventions, as well as the assessment of balance outcome measures.

6.9 Conclusion

Attendance and adherence rates for both M-DTT and C-DTT were high, with no reported adverse events. However, improvements are required in the content and technical aspects of the training programs and session videos to enhance overall acceptability. The C-DTT would benefit from enhancements in these areas, with participants suggesting a range of changes, whereas the M-DTT received outright recommendations from the two participants.

In summary, the home-based unsupervised M-DTT and C-DTT interventions demonstrated to be safe and feasible. Nevertheless, addressing issues in training content and technical aspects is essential for optimising the overall experience. The assessments, on the other hand, were generally well-received and deemed acceptable by participants.

Within the literature, numerous studies have explored the efficacy of DTT for pwPD, with findings suggesting its effectiveness in enhancing balance among this population (Garcia-Lopez et al., 2023). Despite these positive outcomes reported in the literature, interviews with participants did not reveal a perceived improvement in their overall balance.

No statistical analysis was conducted to assess the change due to the small sample size and imbalance between groups. On an individual level, both M-DTT and C-DTT demonstrated promising effects on the MiniBESTest and standing balance in specific conditions. While M-DTT led to improved MiniBESTest scores, neither group exhibited a clinically meaningful change in MiniBESTest outcomes. Multiple potential factors may influence the effectiveness of M-DTT and C-DTT.

The earlier discussion highlighted potential factors that could influence outcomes related to balance. Both the M-DTT and C-DTT interventions exhibit promising effects on standing and dynamic balance outcomes, and further enhancements in their design could be achieved by addressing the following: (i) extending the duration of each session, (ii) prolonging the overall training program, (iii) diversifying tasks to enhance enjoyment and adherence, and (iv) redesigning task combinations while considering participants' visual areas.

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Appendix 1: PRISMA-ScR

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	

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SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	
Limitations	20	Discuss the limitations of the scoping review process.	
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

Appendix 2: Characteristics of the included primary research and protocols

DTT Delivery Form	***Intervention (intervention group)***	***Intervention (control group)***	***Sample***	***Setting***	***Supervision type***	***Session type***	***Balance Outcome Measure***	***Study ID(design)***[(sequence number)]
Complex Balance Training	Highly challenging progressive group balance training (HiBalance) 1 hour/session, 3 times/week, 10 weeks	No intervention. Participants were encouraged to participate their usual level of exercise and physical activity.	H&Y 2-3, MMSE score ≥24	Clinic	Supervised	Group	MiniBESTest, ABC scale	Conradsson et al., 2012 (protocol)[1], Conradsson et al., 2015 (RCT)[2], Franzen et al., 2019 (protocol)[3], Johansson et al., 2020 (feasibility study)[4], Joseph, Leavy & Franzen, 2020 (pre-posttest design)[5] , Leavy et al., 2017 (protocol)[6] , Leavy et al., 2017 (qualitative)[7], Leavy et al., 2020 (quasi-experimental)[8], Lofgren et al., 2019 (RCT)[9], Wallen et al., 2018 (RCT)[10]
	HiBalance 45 min/session, 3 times/week, 12 weeks	No intervention	H&Y 2-3, MMSE score ≥24	Clinic	Supervised	Group	MiniBESTest, ABC scale	Conradsson et al., 2014 (feasibility study)[11]
	Balance class; balance exercises with focus on feed forward and feedback postural control	No intervention	H&Y 1-4 MMSE score ≥24	Clinic	Supervised	Group	Brief BESTest	Belton, 2014 (RCT)[12]

1 hour/session, once a week, 6 weeks							
Intervention1: Cognitively Challenging Agility Boot Camp Program 80-min/session, 3 times/week, 6 weeks Intervention 2: a chronic disease education program- 80 min/session, once a week, 6 weeks + 5 days per week for 30 minutes relaxations at home	No control group	H&Y 2-3	Clinic	Supervised	Group	MiniBESTest	King et al., 2020 (Randomized cross-over trial)[13]
Intervention 1: Traditional balance exercise + treadmill training An hour/session, twice a week, 6 weeks Intervention 2:	Fall-prevention education encouraged to maintain regular exercise	H&Y 2-3 MMSE score ≥24	N/A	N/A	N/A	LOS, SOT	Liao et al., 2015 (RCT)[14]

Virtual reality-based Wii Fit Exercise + treadmill training An hour/session, twice a week, 6 weeks							
interdisciplinary, multifactorial group program including physical, speech, and cognitive components plus self-management education 1.5-2 hours/session, twice a week, 4 weeks	Standard exercise programme 1.5-2 hours/session, twice a week, 4 weeks	Should be H&Y 1-3 Should no cognitive impairment	Clinic	Supervised	Group	External perturbation, Step Test	Peters et al., 2012 (protocol)[15]
Balance training involving three different groups of exercises 50 min/session, 3 times/week, 7 weeks	A training consisting of active joint mobilization, muscle stretching, and motor coordination exercises. 50 min/session, 3 times/week, 7 weeks	H&Y 3-4 MMSE score >23	Clinic	Supervised	N/A	BBS, ABC, CFP self-destabilization, and postural transfer test	Smania et al., 2010 (RCT)[16]

	Comprehensive, task and context specific balance training programme with indoor and outdoor activities 2-hour/session, once a week, 8 weeks	Upper limb training 2-hour/session, once a week, 8 weeks	Modified H&Y 1-5 MMSE score ≥24	Community	Supervised	Group	Mini-BESTest, 1-leg stance (OLS) time	Wong-Yu & Mak, 2015 (RCT)[17] Wong-Yu & Mak, 2015 (RCT)[18]
Exergaming/Virtual Reality-Based Training	Tailored balance and gait rehabilitation, with cognitive load in several virtual reality environments 30-45 min/session, total 12 sessions	N/A	Parkinson's disease& Parkinsonism, Traumatic Brain injury, Post-stroke, Multiple Sclerosis, Other condition (myelopathy and cerebral palsy, etc.)	Clinic	Supervised	Individual	ABC Scale, BBS, Mini-BESTest	Cano Porras et al., 2019 (retrospective study)[19]
	Balance-based exergaming programme using Kinect sensors 50-min/session,	Conventional balance training 50-min/session, twice a week, 8 weeks	H&Y 1-3 MMSE score ≥24	clinic	N/A	N/A	BBS, LOS, OLS	Shih et al., 2016 (RCT)[20]

twice a week, 8 weeks							
Exergaming + treadmill training with Xbox Kinect 1-hour/session, once a week, 8 weeks	No control group	Modified H&Y stage:3 MoCA score:24	Home	Independent (first week three supervised sessions. Each week one supervised session)	Individual	MiniBESTest, postural control under eyes open and eyes closed conditions	Vallabhajosula et al., 2017 (case study)[21]
Intervention 1: Virtual Reality-augmented balance training, 30 min/session, twice a week, 6 weeks Intervention 2: Conventional Balance training 30 min/session, twice a week, 6 weeks	No intervention	H&Y 2-3 MMSE score ≥24	Clinic	Supervised	Individual	SOT	Yen et al., 2011 (RCT)[22]
Motor-cognitive DTT with the focus of balance 1-hour/session, twice a week, 6 weeks	Single-task training 1-hour/session, twice a week, 6 weeks	Modified H&Y 1-3 Exclusion criteria: MMSE cut-off values according to the education level (22	Clinic	Supervised	Individual	Centre of pressure analysis under eyes open and closed conditions	Fernandes et al., 2015 (pilot study)[23]

			for 0–2 years of literacy; 24 for 3–6 years; and 27 for 7 years					
DTT Alone	Intervention 1: DTT under a fixed priority instruction 45-min/session, 5 times/week, 4 weeks Intervention 2: under a variable priority instructions 45-min/session, 5 times/week, 4 weeks	Single-task training 45min/session, 5 times/week, 4 weeks	Modified H&Y 3-4 MMSE score ≥24	N/A	Supervised	N/A	DGI BBS	Perumal et al., 2017 (RCT)[24]
	Intervention 1 : Motor DTT 45min/session, 3 times/week, 10 weeks Intervention 2: Cognitive DTT 45min/session, 3 times/week, 10 weeks	Single-task training 45min/session, 3 times/week, 10 weeks	H&Y 2-3 MMSE score ≥24	Clinic	Supervised	Individual	TUG	*Pourkhani et al., 2019 (quasi=experimental)[25]
	Intervention 1: Motor-cognitive DTT with attention on both postural and cognitive	No control group	MMSE score ≥ 24	N/A	N/A	N/A	BBS	Sethi & Raja, 2012 (quasi-experimental)[26]

	task at all the time 45min/session, 5 times each week, 3 weeks Intervention 2: motor-cognitive DT balance training with variable priority instructional set 45min/session, 5 times each week, 3 weeks							
	Aquatic DTT 1-hour/session, twice a week, 10 weeks	Keeping current activities without following an exercise programme	H&Y 1-4	N/A	Supervised	Group	BBS	Silva & Israel, 2019 (RCT)[27]

Legend- *: superiority study; ABC: Activities-Specific Balance Confidence scale; BBS: Berg Balance Scale; BOM: Balance-related Outcome Measures; Brief BESTest: Brief Balance Evaluation System Test; CFP: Centre of foot pressure self-destabilization test; DGI: Dynamic Gait Index; DTT: dual-task training; H&Y: Hoehn & Yahr scale; LOS: Limit of Stability test; Mini-BESTest: Mini- Balance Evaluation System Test; MMSE: Mini Mental State Examination; MoCA: Montreal Cognitive Assessment; OLS: One Leg Stance test; RCT: Randomized control trial; SOT: Sensory Organization Test, TUG: Timed-Up and Go test.

Appendix 3: Findings of the superiority study (Pourkhani et al., 2019)

Sample size & Calculation	**Test Time** **a)Post-test time** **b)Follow-up test time**	**BOM**	**CDTT Group** ***a) before group mean (95% CI)*** ***b) after mean (95% CI)*** ***c)follow-up mean (95% CI)***	**CDTT Group** ***Change in score*** ***a)pre-post test*** ***b)pre-follow up test***	**CDTT Group** ***P value***	**MDTT Group** ***a) before group mean (95% CI)*** ***b) after mean (95% CI)*** ***c)follow-up mean (95% CI)***	**MDTT Group** ***Change in score*** ***a)pre-post test*** ***b)pre-follow up test***	**MDTT Group** ***P value***	**STT Group** ***a) before group mean (95% CI)*** ***b) after mean (95% CI)*** ***c)follow-up mean (95% CI)***	**STT Group** ***Change in score*** ***a)pre-post test*** ***b)pre-follow up test***	**STT Group** ***P value***
MDTT group (n=10) **CDTT group (n=10)** **STT group (n=10).** **Estimated as 30. Alpha=0.05, Beta=0.8, Effect size= 0.5. Sample size reportedly achieved**	a)10-week training completion b)1 month after completion of the training	TUG (sec)	a) 13.92 (13.61-14.23) b) 12.28 (12.01-12.55) c) 12.67 (12.37-12.98)	a)1.74 b)1.25	P=0.00	a) 13.99 (13.69-14.30) b) 12.64 (12.37-12.91) c) 13.39 (13.09-13.70)	a) 1.35 b)0.6	P=0.00	a) 13.82 (13.51-14.12) b) 13.03 (12.76-13.30) c) 13.43 (13.12-13.73)	a)0.79 b)0.39	P=0.00

Legend-BOM: Balance Outcome Measures, C-DTT: cognitive-motor dual-task training, CI: confidence interval, M-DTT: motor-motor dual-task training, P: p value, STT: single task training, TUG: Timed Up and Go Test.

Appendix 4: Appraisal for the study by *Pourkhani et al.* (2019) utilizing of JBI critical appraisal tool for quasi-experimental studies via JBI SUMARI software.

Form of the JBI Critical Appraisal Tool for Quasi-Experimental Studies

Yes
No
Unclear
N/A

1. Is it clear in the study what is the 'cause' and what is the 'effect' (i.e., there is no confusion about which variable comes first)?

Yes

2. Were the participants included in any comparisons similar?

Yes

3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?

Yes

4. Was there a control group?

Yes

5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?

Yes

6. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?

Yes

7. Were the outcomes of participants included in any comparisons measured in the same way?

Yes

8. Were outcomes measured in a reliable way?

Yes

9. Was appropriate statistical analysis used?

Yes

Appendix 5: Qualitative Study Advertisement

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Would you like to be *heart* of a research study?

This research is exploring the perspectives of people who are diagnosed with Parkinson's disease and physiotherapists regarding a physiotherapy approach-called dual-task training- in balance rehabilitation. This study, ultimately, will help to design a future clinical trial which will investigate the superiority of two different dual-task training on balance in people with PD. So, if you are volunteered to participate this study, you will be heart of a clinical research!!

If you are either;

- Diagnosed with Parkinson's disease and at mild or moderate disease stage,

OR

- Physiotherapist experienced in Parkinson's disease rehabilitation or has a special interest in this field,

AND

- Able to communicate in English (if there is a need, open to discuss carer/translator options).

To participate, please get in touch with Nesibe Cakmak, the researcher at University of Plymouth.

Email: nesibe.cakmak@plymouth.ac.uk

Appendix 6: Participant Information Sheet for pwPD

FREIC Code: 2512

UNIVERSITY OF PLYMOUTH
Faculty of Health

Participant Information Sheet for People with Parkinson's disease (PD)

Project: *The key features of a feasible and engaging randomized control trial design investigating the effects of dual-task training on balance outcomes in people with Parkinson's disease: A qualitative study.*

Research Team: Nesibe Cakmak (Chief investigator), Dr Lisa Bunn, Dr Camille Carroll, Prof Jenny Freeman

Focus group lead: Nesibe Cakmak. Note-taker: Dr Lisa Bunn.

What is this project about?

The literature suggests that performing two tasks at once ('dual-task training') can improve balance in people with PD but it remains unknown whether some task combinations are better than others.

For example, is the use of a 'balance plus a physical activity task' better than a 'balance plus mental exercise or distraction task'? This question forms the basis of a research project that is part of a PhD for Nesibe Cakmak. Understanding what type of research design and dual-task training program is acceptable and feasible to people with PD will help us to shape this research study. The group interviews in this study aim to help the researcher design a study to find out which dual-task training interventions are most effective.

Why am I eligible to take part?

You are being invited to participate in this project because you are diagnosed with PD and your disease severity is classified as mild or moderate.

It is important to this research team to be as inclusive as possible. If you require help from a supporter to use virtual technology to communicate or you need help from a translator please contact the lead researcher to discuss your options.

What are the benefits of taking part?

Your participation may not benefit you directly, but will contribute to shaping future therapy research in PD.

Do I have to take part?

No, your participation is voluntary. Please only take part if you want to. If you choose not to take part, this will not disadvantage you or impact your health care in anyway. Once you have read the information sheet, please contact us if you have any questions that will help you make this decision.

What will happen if I take part?

Step 1

If you decide to take part, we will schedule a short online (Zoom) meeting at a convenient time and date during which time we will ask a series of questions to ensure you are well informed about the study and formally record your consent.

This short meeting would need to be at least 48 hours ahead of the scheduled group interview and at least 24 hours after reading this information sheet. Questions you will be asked in the short ‘consent’ meeting are detailed on the

'Consent Form Template', attached to the same email as this 'Participant Information Sheet'. Please read this ahead of the consent taking procedure and retain it form your records, should you wish to. The consent taking meeting will be audio recorded and securely stored by the research team. This will be stored in a separate location to the focus group meeting audio-recordings.

Step 2

If you consent you will be invited to join a group interview, known as a 'focus group'. This will involve approximately five participants who are people with PD and two members of the research team. If you decide to join the group, a researcher would ask you questions about your perspectives of dual-task training, your opinion regarding how improvements in your balance should be measured and what you feel would be acceptable to undertake when participating in a clinical trial.

This would take approximately an hour and no more than 90 minutes (with short breaks when needed). You may choose whether you reveal a video image within Zoom or just use audio, but regardless, only audio will be recorded and later written into text (transcribed).

Written text will be analysed and, if you agree, the findings will be shared via email with you so that you can comment on them. If you prefer to provide your comments verbally rather than an email, a researcher will call you by telephone so that you can share your comments.

What will happen to the results of the research study?

As well as guiding future trial design the results of the study will be written into an academic thesis, a peer-reviewed journal publication and presented at a PD research conference. No person will be individually identified in any report or publication.

What if I change my mind about taking part?

You are free to change your mind and withdraw from the project, without having to give a reason, **until the group interview audio recording officially starts. As the group interview starts, you may personally withdraw at any time but your voice in the recording would not be possible to extract so any verbal contributions that you make would not be possible to withdraw**. Withdrawing from the project will not affect your experience of care or any future involvement that you may have with the University of Plymouth in any way.

Data handling and confidentiality

Your data will be handled in accordance with the UK-General Data Protection Regulation 2021 (UK-GDPR). University of Plymouth (UoP) is the sponsor for this study. The information from participants and all collected data during focus group will be used only for the purpose of this study by the researcher.

Your name will be removed and replaced with a random pseudonymous code so that all of the information about you can linked by the research team. You will not be identifiable in any of the information that we analyse or results shared. You will be also asked to maintain the confidentiality of the all participants who attending to focus group. Once you contribute to a group interview, you will no longer be able to withdraw from the study. If you agree to review the findings of your group session and comment on them, we will keep your email address in a correspondence file to enable us to do this. Once this correspondence is complete, your personal contact details will be securely deleted from our records. Transcribed conversations will be anonymous and indirectly identifying information within them will be altered to protect personal identities. After data analysis is complete, audio-records will be securely destroyed.

All remaining information will be stored securely for 10 years at the University before being securely deleted (in accordance with the University of Plymouth's Research Data Policy, https://www.plymouth.ac.uk/uploads/production/document/path/6/6913/Research_Data_Policy.pdf).

Only the research team will have access to any personal contact information, audio-recording or indirectly identifiable information within original transcripts.

What happens if I am not eligible to take part?

Inclusivity in research is important to us. We will also undertake further informal discussions - Patient and Public Involvement and Engagement (PPIE) with people with PD and their supporters at a later stage of this project. If you are not eligible to participate and want to contribute to study, please contact us to express an interest in becoming a member of our PPIE group.

What happens if I need to complain?

If you have a complaint, you may contact the University of Plymouth's Faculty of Health's ethics committee using the email address: FOHethics@plymouth.ac.uk.

If you do not wish to complain but wish to give feedback about the study please contact the project supervisor at the email address at the end of this information sheet.

Can I get a summary of the results of this study?

If you would like to receive a copy of a summary of the findings when it is completed, please feel free to contact the principal researcher. Your email will be securely stored for this purpose and then deleted once correspondence has been sent. A summary of study findings will be sent to the Parkinson's Disease Group leader to circulate to all members, which may include you, so you may not need to make direct contact with the researcher for this purpose.

Thank you for your interest in this research. Please do not hesitate to contact me if you have any questions.

Project contact details:

Name of researcher: Nesibe Cakmak PhD student

Email address: nesibe.cakmak@plymouth.ac.uk

Name of Supervisor: Dr Lisa Bunn

Email address: lisa.bunn@plymouth.ac.uk

Appendix 7: Participant Information Sheet for Supporters

FREIC code: 2512

UNIVERSITY OF PLYMOUTH
Faculty of Health

Participant Information Sheet for Supporters

Project: *The key features of a feasible and engaging randomized control trial design investigating the effects of dual-task training on balance outcomes in people with Parkinson's disease: A qualitative study.*

Research Team: Nesibe Cakmak (Chief investigator), Dr Lisa Bunn, Dr Camille Carroll, and Prof Jenny Freeman

Focus group lead: Nesibe Cakmak. Note-taker: Dr Lisa Bunn.

What is this project about?

The literature suggests that performing two tasks at once ('dual-task training') can improve balance in people with PD but it remains unknown whether some task combinations are better than others.

For example, is the use of a 'balance plus a physical activity task' better than a 'balance plus mental exercise or distraction task'? This question forms the basis of a research project that is part of a PhD for Nesibe Cakmak. Understanding what type of research design and dual-task training program is acceptable and feasible to people with PD will help us to shape this research study. The group interviews in this study aim to help the researcher design a study to find out which dual-task training interventions are most effective.

Why am I eligible to take part?

You are being invited to participate in this project because you are a supporter (carer, partner, or a family member) of people with PD.

What are the benefits of taking part?

Your participation may not benefit you directly, but will contribute to shaping future therapy research in PD.

Do I have to take part?

No, your participation is voluntary. Please only take part if you want to. If you choose not to take part, this will not disadvantage you. Once you have read the information sheet, please contact us if you have any questions that will help you make this decision.

We will also undertake further informal discussions - Patient and Public Involvement and Engagement (PPIE) with people with PD and their supporters at a later stage of this project. If you do not want to take part of such a formal group interviews, but want to contribute to the study in anyway, please contact us to express an interest in becoming a member of our PPIE group.

What will happen if I take part?

Step 1

If you decide to take part, we will schedule a short online (Zoom) meeting at a convenient time and date during which time we will ask a series of questions to ensure you are well informed about the study and formally record your consent.

This short meeting would need to be at least 48 hours ahead of the scheduled group interview and at least 24 hours after reading this information sheet.

Questions you will be asked in the short ‘consent’ meeting are detailed on the ‘Consent Form Template’, attached to the same email as this ‘Participant Information Sheet’. Please read this ahead of the consent taking procedure and retain it form your records, should you wish to. The consent taking meeting will be audio recorded and securely stored by the research team. This will be stored in a separate location to the focus group meeting audio-recordings.

Step 2

If you consent you will be invited to join a group interview, known as a ‘focus group’. This will involve approximately five participants who are supporters of people with PD and two members of the research team. If you decide to join the group, a researcher would ask you questions about your perspectives of dual-task training, your opinion regarding how improvements in balance should be measured and what you feel would be acceptable to as a patient with PD to undertake when participating in a clinical trial.

This would take approximately an hour and no more than 90 minutes (with short breaks when needed). You may choose whether you reveal a video image within Zoom or just use audio, but regardless, only audio will be recorded and later written into text (transcribed).

Written text will be analysed and, if you agree, the findings will be shared via email with you so that you can comment on them. If you prefer to provide your comments verbally rather than an email, a researcher will call you by telephone so that you can share your comments.

What will happen to the results of the research study?

As well as guiding future trial design the results of the study will be written into an academic thesis, a peer-reviewed journal publication and presented at a PD research conference. No person will be individually identified in any report or publication.

What if I change my mind about taking part?

You are free to change your mind and withdraw from the project, without having to give a reason, **until the group interview audio recording officially starts. As the group interview starts, you may personally withdraw at any time but your voice in the recording would not be possible to extract so any verbal contributions that you make would not be possible to withdraw**. Withdrawing from the project will not affect your experience of care or any future involvement that you may have with the University of Plymouth in any way.

Data handling and confidentiality

Your data will be handled in accordance with the UK-General Data Protection Regulation 2021 (UK-GDPR). University of Plymouth (UoP) is the sponsor for this study. The information from participants and all collected data during focus group will be used only for the purpose of this study by the researcher.

Your name will be removed and replaced with a random pseudonymous code so that all of the information about you can linked by the research team. You will not be identifiable in any of the information that we analyse or results shared. You will be also asked to maintain the confidentiality of the all participants who attending to focus group. Once you contribute to a group interview, you will no longer be able to withdraw from the study. If you agree to review the findings of your group session and comment on them, we will keep your email address in a correspondence file to enable us to do this. Once this correspondence is complete, your personal contact details will be securely deleted from our records. Transcribed conversations will be anonymous and indirectly identifying information within them will be altered to protect personal identities. After data analysis is complete, audio-records will be securely destroyed.

All remaining information will be stored securely for 10 years at the University before being securely deleted (in accordance with the University of Plymouth's Research Data Policy, https://www.plymouth.ac.uk/uploads/production/document/path/6/6913/Research_Data_Policy.pdf).

Only the research team will have access to any personal contact information, audio-recording or indirectly identifiable information within original transcripts.

What happens if I need to complain?

If you have a complaint, you may contact the University of Plymouth's Faculty of Health's ethics committee using the email address: FOHethics@plymouth.ac.uk.

If you do not wish to complain but wish to give feedback about the study please contact the project supervisor at the email address at the end of this information sheet.

Can I get a summary of the results of this study?

If you would like to receive a copy of a summary of the findings when it is completed, please feel free to contact the principal researcher. Your email will be securely stored for this purpose and then deleted once correspondence has been sent. A summary of study findings will be sent to the Parkinson's Disease Group leader to circulate to all members, which may include you, so you may not need to make direct contact with the researcher for this purpose.

Thank you for your interest in this research. Please do not hesitate to contact me if you have any questions.

Project contact details:

Name of researcher: Nesibe Cakmak PhD student

Email address: nesibe.cakmak@plymouth.ac.uk

Name of Supervisor: Dr Lisa Bunn

Email address: lisa.bunn@plymouth.ac.uk

Appendix 8: Participant Information Sheet for Physiotherapists

FREIC Code: 2512

UNIVERSITY OF PLYMOUTH
Faculty of Health

Participant Information Sheet for Physiotherapists

Project: *The key features of a feasible and engaging randomized control trial design investigating the effects of dual-task training on balance outcomes in people with Parkinson's disease: A qualitative study.*

Research Team: Nesibe Cakmak (Chief investigator), Dr Lisa Bunn, Dr Camille Carroll, and Prof Jenny Freeman

Focus group lead: Nesibe Cakmak. Note-taker: Dr Lisa Bunn.

What is this project about?

The literature suggests that dual-task training can improve balance in people with PD but it remains unknown whether some task combinations are better than others.

For example, is the use of a 'balance plus a physical activity task' better than a 'balance plus mental exercise or distraction task'? This question forms the basis of a research project that is part of a PhD for Nesibe Cakmak. Understanding what type of research design and dual-task training program is acceptable and feasible to people with PD will help us to shape this research study. The group interviews in this study aim to help the researcher design a study to find out which dual-task training interventions are most effective.

Why am I eligible to take part?

You are being invited to participate in this project because you are a qualified physiotherapist who works in neurological rehabilitation.

We ask you only to participate if you have used dual-task training with at least three people with PD in last one year.

What are the benefits of taking part?

Your participation may not benefit you directly, but will contribute to shaping future therapy research in PD.

Do I have to take part?

No, your participation is voluntary. Please only take part if you want to. If you choose not to take part, this will not disadvantage your practice or relationship with the University in any way. Once you have read the information sheet, please contact us if you have any questions that will help you make this decision.

What will happen if I take part?

Step 1

If you decide to take part, we will schedule a short online (Zoom) meeting at a convenient time and date during which time we will ask a series of questions to ensure you are well informed about the study and formally record your consent.

This short meeting would need to be at least 48 hours ahead of the scheduled group interview and at least 24 hours after reading this information sheet. Questions you will be asked in the short 'consent' meeting are detailed on the 'Consent Form Template', attached to the same email as this 'Participant

Information Sheet'. Please read this ahead of the consent taking procedure and retain it form your records, should you wish to. The consent taking meeting will be audio recorded and securely stored by the research team. This will be stored in a separate location to the focus group meeting audio-recordings.

Step 2

If you consent you will be invited to join a group interview, known as a 'focus group'. This will involve approximately five participants who are physiotherapists and two members of the research team. If you decide to join the group, a researcher would ask you questions about your perspectives of dual-task training, your opinion regarding how improvements in patient's balance should be measured and what you feel would be acceptable to ask patients to undertake when participating in a clinical trial.

This would take approximately an hour and no more than 90 minutes (with short breaks when needed). You may choose whether you reveal a video image within Zoom or just use audio, but regardless, only audio will be recorded and later written into text (transcribed).

Written text will be analysed and, if you agree, the findings will be shared via email with you so that you can comment on them. If you prefer to provide your comments verbally rather than an email, a researcher will call you by telephone so that you can share your comments.

What will happen to the results of the research study?

As well as guiding future trial design the results of the study will be written into an academic thesis, a peer-reviewed journal publication and presented at a PD research conference. No person will be individually identified in any report or publication.

What if I change my mind about taking part?

You are free to change your mind and withdraw from the project, without having to give a reason, **until the group interview audio recording officially starts. As the group interview starts, you may personally withdraw at any time but your voice in the recording would not be possible to extract so any verbal contributions that you make would not be possible to withdraw**. Withdrawing from the project will not affect your any future involvement that you may have with the University of Plymouth in any way.

Data handling and confidentiality

Your data will be handled in accordance with the UK-General Data Protection Regulation 2021 (UK-GDPR). University of Plymouth (UoP) is the sponsor for this study. The information from participants and all collected data during focus group will be used only for the purpose of this study by the researcher.

Your name will be removed and replaced with a random pseudonymous code so that all of the information about you can linked by the research team. You will not be identifiable in any of the information that we analyse or results shared. You will be also asked to maintain the confidentiality of the all participants who attending to focus group. Once you contribute to a group interview, you will no longer be able to withdraw from the study. If you agree to review the findings of your group session and comment on them, we will keep your email address in a correspondence file to enable us to do this. Once this correspondence is complete, your personal contact details will be securely deleted from our records. Transcribed conversations will be anonymous and indirectly identifying information within them will be altered to protect personal identities. After data analysis is complete, audio-records will be securely destroyed.

All remaining information will be stored securely for 10 years at the University before being securely deleted (in accordance with the University of Plymouth's Research Data Policy, https://www.plymouth.ac.uk/uploads/production/document/path/6/6913/Research_Data_Policy.pdf).

Only the research team will have access to any personal contact information, audio-recording or indirectly identifiable information within original transcripts.

What happens if I need to complain?

If you have a complaint, you may contact the University of Plymouth's Faculty of Health's ethics committee using the email address: FOHethics@plymouth.ac.uk.

If you do not wish to complain but wish to give feedback about the study please contact the project supervisor at the email address at the end of this information sheet.

Can I get a summary of the results of this study?

If you would like to receive a copy of a summary of the findings when it is completed, please feel free to contact the principal researcher. Your email will be securely stored for this purpose and then deleted once correspondence has been sent. A summary of study findings will be sent to the Parkinson's Disease

Group leader to circulate to all members, which may include you, so you may not need to make direct contact with the researcher for this purpose.

Thank you for your interest in this research. Please do not hesitate to contact me if you have any questions.

Project contact details:

Name of researcher: Nesibe Cakmak PhD student

Email address: nesibe.cakmak@plymouth.ac.uk

Name of Supervisor: Dr Lisa Bunn

Email address: lisa.bunn@plymouth.ac.uk

Appendix 9: Consent Form

Faculty of Health Ethics and Integrity Committee study code: 2512

UNIVERSITY OF PLYMOUTH
Faculty of Health: Medicine, Dentistry & Human Sciences

CONSENT FORM FOR PARTICIPANTS – THIS IS A TEMPLATE OF QUESTIONS THAT YOUR RESEARCHER WILL ASK YOU IN THE SHORT RECORDED ZOOM MEETING THAT IS ARRANGED AHEAD OF THE MAIN FOCUS GROUP SESSION.

PLEASE RETAIN THIS DOCUMENT FOR YOUR RECORDS BUT NO WRITTEN CONSENT WILL BE REQUIRED BY THE RESEARCH TEAM.

Project Title: The key features of a feasible and engaging randomized control trial design investigating the effects of dual-task training on balance outcomes in people with Parkinson's disease: A qualitative study.

Chief investigator: Nesibe Cakmak (Director of PhD studies for NC: Dr Lisa Bunn; Supervisors: Dr Camille Carroll, Prof Jenny Freeman)

Future focus group lead: Nesibe Cakmak. Note-taker: Dr Lisa Bunn.

In order to gain informed consent ahead of the focus group session, your researcher will ask the following questions to you within a securely recorded short Zoom meeting:

- Have you read and understood the information sheet for the above titled research project and freely and voluntarily consent to be a participant in this project? *Answer yes or no.*
- Do you consent to your voice (not visual image) being audio recorded in the focus group session and thereafter transcribed? *Answer yes or no*.
- Do you understand that your responses will be kept strictly confidential? *Answer yes or no.*
- Do you understand that your participation in this study is voluntary, and you can fully withdraw yourself from the study at any time without negative consequences? *Answer yes or no.*
- Do you understand that if at any time during the focus group session you feel unable or unwilling to continue, you can refuse to answer questions and you can exit the meeting if you wish to, without negative consequences? *Answer yes or no*.
- Do you understand that you can withdraw yourself but you cannot withdraw your comments (i.e. data) from the focus group recording and subsequent data analysis, should you have contributed in part to the focus group? *Answer yes or no.*

Consent Form, Version 2.0 *19/03/2021*

- Do you understand that confidentiality and anonymity will be maintained in all data held by the researcher, and it will not be possible to identify you in any research outputs? *Answer yes or no.*
- Do you understand that anonymity will not be possible to maintain within the focus group session itself since people may recognise you and you may recognise others, but that the session will strive to not use names or voice any personal details and these will be removed from the transcribed accounts of the session, to anonymise as far as possible any data held by the research team for the longer term? *Answer yes or no.*
- Do you understand that confidentiality cannot be guaranteed (owing to the group method employed in this research) but that group members will be asked to agree to maintaining confidentiality of all members of the group and what was discussed in the focus group? *Answer yes or no*.
- Do you agree to maintain confidentiality regarding the participation of others and what they have spoken about? *Answer yes or no.*
- Do you understand that you will not be identifiable in all data held by the researcher, and that it will not be possible to identify you in any research outputs, unless you personally recognise an otherwise anonymous quote that you provided? *Answer yes or no.*
- Have you been given the opportunity to ask questions regarding your focus group participation, and have your questions been answered to your satisfaction? *Answer yes or no.*
- Have you been informed that if you have any general questions about this project, you should feel free to contact the principal researcher (Nesibe Cakmak)? *Answer yes or no.*
- **If you have answered yes to all of the questions so far, do you confirm that you are consenting to participate in this study? *Answer yes or no.***
- After the focus group session, would you like an opportunity to see a summary of study findings and to add further comment on it? **(Please note this is optional).** *Answer yes or no*.

Please can I ask you to confirm your name and today's date?
I am Nesibe Cakmak, and I confirm the date and that I bear witness to your consent.

Appendix 10: Eligibility Screening Form

Screening tool against inclusion/exclusion criteria: Potential participant with PD

Provisional participant code:

Hoehn and Yahr scale 2 or 3:

If a participant doesn't know their H&Y scale score then ask (table informed by assessment criteria in MDS-UPDRS https://www.movementdisorders.org/MDS-Files1/PDFs/MDS-UPDRS_English_FINAL.pdf):

	No sign or symptoms (exclude)	**Mild (include) H&Y 2**	**Moderate (include) H&Y 3**	**Severe (exclude) H&Y 4**	**Severity determined or unsure:**
What is your overall impression of your disease severity?					**(ask if ok to ask some additional questions)**
Additional questions:					
Over the past week have you had problems remembering things, following conversations, paying attention, thinking clearly, or finding your way around the house or in town?	None or impairment appreciated by patient or caregiver with no concrete interference with the patient's ability to carry out normal activities and social interactions.	Clinically evident cognitive dysfunction, but only minimal interference with the patient's ability to carry out normal activities and social interactions.	Cognitive deficits interfere with but do not preclude the patient's ability to carry out normal activities and social interactions.	Cognitive dysfunction precludes the patient's ability to carry out normal activities and social interactions.	
Over the past week, have you usually had problems with balance and walking?	None or I am slightly slow or may drag a leg. I never use a walking aid.	I occasionally use a walking aid, but I do not need any help from another person.	I usually use a walking aid (cane, walker) to walk safely without falling. However, I do not usually need the support of another person.	I usually use the support of another person to walk safely without falling.	
How do you typically experience getting out of an arm chair?		Pushes self-up from the arms of the chair without difficulty.	Needs to push off, but tends to fall back; or may have to try more than	Unable to arise without help.	

Do you need to use the arms? Do you have difficulty? Do you sometimes fall back?			one time using the arms of the chair, but can get up without help.		

Would you be happy to share your self identified age, gender and year in which you first had symptoms of PD (disease duration) with us? Y / N

If yes:

- **Age:**
- **Gender:**
- **Disease duration:**
- **Have you received balance rehabilitation in last 6 months?**
- **Have you received or heard of dual-task training?**

Appendix 11: Discussion/Interview Guide

Discussion Guide for Interview/Focus Groups

Discussion Guide for People with Parkinson's disease

- What do you think about your balance performance after diagnosed with PD? Especially during standing or preparing meals in the kitchen or stepping out stairs, are these challenging for you? What are the most challenging activities for your balance?

- Do you have any specific strategies to deal with these daily tasks? Or your physiotherapist suggested any specific exercise?

- Have you ever heard the dual-tasking? What is the meaning of dual-task for you? How you can describe it? As previously mentioned, most of the daily tasks such as standing while preparing food or walking while talking are samples of dual-tasking. If I ask you to explain the meaning of dual-task with your own words for our research information sheets, how can you explain it?

- I intended to use this kind of dual-task exercises to improve your balance. In the literature, we found different types of dual-task training. Here is a couple of them. Some of them are called motor-motor dual-task training (MDTT) like standing while carrying a tray and some of them are called cognitive-motor dual-task training (CDTT) like walking while singing. What do you think about them? Would you like to try these exercises as your training programme in research?

  Prompts: What would be your motivations or concerns to perform or not perform these kinds of exercises?

- What do you think about taking dual-task training in your home? What would be your preference regarding supervised/non-supervised/remote training sessions in your home?

  Prompts: have any concerns about safety/ familiar environment for motivation and engagement.

- What do you think about receiving one of two dual-task training programme (MDTT or CDTT) in research? Would it be a matter to randomly allocate you to one of two programmes?

- What do you think about the dosage of your training programme? In literature, 30 minutes to 2 hours each session, twice or three times a week for 3 weeks to 12 weeks. What would you prefer and with which aspect?
  Prompts: motivation, fatigue

Discussion Guide, Version 3.0 *25/05/2021*

- What do you think about your balance assessments? In literature, different measures were used after DTT training for balance assessment. What do you think about their application in your home or a clinic?

- Would you like to add anything?

- Thank you for your participation.

<u>Discussion Guide for Physiotherapists</u>

- Have you ever used dual-tasking as a training method for balance rehabilitation in people with PD? What do you think about its use for the mild-to-moderate PD stage? What would you consider applying dual-task training (DTT) to a person with PD?

  Prompts: eligibility criteria (cognitive level; education status; having ability to speak, to write, living with a carer, etc.)

- There are different types of primary and secondary tasks from traditional DTT like walking while talking or standing while singing to game-based exercises like bowling within motor-motor dual-task training (MDTT) and cognitive-motor dual-task training (CDTT) in literature. What types of motor and cognitive tasks especially secondary tasks would be your preference with which aspect?
  Prompts: Feasibility for you or patients? Acceptability for you or patients, Effectiveness?

- What do you think about the use of this type of training in a home-based way? What can be risks for patients and therapists? How would you prevent and manage them?
- It is important to decide an acceptable, feasible, and effective intensity of the training programme. In the literature, 30 minutes to 2 hours each session, twice or three times a week for 3 weeks to 12 weeks. What would you prefer and with which aspect?

  Prompts; acceptability, feasibility, effectiveness.

- What do you think about the progression of DTT? Should be it individually tailored or a standard program (based on a framework or guidance)?

- What do you think about balance measures? In literature, different measures were used after DTT training for balance assessment. These measures can be applied in a participant's home environment? What can be risks to use them in a home environment? What would be your strategy to prevent and manage them?

- What do you think about delivering DTTs as supervised or non-supervised or remote?

- Would you like to add anything?
- Thank you for your participation.

Discussion Guide for participants who are a supporter of participants with Parkinson's disease

- What do you think about their balance performance after diagnosed with PD? Especially during standing or preparing meals in the kitchen or stepping out stairs, are these challenging for them? What are the most challenging activities for them?

- Do they have any specific strategies to deal with these daily tasks? Or a physiotherapist suggested any specific exercise? What is your role in performing the strategies/exercises?

- Have you ever heard the dual-tasking? As previously mentioned, most of the daily tasks such as standing while preparing food or walking while talking are samples of dual-tasking. I intended to use this kind of dual-task exercises to improve their balance in research. In the literature, we found different types of dual-task training. Here is a couple of them. Some of them are called motor-motor dual-task training (MDTT) like standing while carrying a tray and some of them are called cognitive-motor dual-task training (CDTT) like walking while singing. What do you think about them? Are these challenging to perform for them?

Prompts: What would be your concerns for them while they are performing these kinds of exercises?

- What would be your preference for the delivering type of these exercises to them? What do you think about a home environment?

Prompts: possible advantages and disadvantages of a home environment for them?

- What would be your preference regarding supervised/non-supervised/remote training sessions at home?

Prompts: have any concerns about safety/ familiar environment for motivation and engagement.

- What do you think about supporting them during taking non-supervised or remote training at a home? What is your motivation or concern about supporting them?

- What do you think about the dosage of a training programme? In literature, 30 minutes to 2 hours each session, twice or three times a week for 3 weeks to 12 weeks. What would you prefer for in case you support them during the training and with which aspect?

Prompts: time limitation, tiredness.

- What do you think about their balance assessments? What do you think about their application in a home environment or a clinic?

- Would you like to add anything?

- Thank you for your participation.

Appendix 12: The Charted Data with Themes and Sub-themes

The charted data with themes and sub-themes

	Theme 1: An engaging DTT and participation to it
	Sub-theme 1: The secondary task: Creating a challenge or a facilitator
Quotes from pwPD	"I struggle carrying the saddle back up the steps to the tack room because my balance goes a bit there." P2 "…if I'm having a complicated conversation with somebody, I would tend thinking about it more often than not to lean on something, if there was something to lean on" P5 "Actually, interestingly balance is okay doing yoga. I can actually balance quite okay standing up, even on one leg sometimes. But yes, that's fine. but dressing is a bit more of a challenge." P3 "I find it difficult getting dressed. I have to sit down and put my trousers on or my skirt or something like that…" P2 "I also tried spelling the names of cities or birds as I walk along. That tends to take my mind off the walking and makes walking more difficult. I have to concentrate fairly hard on my walking normally." P1 "I'm a little bit wobblier than I was so If the teacups are too full, I tend to spill a bit, but not too badly." P2 "The fact when you are putting trousers on obviously your legs are somewhat tied tethered together. You can't step out and get your balance by pulling your leg out because it's tethered to the other one. So that's when you have problems." P3 "Getting dressed and getting my foot caught on a garment and then nearly falling over. That's the kind of thing that happens these days that never used to happen. I think it's a combination of coordination and fine motor control and balance, all in concert." P5 "I kick a stick, just a light stick with alternate feet as I walk along, gives myself a cue for walking, which makes walking easier sometimes. But I have lots and lots of different strategies" P1 "Singing is useful for walking because you can do it, you can walk in time to the singing and it's a cue. So, singing makes it easier, because it's sort of part of the rhythm." P1

	"...as it is only the two of us, we do a lot of dual tasking in everyday life one way and another, and it's pushing it to a higher level, but that would be useful for me. The cognitive challenge of the physical activity would need to be pushing it to the limit, rather than just doing normal everyday dual tasking that we do, talking and walking, that sort of thing. "P1 "I was off for four or five hours, I was really, really irritated. I got on the bike, I put my music on exceptionally loud, and I just cycled for about half an hour." P4
Quotes from Physiotherapists	"They get frustrated when they can't do two things at once because nobody ever walks around a room and not does anything else." PT1 "I think, I guess, and challenge is probably the other component I'd say to it, you know, the level of challenge…you can challenge the motor, or you could challenge, the cognitive component of it. And I guess that's probably what I think about dual tasking." PT1 "So once people have learned their basic exercises, the next level of maybe dual tasking is to mess the exercise up in some ways to make it more complex. So, it could be changing sequences within that exercise, making it a little bit harder."PT2
Quotes from Supporters	"Having to balance on the bike and multitask with the iPod on top of the bike and trying to do both at the same time. I think using the different parts and actually having to think it through has definitely helped his balance, I think." S2 "I reckon just having motor and cognitive, because he is strong …if he's thinking about things or if he's trying to do another thing. It's multitasking, yeah, that would be the challenge adding more things in." S2
	Sub-theme 2: Combining enjoyment and benefit in DTT
Quotes from PwPD	"I was walking with my wife playing Simon says she would do it again." P1 "Singing is quite good. I was singing one man went to mow a meadow, but it's got to be sort of vaguely entertaining." P1 "You have got to be quite creative to keep the interest going if you are doing things when you're just walking normally from day to day." P1

	"Spelling words is quite a good one, I guess. Just to sort of keep your mind going, because there's an awful lot of words you could choose to spelling. You will never run out of words, but you would soon run out of cities and countries and animals." P1 "I've got the indoor bike with which I'm still trying to do the effort and be a little bit creative rather than just pedalling at the same speed. So, it's a bit like spinning and a bit like training and also, I'm multitasking by trying to change my music to match the speed I want to go to as well." P4 "I think another good activity is table tennis…. that provides balance and sort of cognitive and motor activities all at the same time…" P1 "…when we were doing it in classes with the others in the village hall it was more fun really. When you're home on your own it's less expensive because you are not having to drive anywhere, just do it at home, but it's more fun doing it with other people." P1 I've always been a bit of a lone exerciser. I don't have a strong preference, but if I was to express a preference, it would be an individual one…If I did it in a group context, I'd start getting competitive and then form would go in the value of the exercises, it would be lost." P5 "I feel the same doing PD Active classes because of the social aspect of it it's more motivational." P2 "… but my instinctive reaction is that the group would probably be more fun than one to one?" P1 I suppose a group would be okay wouldn't it really." P2? I think this is why a group session once a week, I enjoyed and it was very, very motivational, something different. P1 "I can do exercises and I actually the yoga I found that, I do yoga it's best for me to do in the group exercise at a class because I actually go and do it. Whereas during lockdown she started doing it online and sending out videos. And I wasn't really doing it at all because you just think I'm really not up for this." P3

	"I think it might even be a bit more complicated than that. So, if you put everybody together and split everybody up in a group by ability, you know, I can walk a mile, you can walk two miles, you can walk three miles. On that morning on that day, you meet at eleven o'clock in the morning, how I'm feeling could be completely different to how I feel at one o'clock or when I filled out the form. So, you have to differentiate the activities you are going to do, even within that class, even though they can all run three miles." P4
Quotes from Physiotherapists	"…for some patients, games might be a really fun way of engaging in therapy or in a therapeutic approach to things." PT1 "if they were interested in sports, even they may never play basketball, but that might be something that they'd be interested in doing. And through that you can increase their balance, or their arm control, or their standing balance, or their movement abilities. we all know we know ourselves, if we're interested in something, we'll do it." PT1 "I think also dual tasks are more interesting as well as a whole, as well as having the benefits therapeutically. They're more interesting for the patient to be doing sort of two things at once." PT1 "We have so much fun with the cognitive tasks and we go over these…" PT2 "We work in a group yeah, I think games are really, really key to fun, but also change difference and stimulation. We also do things in two teams, maybe in a row, passing a ball overhead, under head and pass it back to front and things like that…"PT2 "We sometimes play ping pong. We have a ping pong table set up so we could have lots of people working around the table together or just in pairs or in doubles. We did things with scarves, so we would have a thing where you'd have to be in a big circle, and we'd all be throwing scarves in different ways. Green scarf you have to throw it with your right hand if you have the orange scarf you have to pass it behind your back…"PT2

	“Intensity, I feel, has a much better impact than frequency or volume. Because I firmly believe if you work hard, really intensely and then have your rest, you'll have a bigger impact. The other thing is patients see the progress quicker, are much more motivated and actually feel this is working for me, so I'm going to do it again. “PT1 “…something it's actually thinking about how the quality of the movement, the precision, the intensity so getting a nice power output, getting large movements. It's really about the quality of the movement over that period. So there's a lot of attention to what they're doing, rather than just going through the motions.”PT2 “I have to start somewhere, so I started off with simple and safe. And as he moved through the task, I think he is managing that okay let’s make it a little bit harder.” PT1 “…then you start challenging the mobility section, you start challenging the physical, the visual section, and then you start challenging the action.”PT1 “Just sometimes I can mash exercises together we do combos, sometimes two exercises we are in and out of one and the other constantly or sometimes do that with three exercises in and out of them so really keep changing the sequence.” PT2 “I'll maybe get them first of all for 30 seconds to work on their normal motor activity that they're familiar pattern they get it going. And we try and get it as really good and strong precise and find the nice rhythm and then I say okay keep the size, keep the rhythm, now I want you to list these things…”PT2 “Sometimes what I would have done in a live class was set a metronome where I changed the pace of the metronome during the activities and some of its going to be at high pace and some of it at low pace, because again that's one of the things sometimes I like to chop, and changes is speed of movement.”PT2 “They only learn a little bit at a time to take away with them. But they also then learn from each other in the classes as well…”PT2

	“We vary whether we have it muted or unmuted because sometimes it's really nice when we're all doing things and shouting out together because there's quite a lot of fun, you know when we do the dual task and the cognitive tasks it's more fun if everyone's doing that together out loud…”PT2
Quotes from Supporters	“Whereas with the TRX there's lots of different exercises you can do that allow you to exercise different parts of your body whilst maintaining your balance all the time.” S1 “…added music, he'd concentrate so much more on music, especially if it’s something he likes… He’d be singing along and then he’d have to concentrate on both to get it all done.” (S1 & S2) “So, to start off with he was balancing on the ball side and then he’d got the flat base. Then he progressed so that we turned it and your balancing on the base and obviously you’re on a ball so you have to literally keep up. I found it very good.” S1 “My Pilates teacher had been saying to balance on the gym ball and do some exercises with the shoulders and neck whilst balancing. So, we kind of started from the gym ball and balancing and doing all the shoulder exercises and putting your arms out and all of that and then raising one leg and trying to maintain your balance…” S1
	Sub-theme 3: Training as part of daily life
Quotes from PwPD	“The only impediment to getting people involved in the programme like that would be to make them see the potential collateral benefits rather than just perceive that I’m going to get better at standing on one leg whilst one's humming Dixie. But you're also going to get better at getting in and out of the shower, getting dressed, doing the hoovering, whatever it might be. There are so many different things where balance comes into play.” P5 “When I clean my teeth at night, I stand on one leg and then I might swap over halfway through. My weak side is my left side, so I stand on my left leg to start with and then if I get bored, I might change legs or I don’t, but I try and spend a minute on one leg just brushing my teeth.” P6 “I feel less Parkinsonian when I'm on the water paddling. Paddling is not an issue. I've lost strength, I think but apart from that, I can do eskimo rolls and I can just feel perfectly normal once I'm sitting in the canoe. As soon as I get out of it and try and walk up the beach I’m back to where I was. So, it's a great release from.” P1

	“I am no good at singing. I remember at school, the teacher said someone was singing out of tune and I was sure it was me; I haven't sung since. So, I am no good at singing... It would be a challenge for me to sing” P2 “Where if you said to me you’ve got to run 10 miles by the end of the month, I wouldn’t really like that. If you said you've got to cycle 50 miles by the end of the month, I'd be quite happy with that. That’s tapping into individual’s personal things” P4. “I'm not a computer whiz and I'm an outdoors person. I use computers every day in work, but I'd rather go outside and go for a cycle, go sailing, rather than sit inside and play with your machines.” P6 “Wii balance games, which I think, it is hard to assess how I think, I haven't played it for a long time, and I should do. Last time I played it balance was not so much of an issue as it is now. So it's something I definitely should do and perhaps will do more in the winter… Something I know I should be doing and haven't been because it's summer and I’ve been out gardening and doing things.” P1 “I think twice a week is something I would definitely do. Three times a week, I might struggle to get on and do.” P2? “So maybe if there was a weekly or twice weekly videos, like video classes of that nature might work.” P1 “Half an hour…Time, I still work full time. I don’t work like five days a week, but half an hour I could give up easy, but an hour it would be a struggle.” P6 “I think it's going to be long enough to feel, worthwhile and not too long to feel intrusive or onerous. Thirty minutes would be fine for me. I think that any longer than that would tend to put some people off. Any shorter than that people would probably default more often than attending. So, it's going to be long enough to feel worthwhile.” P5 “Two or three times a week. It depends how much of other life activity people are doing.” P5

	“I think that if people have got an active lifestyle outside of therapy sessions, then two or three, three times a week would be manageable. Anymore and again, you’re likely to get people starting to default. Any less and people would be likely to be sceptical about the benefits. P5 “I think anything longer than half an hour you will struggle to keep people engaged. P4 “It depends whether the people are working full time, working or not. What time people have got. I mean, I have the flexibility. I'm not working, so I have the time to do stuff, but time still has a habit of running away with you.” P3 “If I look at YouTube, for example, any fitness thing is at 20 minutes, 45 minutes maximum. I imagine they have learnt that the hard way, everyone switches off. So, by all means kind of repeat it at the same time each week would be useful.” P4 “Little and often.” P3 “Actually, multitasking and balancing tends to be fine, it is just when my meds go off that’s when I start to struggle.” P4 “I do pilates not yoga, same as P3. But recently I’ve had to do some of the sessions when I’ve been off my meds. So, I’ve had to do it lying on the floor otherwise I’d probably fall over, but normally my balance is really, really good.” P4
Quotes from Physiotherapists	“I've done things like patients hoovering. In their homes. And that is dual tasking really when you think about this, where they're trying to stand, and they want to do something to help in the home…” PT1 “So, I will try and be a bit more imaginative and creative with my exercises and make them yes, functionally relevant to the individual, but actually quite meaningful to what I need to help them with.” PT1 “My whole aim with any patient really is to get them to engage in what they see as meaningful and have a therapeutic background to it or a sort of evidence-based component to it…I guess that's dual tasking in some respects, putting it into the functional situation…” PT1

	“It needs to be meaningful in the sense that when they're doing the task, that they see the value of it to encourage their improvement.” PT1 “I want them to sit on a stool at the kitchen sink and then they've got to stand up three or four times while they're doing the washing up, or they're standing up and I want them to reach up to the cupboard to get a cup of tea out or coffee or something like that. “PT1 “What they can do if they're gardening, cooking, just doing housework, how they can incorporate some of the principles so they're still getting that 20 minutes high intensity, challenge themselves and get them know do their cognitive tasks, while they're out for a walk and you know just yeah try to incorporate it that way, so that they don't really have to do every single day still, but they are still using it every single day they're still using the principles.” PT2 “When I see them one to one, they get a few very specific exercises based on how I've assessed them to go away with and learn and to work on at home to really work with it.”PT2 “A small uptake from the people that could have come, maybe 30% actually. So, it wasn't for everybody. So, I guess the people who chose to do it with a more motivated and maybe the more confident in their own physical ability. So, everybody who took it up on zoom has kept going with it…”PT2 “The other thing you have to remember is that each person in the group will be so different because I'm just thinking about the people in my groups as well, and they are so different, they are so different in how they respond to different things…”PT2 I roughly have an hour with patients. Okay, and it doesn't have to be an hour. It can be less, or it can be more. And the reason it less is because they can't cope with anymore, they’ve had enough of me and the reason it's more is because they're responding well.” PT1 “The frequency, … I probably only see patients once a week. Those are the ones that I feel are really responding to therapy and there are other ones that I need to see once a week because they're changing quickly. So, I need to keep my therapeutic intervention up with that change. So, if I feel that kind of a little bit stagnating, I might move them to every two or three weeks.” PT1

	"The original programme that I have done with all of these people was a 10-week programme. Where once a week, they did an hour with me and then they had to do something every single day on their own for 20 minutes every single day for that 10 weeks, after the 10 weeks, but as you built up to 20 minutes, so to start with it would be five minutes every day, then 10 minutes every day, then 15 minutes every day, then they can spread those 20 minutes however they wanted in the day. They could do 10 minutes in the morning and 10 in the evening, or they could do all in one go, it was up to them, but they had to do every day for the 10 weeks…"PT2 "I regularly use family members. It's sometimes spouses, it can be even grandchildren…" PT1
Quotes from Supporters	"They might be able to take a dispersible to bring them up to speed a bit and that would give them enough to get them through a half an hour session." S1 "If you say you need this many times a week, then he could do that when he's on because I think it's highly likely he'd be off at some point during one of the exercises and he wouldn't be able to do it." S2 "I think there's an element of timing that in order for it to be beneficial, it needs to be when the person is on and not experiencing severe off symptoms because I don't think it would work. I think they would tire very quickly if they were off. He wouldn't have the cognitive function. He gets the brain fog." S2 "And I mean, the chance of having like nine to 12 or whenever that chance, it's highly likely they're going to be on at some point during those couple of hours in the morning. And if they know, then say they normally set their alarm for 7 o'clock, like you said they could set it for 8:30 and then they know that they can get up, have breakfast and kind of carry on my routine as they normally would but just a bit later, then they know that they'll be okay for it." S2
	Sub-theme 4: Different sorts of support
Quotes from PwPD	"My husband's retired now, but he's not here all the time but I could make sure he was around when I did it." P2 "But I can certainly see some of the people I've met with their condition needing a fairly large space and needing somebody else some kind of support." P5

	“It may just be wishful thinking on my part, but I think having the carer or supporter there is vital. A they can motivate the person and B they can check that they are doing what they should be doing safely. Or they haven’t totally misunderstood what they’ve been asked to do. If they want to go along and do that, I don't know, but ideally, I would like the option to take with me to some of the things.” P4 “I think that could certainly work better for people, some kind of buddy or friend rather than necessarily your husband, wife, partner.” P4 “Some people think they are going along just to support somebody when actually when they look back at it they used it just as much as the other person, but they just didn't imagine in that way when they started.”P4 it's kind of weird and finding people with the right skills set or that know a bit about that or sometimes it would be two people and getting them together is really difficult…People are quite siloed, which I suppose is because they specialise. But if you're outside of that specialism a little bit, it's not easy.” P4 “it's because you've got such a key role to play in keeping people healthy. And they are one of the key preventions that people with Parkinson’s should have at a very early stage would be my view. Because you can look at all of the research, which is coming out from America or anywhere, exercise can be, not just activity, exercise is very different. It has to be as good as medication if not better. So we kind of need a bit of an approach…” P4 “I think you need somebody there, if you’re performing actions or exercises. You need some nursing, you're leaning forward, you're leaning back, you tend to do this to counteract the physical posture…And getting it right is important, otherwise it is easy to have the wrong consequence.” P5
Quotes from Physiotherapists	“I don't use carers or family members if there is conflict because that won't work, it will work to anyone's advantage. And I think that's probably the only time I don't do it because if there's a conflict there, it's not going to generate a positive exercise or rehabilitation environment.”PT1 “I do think carers and family members and spouses and friends are very well placed because at the end of the day, they're there twenty-

	four hours a day and I'm not, for the hour. And I think it's so important that we include their observations, but don't have them as the main observer…"PT1 "I don't use them if I feel the individual can manage on their own two feet, literally, because I think that's an unnecessary distraction." PT1 "I do ask them to bring somebody with them as well for that (one-to-one assessment), a member of the family or somebody who would maybe exercise with them in the community afterwards as well. So they have somebody who's there with to listen to what I have to say to them, but also to maybe give some more information. Sometimes people forget to say things and then the other person has a little bit more to offer." PT2 "I think it's really valuable in this sort of setting to have a member of family or a carer come to the sessions, that we do so that there's both a sense of continuity if they are working on into home, but also a sense of collaboration. You know it's not just me working with this person that we're all working together, and some people really like that some people love to have a member of family, or whoever come and be part of it and see what they're doing and share it and work on it with them. Some people really don't want to do that, and some people's families don't want to be that person either, they don't want to come in and be involved in that, that's just a step too far for them."PT2 "…sometimes the carer will film them doing some things with me. So, they can work on it better at home..."PT2 They're not interested in what I know. They just know that I'm a physio who knows how to help them get better or to achieve something. And I think that's where this tailored approach to our individual who's sitting in front of us or standing in front of us, we've got to think outside the box. "…I would see that as really beneficial and I think what I do with most of my patients, I try to educate them as to why we're doing this." PT1 "I think that's what we need to do, we need to think about what is it I'm trying to achieve this individual, how can I make it safe where they are right now and if they cope with that, how can I progress it, how can I challenge the task a bit more each time." PT1

Quotes from Supporters	"I think it would be fun. If you use the BOSU ball and then you've got a tray and you put the tray in front and you're doing your exercises and then your buddy takes away one thing off the tray, you've got to think what it is. I think that would be quite a good fun thing to do as something you could do." S1 "I think he'd be more motivated to do it, if mum was there. "S2 "Yes. I think he'd enjoy doing it, and we would we get a bit competitive. S1 "I would say is I'm very mindful that I'm fortunate that I can be with him and I can bring him to appointments and assessments, etcetera but there's quite a few people out there that are on their own that find that environment quite stressful. S1
	Theme 2: Home-based DTT
	Sub-theme 1: Advantages and disadvantages of being at home
Quotes from PwPD	"Walk, moving in confined spaces I find more difficult indoors. So, moving around the room is more difficult than it is moving around outside potentially because it's all about starting. " P3 "…once I'm going, then it's a lot easier once I get going. So, if I have to keep stop starting and yes, if it's cluttered, then it's trickier." P3 "…But I can certainly see some of the people I've met with their condition needing a fairly large space and needing somebody else a some kind of support." P5 "When you're home on your own it's less expensive because you are not having to drive anywhere, just do it at home, but it's more fun doing it with other people." P2 "I think with traveling, it is easy in your own home but it doesn't bother me in front of people, or whoever." P6 "I wouldn't have a problem in the home because I think my balance is good enough to avoid any big problems. But I can certainly see some of the people I've met with their condition needing a fairly large space and needing somebody else, some kind of support."P5 "I think once somebody is comfortable with the exercises and knows how much space they need and what their likely balance problems or issues are then it's something you can translate into the home environment," P5

	"I'm always mindful of the fact that I've got to get somewhere, do I have to drive and how do I get there and am I going to be okay to get there and am I going to be okay to get back. Because obviously, if you do it on Zoom you don't have that travel time. It takes far less time because you don't have half an hour either side. P3 "…perhaps is there is a regular routine that you can adopt for 12 weeks at home might be easier I guess it's less enjoyable, I think longer time, I would want the flexibility to do things in my own time, to set aside an hour twice a week for myself and my partner probably." P1 "It's easy to duck out being at home. We've been talking, getting exercises at home, it's easier to kind of say, right, I'll stop that and then start it when I'm feeling better. P3 "It's alright when I go to the class the hour is fine when I'm there with other people interacting an hour is good. But at home for an hour, it's just too long. "P3 "we have got a conservatory or we have got the garden outside. It's always easier to fall on the grass if you are going to fall over." P2
Quotes from Physiotherapists	"that's where he lives and that's where he has to function. So I did loads of work with him just walking up and down his living room at different paces and different speeds and high knee lifting and just walking slowly. And then I started putting objects on the floor that he had to pick up and I started off with the big object, so he didn't have to bend too far, pick it up and put it on the table at the end when he got there, then walked down the other end of the room. … So he started … dual tasking and then he had to reach down and pick it up. And then I slowly made the bottles smaller… So, you can progress the balance and the dual tasking that way in someone's environment. This bottle could have fallen on the floor... So they were all objects that had meaning to him…" PT1 "I guess the barriers for me, and as is so often the case, in community, is around safety." PT1 "…in their own homes, sometimes dual tasking is just not possible to be able to execute given the environmental hazards, shall I put them down as, and the constraints and also to do around social circumstances of that individual." PT1

	You might actually find for home-based programmes Nesibe that the risk is less at home because it's a known environment. Yeah, it's a comfortable environment." PT1 "I did send out sort of suggestions of the space, use of space and ventilation, clothing and having something either being near a wall or a high back chair, or something that could provide support if they needed to have another member of somebody in the household with them or telephone that they could reach easily beside them I have their emergency contact details also so that if there was an incident and they can call for help, I can do something on their behalf, so yeah we kind of covered those safety issues right at the start,…"PT2 "I am risk assessing the whole time as I go along because I'm just checking each component." PT1 "the safety was based around his cognitive status rather than anything else. There weren't environment issues. there weren't carer issues, it was his cognitive status and his fatigue, probably to some degree as well." PT1
	Sub-theme 2: Use of different technological options for different purposes
Quotes from PwPD	"I prefer face to face because I like human interaction with people which is a different thing to Parkinson's. But in this lockdown scenario when budgets are being cut, it is your time as well as mine. So, you've got more people to see than I've got. So, I have 4 people on this trial and you have 34 in total. So, for you it's easier to do it by zoom I would say." P6 "There's certainly somethings that can be done effectively over zoom, and other things that cannot be done effectively over the zoom." P5 "I think perhaps twice a week, and I think it would be nice to do live with you, to be honest, at a set time that was mutually agreeable." P2 "I think there are real positives using zoom but there are some negatives because that kind of social interaction that you can get from being able to get a coffee and have a chat and say oh do you know so and so. Kind some of that social bit doesn't happen…it is good way of focussing activity which with physios being very time precious it would be a very good use of time. So, yeah, it could actually be a positive thing but there are a few caveats, I suppose, with that." P4

	“Talking about anxiety and trying to feel more relaxed about what's going on, zoom is actually a really good thing for me because you can only see this much for me.” P3 “So, if you are going to have that kind of thing you need to have a set of rules that everybody needs to be visible. Otherwise, it kind of defeats the object. I think it helps that sense of community and openness if everyone can see each other. P4 “If I refer back to the point I made earlier on about anxiety, indoors on Zoom to me is a lot easier. I'd certainly be a lot less anxious, a lot more calm and less anxious than if I could be fully seen…” P3 “So, I kind of prefer Zoom if I had a choice to get up and wander out of frame if I had to. Where being in a group setting now I would be quite challenging and would probably make my symptoms worse, rather than more enjoyable.” P4 “you know, I'm sure there are things like that, that are associated with people that have Parkinson’s that also have other conditions like that that can affect them, that it's much easier to disappear in them and go and sort yourself out.” P3 “long term for something for everybody to participate with, then maybe a YouTube video type thing that you could just do when you need, when you wanted to would be good. “P1 “If I couldn’t make it to a like a live video, to perhaps to then have it sort of recorded for the times you couldn’t make it, because then you are not so committed for when something else cropped up. That would be okay to do something like that?” P1 “I think it's the kind of thing that you need to be shown in person first and thereafter YouTube videos could, I mean we do all sorts of things via YouTube videos these days. And it can be very effective and certainly cost effective and flexible.” P5 “A combination would be good… having gone to the classes, sitting on zoom you still see her it’s still okay, but it's not the same as having others in the room with you.” P2

	“I haven't tried anything on Zoom and I'm not particularly keen on that. I'd rather just go and work on my exercise machines, but a combination would perhaps be good.…” P1
Quotes from Physiotherapists	“when we started lock down I was not convinced I wanted to do these classes online, I was concerned from a safety perspective and I just wasn't sure how it would flow, because part of the group coming together is how we all communicate and interact…” PT2 “That is a really important part of it, so not just a fun that we all do together, but what they do, on their own is really important that they feel they are in control of it, they know what they're doing and why they're doing it and that helps again with motivation to do that on their own.”PT2 “I've kept the numbers quite small online, so the maximum I think I've had in a class has been eight and that's maybe just a little bit too many and I've now got it back down to six maximum in one of those classes. And that way I can still see everybody reasonably well. They know that they should pin me as their big screen. And they have themselves as the smaller parts, so they're mostly able to see what I'm doing.”PT2 “I think when it's online I have just got to watch for pacing and make sure people aren't just going hammer and tongs at something and yeah, it is quite hard to see each person individually.”PT2 “Even the people who are in the zoom classes have said no if it's going live they just wanted to do it live, they don't want the zoom. Even though they are doing zoom and the people who didn't take up the zoom obviously wanted to come back to live and then other people have said they'd like to have both, and some people said, they only want stay online, so you know that, obviously, is an interest in both, and I so that's why we're trying to keep going.”PT2 “I've tried doing that online that does not work there's a lag going on and the metronome just didn't work online at all. I try music in the classes, but music online doesn't work. And yeah, so there are things that don't work online.” PT2 “I will also use it to follow people up when I know the background of the individual and know that the video consultation can just be a support mechanism or a checking mechanism, because I think it's like any other concept that no one size fits all and it will be useful in

	some situations and a hazard in others and a constraint in others." PT1 "But equally, it can be an amazing and supportive tool because I know our patients, when they weren't allowed to have face to face, that video link was such an important tool to them to have that support. And I think we need to introduce video components to our therapeutic management." PT1 "I think thought the video intervention was just going to be a pandemic thing, and I think it'd be nice to start assessing its use and purpose outside of pandemic environment, because I think the pandemic has set the scene, but I think we haven't captured all the components of virtual rehabilitation and intervention yet because I think, as I said, patients just thought it was a stop gap, and I don't think it should be a stop gap, I think it should be an integrated part." PT1 "sometimes the carer will film them doing some things with me. So, they can work on it better at home and sometimes I will send everybody a video of me doing it to remind them what they're looking for a home…"PT2
Quotes from Supporters	"…he's trying to through the iPod and the cycling and watch the YouTube thing that he's got on training on the telly." S1
	Theme 3: Acceptable assessment options
Quotes from PwPD	"I think to have to go to Plymouth at the beginning and end of a trial would probably only be twice, so that's doable. It would be a luxury to have it done at home. You know, I could do either way."P1? "it would be doable to do an assessment before and after." P2 " I think I know it's getting worse. If it's at home I can fudge it, if it's in a clinic or whatever, people would see me differently than I see me, and if you want a lot more realistic results, I think you'd see me better face to face be it at a clinic or somewhere rather than over zoom." P6 "I think it's perfectly reasonable to ask people to attend the clinic for that initial assessment and if you've got the tech and the tech is available then using it for incremental assessments is going to facilitate the greatest level of participation. So, I'd be quite happy to go into clinic to have initial, interim and final assessments, for example." P5

	“I think it's important to do the science if you like and do the travelling. P1 “I think the wearable is a good idea.” P1 “I have been doing this patient reported outcome in the websites where you assess yourself at regular intervals and get a score, I think it is very subjective and the temptation to be optimistic about your condition makes it very unscientific. I would say I think a more objective assessment by the third party is much more useful, perhaps and a wearable equally I think would be useful.” P1 “I don't think it matters to me really.” P2 “I'm part of the home-based care pathway. So, I don't physically see my consultant anymore, it's all done remotely. So, I email them if I need a consultant to come and chat with me on Zoom, which is great. She is not having to go outside the hospital and I'm not having to go somewhere where I might catch something I don’t want to catch, you know. I'm more likely to be off when I get there because it is quite stressful environment. So anything you can send somebody in a post, you know, put this on, set this up in your room, would be amazing from my point of view. P4 “I'd be quite happy to use that kind of assessment, yes, but I think in order to make it feel more relevant individually to the patient using those kinds of assessments as an adjunct rather than as a sole means of assessment would be more appropriate.” P5 “the information that you can collect now through wearing tech and doing other assessments at the same time is so much more rich because you've got a baseline.” P4 “I think from an assessment point of view, my theory has always been to use a broad enough range, then you can kind of pick up what you need to pick up...Now you don't want to know as a physio that for the next 12 weeks you've got no idea how people are doing. So small mini assessments along the way. A it gives you the reassurance that people are doing what they're doing, people also have got the impression that they're being monitored. But there is kind of, a bit of an edge, if I don't do this and some people are saying hang on you need to do this in a motivational way.” P4

	“In terms of validity and robustness, you don't want people thinking they're doing better than they are. But at the same time, people need to know that they're being encouraged and going along the right track essentially. Otherwise, people will drop out and you don't want that.” P4
Quotes from Physiotherapists	“You can pick up certain bits, but I think there's a lot missing. And I think the bits that are missing actually are the cognitive components and some of maybe the emotional stuff as well. And certainly, the basic social components are missing as well. But there are the obvious bits that are missing, I think.”PT1 “Things like I was doing a six-minute walking test first of all, so measuring how far people walked in six minutes and analysing their gait, so obviously that's not possible online like that. I could ask someone to walk for six minutes and try and measure the distance themselves but it's not going to give me the information I'd be looking for, so that wouldn’t have been worth doing.”PT2 “…So, it would have been a lot harder to do the baseline outcome measures online.” PT2 I think, to have both would be perfect, I think, to start off initially definitely face to face, without a doubt, and have some regular face to face drop ins would be brilliant, but to still keep some online…”PT2 “…even though somebody may have had a full cognitive assessment completed, it doesn't necessarily translate into what you're finding in somebody's home. It can make sense a bit sometimes, but it doesn't necessarily give the full answer.” PT1 I'm using a situation to kind of judge how he responds to it or they respond to it. And then that in its own right allows me to make a judgement about whether the individual can continue.” I don't know if there's any research out there to prove that or otherwise, but if somebody is able to sustain a task or an instruction throughout the task, that it can be quite meaningful of how they're seeing what they're doing and interpreting what's going on.” PT1 it's a very informal decision on their cognitive abilities, but basically before they join the group I, I have a one-to-one assessment session with them”PT2

	"…when they attend, I do both a physical assessment and within that I am looking at their cognition. So, if they were struggling to follow instructions or to remember things that would be a little bit of a warning sign to me…"PT2 The other thing I was doing was a 10 meter walking test that I added on a motor task and cognitive task on top of it and taking averages, and I was getting them to do a hand function tests and balance, I was using my own version of a mini best, and I adapted it because I found a lot of people just too good for the best minute best, and so I put in a few of my own things in there. I use the four-square step test sometimes as well."PT2 "I did find that it was really hard to find a balance test that isn't really time consuming or needs equipment or whatever, that is replicable. So, it was just kind of using the mini best as the basis, but I've just put in a couple of other things that were maybe more salient or pertinent for what I was looking for."PT2 "For example, could they hold a lunge position, could they come into a lunge hold and then step out of it safely. I do a measure where for 30 seconds they have to tap a box with their feet evenly keeping an even pace and I just count how many they do. So easy to repeat it, I know the height of the box. Just a couple of things like that that were just a little bit quicker and easier to measure but did reflect their balance potential as well." PT2 "I find those forms are a little bit condescending and negative and I just really hate them, and I know a lot of people hate to filling them out. So, I drew on a piece of paper, I just drew a vertical line and a horizontal line. People could mark an x on it." PT2
Quotes from Supporters	"I think zoom is really difficult to try and assess somebody. I don't know how that would work." S1 "I think as well, you could get more out of the research by doing specific tests at uni, if that makes sense. So, like you could probably do more tests and more specific ones and get more information out of what you need really and be able to target specific things whereas you can do generalised tests at home." S2 "I would say is I'm very mindful that I'm fortunate that I can be with him, and I can bring him to appointments and assessments, etcetera but there's quite a few people out there that are on their own that find that environment quite stressful." S2

Appendix 13: Advertisement for WP3-Feasibility Study

FREIC Code:3332

UNIVERSITY OF PLYMOUTH
Faculty of Health: Medicine, Dentistry & Human Sciences

As a person with Parkinson's disease, do you find it *difficult to keep your balance whilst you undertake a different task*-like *'walking and talking'*, or *walking and carrying a drink'*? If so, then you may be interested in taking part in a research project we are undertaking at the School of Health Professions, University of Plymouth.

My Ph.D. research is trying to understand whether training programmes using activities involving a 'balance plus a physical activity task' and a 'balance plus mental exercise task' are acceptable and feasible to people with Parkinson's disease and to see what the impact of these different programmes are on people's balance.

If you;

- Are able to stand by yourself, without the use of an aid or another person, for more than one minute,
- Are able to commit to participating in home-base balance exercise sessions over a 6-week period,
- Have a supporter (carer, spouse, friend, a family member who is at least 18 years old). During these training tasks, your supporter role will be acting as an exercise buddy for you,
- Are able to use web-based/online applications to complete questionnaires. You can do this independently, or with a help of a supporter,
- Have an available safe training area in your home (an area approximately 2 metres square, next to a wall, which is free of clutter).

You are invited to look at the Participant Information Sheet for more details and take part in my research.

If you are interested to take part, please get in touch with Nesibe Cakmak, the researcher at University of Plymouth.

Email: nesibe.cakmak@plymouth.ac.uk

Supervisory Team: Dr Lisa Bunn, Prof Jenny Freeman, Dr Camille Carroll

Appendix 14: Participant Information Sheet for PwPD

FREIC Code:3332

UNIVERSITY OF PLYMOUTH
Faculty of Health

Participant Information Sheet for People with Parkinson's disease (PD)

Project: *Investigating the effectiveness of two different balance training programmes in people with Parkinson's disease: a feasibility study.*

Research Team: Nesibe Cakmak (Chief investigator), Dr Lisa Bunn, Dr Camille Carroll, and Prof Jenny Freeman

What is this project about?

The literature suggests that performing two different tasks at once ('dual-task training') can improve balance in people with PD. However, we do not know whether some task combinations are better than others.

For example, is the use of two different physical tasks (e.g. carrying a cup while walking) better than the use of one physical task and one thinking task (e.g. singing while walking)? This question is the basis of this research project that is a part of a PhD for Nesibe Cakmak. The main objectives of this project are to assess the feasibility and acceptability of these two types of dual task training programs and their effects on the balance of people with PD.

Am I eligible to take part?

You are eligible and invited to take part in this project if you meet all of the criteria listed in the Table below.

Table 1: Eligibility criteria

You are eligible if you:
Are diagnosed with PD and your disease severity is mild or moderate for example; . You do not too often need a support to get out of an armchair/you may experience tend to fall back. . You usually do not need any kind of support to walk or stand/ you need a support of walking aid but not any help from a person.
Are able to follow the instructions of a home training video.
Have a supporter, aged 18 years or more, who is willing and able to act as an exercise buddy.
Are able to stand independently for more than 1 minute without requiring extra support.
Do ***not*** have any other neurological or musculoskeletal conditions, and severe visual impairment which can affect your balance.
Do ***not have*** severe deafness.
Have a safe training area* in your home.

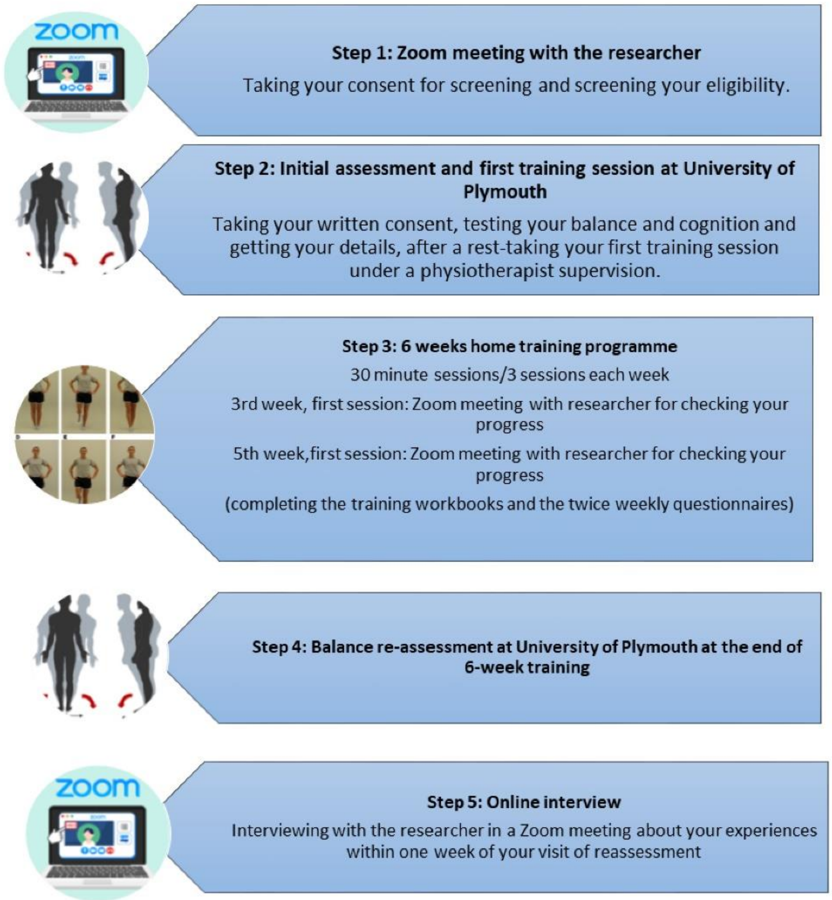
*: a 2-metre square clear area immediately next to a wall, with no trip hazards and with the potential to place a chair close by, within the space (for seated rests). A wall free from hanging objects or shelves and not wallpapered or featuring flaking plaster.

Do I have to take part?

No, your participation is voluntary. If you choose not to take part, this will not disadvantage you or impact your health care in anyway. Once you have read the information sheet, please contact us if you have any questions that will help you make this decision.

What will happen if I take part?

Summary of the Steps



Step 1

If, after reading this information sheet you think that you are eligible and interested to take part, please contact us and we will schedule a short online (Zoom) meeting at a convenient time and date. In this Zoom meeting, we will seek your consent to initially screen your eligibility and ask a series of questions to ensure you are well informed about the study. If you are eligible and willing to take part in the research, you will be invited to the Human Movement Analysis Clinic – located in the accessible lower floor of the Peninsula Allied Health Centre in the University of Plymouth's Northern Campus (close to Derriford Hospital).

Step 2

Here, a researcher will ask you to complete a written informed consent form to enrol into the study. Once consented, they will then ask you for some key details such as your age, what medication you take, your current working status, and your status in terms of your PD. Then, you will have an assessment of your balance and cognitive (thinking) performance which will take no more than an hour. Then you will be randomly allocated to one of the two different training groups. Both training programmes include a combination of balance, motor and thinking tasks.

After the initial assessments, you will be offered a rest and then you will undertake your first training session on the same day with the face-to-face support of a physiotherapist. This session will ensure that your training programme can be individualised to you and safe to undertake with your training buddy at home. During this first session, ***you will be provided with the training equipment and training workbooks for your home training session*** *and trained in the use of this. Training will be provided to both you and your training buddy, so it is really important that they come to this first face to face session with you.*

Step 3

After this face-to-face session, you will then do all of your training in your own home with your training buddy. You will be able to access training movies - the links will be available in your training booklet and QR codes will allow you to scan these links and immediately view the movie that you need each time. Each session will take 30 minutes and you will have 3 sessions each week on your preferred days over 6 weeks. At the end of each two weeks, you will be asked to complete an online survey which includes questions about the programme (e.g., did you enjoy the tasks, did you find them difficult to do). In the first session of the 3rd and 5th weeks, a researcher will contact you via Zoom and assess your standing ability to ensure you are still challenging your balance during training. At this session you will be advised whether and how to safely progress the training programme, and researcher will monitor you while you are taking the training session.

As well as completing the training sessions three times per week, you will also be asked to complete a training workbook for each completed training sessions and share this with the researcher at the end of each two weeks (via email attachment or post). This will allow the researchers to get a sense of how enjoyable and challenging each session was.

Step 4

When you have completed your 6-week training programme, you will be invited back to the Human Movement Analysis Clinic, University of Plymouth for a final face to face re-assessment of your balance performance. For both journeys to the University, your travel expenses will be fully reimbursed by the research study budget (up to a maximum £25).

Step 5

Within one week of your face-to-face reassessment, you will be invited to attend a Zoom meeting where a researcher will interview you to help us understand your experience and opinions about taking part in our research study (both the training programme and assessments). This would take approximately 45 minutes and no longer than an hour. You may choose whether you reveal a video image within Zoom or just use audio, but regardless, only audio will be recorded and later written into text (transcribed) so that it can then be analysed.

What are the benefits of taking part?

Your participation may benefit you in terms of your balance, but this cannot be guaranteed. You will contribute to shaping future therapy research in PD.

What are the possible risks of taking part?

There is no estimated serious risk of participating in the assessments or training programme. There is nothing particularly unusual from a physiotherapy home programme perspective about the training you will undertake. Also, safety precautions have been integrated into the design of this programme but risk when training balance can never be fully prevented, and advice must be followed at all times. You may feel tired during the training session. You will have allocated rest time between tasks within the training session and we advise you not to train when you are feeling tired, as this can sometimes increase the risk of falling. You can stop the exercises at any time if you need.

The most serious risk when training balance is falling. There is a risk that you may experience a fall during the training sessions because of your daily PD-related fluctuations or losing your balance when undertaking the balance training. You can choose the days and the day times of the week. You can contact the lead researcher (NC) if you feel unsafe to do the tasks and discuss the challenge level of them.

In addition to the risk to you personally, there may be a slight risk of damage to the home environment due to the use of your wall to hang visual displays that will be used in the training sessions. These are relatively lightweight, and we will provide a non-damage hanging solution that is widely used to hang pictures and decorations in the home.

You will have a right to withdraw from the study at any time if you feel that the training is too risky or if you decide that you are not happy with the requirements of the study.

What will happen to the results of the research study?

As well as guiding future trial design the results of the study will be written into an academic thesis for Nesibe Cakmak's PhD examination, a peer-reviewed journal publication and presented at a PD research conference. A summary of study findings will be sent to the Association of Chartered Physiotherapists in Neurology secretary to circulate to all members and the PD Society to make sure that people with PD have early access to findings. No person will be individually identified in any report or publication.

What if I change my mind about taking part?

You are free to withdraw from the project at any time up until the results are analysed, without having to give a reason. The results will begin to be analysed after your last day of assessment. Withdrawing from the project will not affect your experience of health care or any future involvement that you may have with the University of Plymouth in any way.

Data handling and confidentiality

Your data will be handled in accordance with the UK-General Data Protection Regulation (UK-GDPR, 2021). University of Plymouth is the sponsor for this study. The information from participants and all collected data will be used only for the purpose of this study by the researchers.

Your name will be removed and replaced with a random pseudonymous code so that all of the information about you can linked by the research team. You will not be identifiable in any of the information that we analyse or in the results shared. After data analysis is complete, audio-records will be securely destroyed.

All remaining information will be stored securely for 10 years at the University before being securely deleted in accordance with the University of Plymouth's Research Data Policy (for more information visit: https://www.plymouth.ac.uk/uploads/production/document/path/6/6913/Research_Data_Policy.pdf).

Only the research team will have access to any personal contact information, any research data or indirectly identifiable information.

What happens if I need to complain?

If you have a complaint, you may contact the University of Plymouth's Faculty of Health's ethics committee using the email address: FOHethics@plymouth.ac.uk.

If you do not wish to complain but wish to give feedback about the study please contact the project supervisor at the email address at the end of this information sheet.

Can I get a summary of the results of this study?

If you or anyone you know would like to receive a copy of a summary of the overall findings when the study has completed, please feel free to email the principal researcher. Your email will be securely stored for this purpose and then deleted once correspondence has been sent.

Thank you for your interest in this research. Please do not hesitate to contact us if you have any questions.

Project contact details:

Name of researcher: Nesibe Cakmak PhD student

Email address: nesibe.cakmak@plymouth.ac.uk

Name of Supervisors: Dr Lisa Bunn, Dr Camille Carroll, Prof Jenny Freeman

Key supervisory contact (Email): lisa.bunn@plymouth.ac.uk

Appendix 15: Participant Information Sheet for Supporters

FREIC Code:3332

UNIVERSITY OF PLYMOUTH
Faculty of Health

Participant Information Sheet for *Supporters* of People with Parkinson's disease (PD)

Project: *Investigating the effectiveness of two different balance training programmes in people with Parkinson's disease: a feasibility study.*

Research Team: Nesibe Cakmak (Chief investigator), Dr Lisa Bunn, Dr Camille Carroll, and Prof Jenny Freeman

What is this project about?

The literature suggests that performing two tasks at once ('dual-task training') can improve balance in people with PD. However, we do not know whether some task combinations are better than others.

For example, is the use of two different physical tasks (e.g., carrying a cup while walking) better than the use of one physical task and one thinking task (e.g., singing while walking)? This question is the basis of this research project that is a part of a PhD for Nesibe Cakmak. The main objectives of this project are to assess the feasibility and acceptability of these two types of dual task training programs and their effects on the balance of people with PD.

Am I eligible to take part?

You are eligible and invited to take part in this project if you:

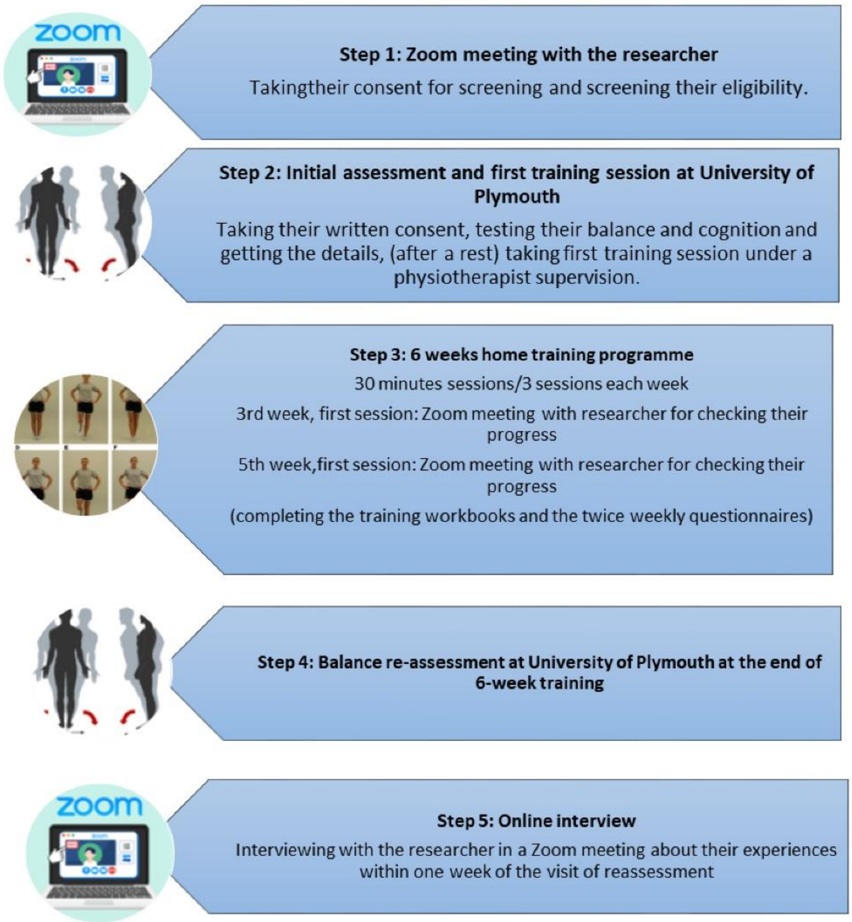
a) Are a carer, partner, family member or friend of a person diagnosed with PD.
b) Are aged 18 years or older.
c) Can understand and follow instructions within the home training video.
d) Are able to act as an exercise buddy.
e) Do **not** have any serious health conditions which can affect your balance while trying to support the person with PD during training sessions.

Do I have to take part?

No, your participation is voluntary. If you choose not to take part, this will not disadvantage you or impact the person who is diagnosed with PD's health care in any way. Once you have read the information sheet, please contact us if you have any questions that will help you make this decision.

What will happen if I take part?

Summary of the Steps



Step 1

If, after reading this information sheet you think that you are eligible and interested to take part, please contact us and we will schedule a short online (Zoom) meeting at a convenient time and date. In this Zoom meeting, we will seek your consent about your agreement to support the person with PD during the study.

Step 2

The person with PD and you will be invited to the Human Movement Analysis Clinic – located in the accessible lower floor of the Peninsula Allied Health Centre in the University of Plymouth's Northern Campus (close to Derriford Hospital). Here, a researcher will ask *both you and the person with PD to complete separate written informed consent forms*. Then they will ask the person with PD some key questions (e.g., age, medications) and assess their balance and cognitive (thinking) performance. This will take no more than an hour. The person with PD will then be randomly allocated to one of the two different training groups. Both training programmes include some balance tasks and secondary motor and cognitive tasks.

After the initial assessments, they will be offered a rest and then will undertake the first training session on the same day with the face-to-face support of a physiotherapist. This session will ensure that the training programme can be individualised to them and safe to undertake **with you** at home. During this first session, ***you will be provided with the training equipment and training workbooks for the home training session*** *and* ***trained in the use of this.*** *Training will be provided to both you and them. Also, as you are the exercise buddy, you will be taught how to position yourself safely in proximity to them and how you can handle to avoid a personal injury should a fall take place. To be clear, you will not be expected to 'catch' your training partner.* ***It is really important that you come to the first face to face session with your training partner as we will not be able to proceed without your attendance.***

Step 3

After the first face to face session in the Human Movement Analysis Clinic, you will act as an exercise buddy to the person with PD in their home, or at a place that is convenient to you both. You will be able to access training movies - the links will be available in the training booklet and QR codes will allow you to scan these links and immediately view the movie that you need each time. All the sessions will take 30 minutes each and there will be 3 sessions each week, on days that are agreed by you both, over 6 weeks. **You will follow their performance while they are doing tasks and note the correct moves/actions within the training tasks.** *You will not need to give feedback or judge your partner's performance in any way. Your role is just to support them with the understanding of the instructions, help set up the training equipment and write down some of the scores during the training tasks.* They will access an online survey which includes some questions (e.g., did they enjoy doing those tasks, did they find them difficult to do) at the end of each two weeks. At two-week intervals, at the first session of 3rd and 5th weeks, a researcher will contact them via Zoom and screen their standing ability to ensure they are still challenging their balance during training. If they are finding the tasks easy and can safely progress to a new training position to do their exercises, a remote physiotherapist will advise you both on what to do next.

As well as completing the training sessions three times per week, the person with PD will also be asked to complete the training workbooks for each completed training sessions and share with the researcher at the end of each two weeks (via email attachment or postal). This will allow the researchers to get a sense of how enjoyable and challenging each session was. *If there is a need, you may support them to complete the training workbooks.*

Step 4

When the 6-weeks training programme has been completed, the person with PD will be invited to the Human Movement Analysis Clinic, University of Plymouth for a re-assessment of their balance performance. For both journeys to the University, travel expenses will be fully reimbursed by the research study budget (up to a maximum £25).

What are the benefits of taking part?

Your participation may not benefit you directly, although involvement in the study may help to improve the balance of the person with PD that you are supporting. You will contribute to shaping future therapy research in PD.

What are the possible risks of taking part?

There is no estimated serious risk of the assessments and the balance training. There is nothing particularly unusual from a physiotherapy home programme perspective about the training undertaken. Also, safety precautions are carefully integrated into the design of this programme. However, risk when training balance can never be fully prevented, and advice must be followed at all times.

The most serious risk when training balance is falling. The person with PD may experience a fall during the training sessions because of their daily PD-related fluctuations or losing their balance during the dual-task balance training programme. You could get injured should you try to physically stop a fall, and hence we will provide training and advice on how best to manage this. You can always contact with the lead researcher (NC) if you feel there are safety concerns and discuss the options with the researcher (NC).

In addition to the risk to you personally, there may be a slight risk of damage to the home environment due to the use of your wall to hang visual displays that will be used in the training programme. These are relatively lightweight, and we will provide a non-damage hanging solution that is widely used to hang pictures and decorations in the home.

You will have a right to withdraw from the study at any time if you feel that the training is too risky or if you decide that you are not happy with the requirements of the study. However, it may affect the continuation of the undertaken training by the person with PD, unless they have another 'exercise buddy'.

What will happen to the results of the research study?

As well as guiding future trial design the results of the study will be written into an academic thesis for Nesibe Cakmak's PhD examination, a peer-reviewed journal publication and presented at a PD research conference. A summary of study findings will be sent to the Association of Chartered Physiotherapists in Neurology secretary to circulate to all members and the PD Society to make sure that people with PD have early access to findings. No person will be individually identified in any report or publication.

What if I change my mind about taking part?

You are free to withdraw from the project at any time. Withdrawing from the project will not affect your experience of care or any future involvement that you may have with the University of Plymouth in any way. *However, it may affect the continuation of the undertaken training by the person with PD, unless they have another 'exercise buddy'.*

Data handling and confidentiality

Your data will be handled in accordance with the UK-General Data Protection Regulation (UK-GDPR, 2021). University of Plymouth is the sponsor for this study.

Your personal contact information which we ask for your consent will be accessible to only the research team.

What happens if I need to complain?

If you have a complaint, you may contact the University of Plymouth's Faculty of Health's ethics committee using the email address: FOHethics@plymouth.ac.uk.

If you do not wish to complain but wish to give feedback about the study, please contact the project supervisor at the email address at the end of this information sheet.

Can I get a summary of the results of this study?

If you or anyone you know would like to receive a copy of a summary of the overall findings when the study has completed, please feel free to email the principal researcher. Your email will be securely stored for this purpose and then deleted once correspondence has been sent.

Thank you for your interest in this research. Please do not hesitate to contact us if you have any questions.

Project contact details:

Name of researcher: Nesibe Cakmak PhD student

Email address: nesibe.cakmak@plymouth.ac.uk

Name of Supervisors: Dr Lisa Bunn, Dr Camille Carroll, Prof Jenny Freeman
Key supervisory contact (Email): lisa.bunn@plymouth.ac.uk

Appendix 16: Participant Screening Form

FREIC Code:3332

Initial Screening Case Report Form

Participant ID:

Participant Initials:

Inclusion Criteria: if the answer to one of following question is NO, the participant is NOT eligible to participate.

	Yes	No	Unknown
1. Diagnosed with PD	☐	☐	☐
2. Graded as Hoehn & Yahr 2 or 3	☐	☐	☐

If the person with PD answers Unknown for second item but answers the following questions as;

Over the past week, have you usually had problems with balance and walking?	I occasionally use a walking aid, but I do not need any help from another person. OR I usually use a walking aid (cane, walker) to walk safely without falling. However, I do not usually need the support of another person.
How do you typically experience getting out of an armchair? Do you need to use the arms? Do you have difficulty? Do you sometimes fall back?	Pushes self-up from the arms of the chair without difficulty. OR Needs to push off but tends to fall back; or may have to try more than one time using the arms of the chair but can get up without help.

Please consider the second item as Yes.

If the person with PD answers Unknown for 2 but answers the following questions as;

Over the past week, have you usually had problems with balance and walking?	None or I am slightly slow or may drag a leg. I never use a walking aid. OR I usually use the support of another person to walk safely without falling.
How do you typically experience getting out of an armchair? Do you need to use the arms? Do you have difficulty? Do you sometimes fall back?	Unable to arise without help.

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Please consider the second item as No.

3. Have a score ≥24 on the Mini Mental State Examination (MMSE) ☐ ☐ ☐

If the answer is Unknown for the third item, and have answered the following questions as;

Over the past week have you had problems remembering things, following conversations, paying attention, thinking clearly, or finding your way around the house or in town?	None or impairment appreciated by patient or caregiver with no concrete interference with the patient's ability to carry out normal activities and social interactions. OR Clinically evident cognitive dysfunction, but only minimal interference with the patient's ability to carry out normal activities and social interactions. OR Cognitive deficits interfere with but do not preclude the patient's ability to carry out normal activities and social interactions.

Please consider the third item as Yes.

If the answer is Unknown for the third item, and have answered the following questions as;

Over the past week have you had problems remembering things, following conversations, paying attention, thinking clearly, or finding your way around the house or in town?	Cognitive dysfunction precludes the patient's ability to carry out normal activities and social interactions.

Please consider the third item as No.

4. Have a supporter (carer/partner/family member aged ≥18) ☐ ☐ ☐

who is willing and able to act as an exercise buddy.

5. Have an available safe exercise area in home as a definition of: A 2 metre square clear area immediately next to a wall, with no trip hazards and with the potential to place a chair within the space (for seated rests). The wall needs to be free from hanging objects or shelves and not wallpapered or featuring flaking plaster. This is to ensure safety during training and prevent unintended damage to the wall. (Closed doors may be considered as part of the 'wall' only if they can be securely shut, so that should a near-fall occur with participant's falling against the door, they would not open. They should also be guaranteed not to be opened by other household members (including pets) during the training session

(which could potentially cause a fall)). ☐ ☐ ☐

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<u>Exclusion Criteria:</u> if the answer to one of following questions is YES, the participant is NOT eligible to participate.

1.Neurological, orthopaedic and any other current medical problems other than PD which can affect the balance (such as stroke, cerebellar disorders, a vestibular impairment, a skeletal fracture (within past 6 months), severe visual impairment). ☐ ☐ ☐

2. Severe deafness ☐ ☐ ☐

3. Unable to stand independently for more than 1 minute without requiring external postural support ☐ ☐ ☐

4. Unable to communicate in English ☐ ☐ ☐

<u>Confirmation of the Participant's Eligibility</u>

Date:

Researcher's Signature:

Appendix 17: Demographic and Medical Data Collection Form

FREIC Code:3332

UNIVERSITY OF PLYMOUTH
Faculty of Health

Demographic and Medical Data Collection Sheet

Participant's study code:

Researcher Name:

Date:

Thank you for your participation. Please answer the following questions.

Section 1

Questions about you

Questions	**Answers**
What is your age in years?	
What is your gender?	
Are you currently working? (Please tick the box)	☐Employed full-time ☐Employed part-time ☐Home duties ☐Unemployed ☐Unable to work ☐Others (write in) ___________
How long have you had Parkinson's disease?	
Do you have any other health issues?	☐Hypertension ☐Cholesterol ☐Osteoarthritis ☐Others (write in) __________

What are your current medications?	
Have you had fallen in the last 3 months? (Please tick the box)	☐Yes ☐No
How many times have you had fallen in the last month? (Please check the box.)	☐2 times or less ☐more than 2 times

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Section 2 is about how Parkinson's affects your experiences of daily living.

This questionnaire will ask you about your experiences of daily living.

We are trying to be thorough, and some of these questions may therefore not apply to you now or ever. If you do not have the problem, simply mark 0 for NO.

Please read each one carefully and read all answers before selecting the one that best applies to you.

We are interested in your average or usual function over the past week including today. Some patients can do things better at one time of the day than at others. However, only one answer is allowed for each question, so please mark the answer that best describes what you can do most of the time.

You may have other medical conditions besides Parkinson's disease. Do not worry about separating Parkinson's disease from other conditions. Just answer the question with your best response.

Use only 0, 1, 2, 3, 4 for answers, nothing else. Do not leave any blanks.

Your doctor or nurse can review the questions with you, but this questionnaire is for patients to complete, either alone or with their caregivers.

Who is filling out this questionnaire (check the best answer):

☐ Patient ☐ Caregiver ☐ Patient and Caregiver in Equal Proportion

Q1. Over the past week, have you had problems with your speech?

0: Normal: Not at all (no problems).

1: Slight: My speech is soft, slurred or uneven, but it does not cause others to ask me to repeat myself.

2: Mild: My speech causes people to ask me to occasionally repeat myself, but not every day. ☐

3: Moderate: My speech is unclear enough that others ask me to repeat myself every day even though most of my speech is understood.

4: Severe: Most or all of my speech cannot be understood.

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Q2. Over the past week, have you usually had too much saliva during when you are awake or when you sleep? ☐

0: Normal: Not at all (no problems).

1: Slight: I have too much saliva, but do not drool.

2: Mild: I have some drooling during sleep, but none when I am awake.

3: Moderate: I have some drooling when I am awake, but I usually do not need tissues or a handkerchief.

4: Severe: I have so much drooling that I regularly need to use tissues or a handkerchief to protect my clothes.

Q3. Over the past week, have you usually had problems swallowing pills or eating meals? Do you need your pills cut or crushed or your meals to be made soft, chopped, or blended to avoid choking? ☐

0: Normal: No problems.

1: Slight: I am aware of slowness in my chewing or increased effort at swallowing, but I do not choke or need to have my food specially prepared.

2: Mild: I need to have my pills cut or my food specially prepared because of chewing or swallowing problems, but I have not choked over the past week.

3: Moderate. I choked at least once in the past week.

4: Severe: Because of chewing and swallowing problems, I need a feeding tube.

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Q4. Over the past week, have you usually had troubles handling your food and using eating utensils? For example, do you have trouble handling finger foods or using forks, knives, spoons, chopsticks? ☐ 0: Normal: Not at all (no problems). 1: Slight: I am slow, but I do not need any help handling my food and have not had food spills while eating. 2: Mild: I am slow with my eating and have occasional food spills. I may need help with a few tasks such as cutting meat. 3: Moderate: I need help with many eating tasks but can manage some alone. 4: Severe: I need help for most or all eating tasks.
Q5. Over the past week, have you usually had problems dressing? For example, are you slow or do you need help with buttoning, using zippers, putting on or taking off your clothes or jewellery? ☐ 0: Normal: Not at all (no problems). 1: Slight: I am slow, but I do not need help. 2: Mild: I am slow and need help for a few dressing tasks (buttons, bracelets). 3: Moderate: I need help for many dressing tasks. 4: Severe: I need help for most or all dressing tasks.

Q6. Over the past week, have you usually been slow or do you need help with washing, bathing, shaving, brushing teeth, combing your hair, or with other personal hygiene? ☐ 0: Normal: Not at all (no problems). 1: Slight: I am slow, but I do not need any help. 2: Mild: I need someone else to help me with some hygiene tasks. 3: Moderate: I need help for many hygiene tasks.

4: Severe: I need help for most or all of my hygiene tasks.

Q7. Over the past week, have people usually had trouble reading your handwriting? ☐

0: Normal: Not at all (no problems).

1: Slight: My writing is slow, clumsy or uneven, but all words are clear.

2: Mild: Some words are unclear and difficult to read.

3: Moderate: Many words are unclear and difficult to read.

4: Severe: Most or all words cannot be read.

Q8. Over the past week, have you usually had trouble doing your hobbies or other things that you like to do? ☐

0: Normal: Not at all (no problems).

1: Slight: I am a bit slow but do these activities easily.

2: Mild: I have some difficulty doing these activities.

3: Moderate: I have major problems doing these activities, but still do most.

4: Severe: I am unable to do most or all of these activities.

Q9. Over the past week, do you usually have trouble turning over in bed? ☐

0: Normal: Not at all (no problems).

1: Slight: I have a bit of trouble turning, but I do not need any help.

2: Mild I have a lot of trouble turning and need occasional help from someone else.

3: Moderate: To turn over I often need help from someone else.

4: Severe: I am unable to turn over without help from someone else.

Q10. Over the past week, have you usually had shaking or tremor? ☐

0: Normal: Not at all. I have no shaking or tremor.

1: Slight: Shaking or tremor occurs but does not cause problems with any activities.

2: Mild: Shaking or tremor causes problems with only a few activities.

3: Moderate: Shaking or tremor causes problems with many of my daily activities.

4: Severe: Shaking or tremor causes problems with most or all activities.

Q11. Over the past week, have you usually had trouble getting out of bed, a car seat, or a deep chair? ☐

0: Normal: Not at all (no problems).

1: Slight: I am slow or awkward, but I usually can do it on my first try.

2: Mild: I need more than one try to get up or need occasional help.

3: Moderate: I sometimes need help to get up, but most times I can still do it on my own.

4: Severe: I need help most or all of the time.

Q12. Over the past week, have you usually had problems with balance and walking? ☐

0: Normal: Not at all (no problems).

1: Slight: I am slightly slow or may drag a leg. I never use a walking aid.

2: Mild: I occasionally use a walking aid, but I do not need any help from another person.

3: Moderate: I usually use a walking aid (cane, walker) to walk safely without falling. However, I do not usually need the support of another person.

4: Severe: I usually use the support of another person to walk safely without falling.

Q13. Over the past week, on your usual day when walking, do you suddenly stop or freeze as if your feet are stuck to the floor? ☐

0: Normal: Not at all (no problems).

1: Slight: I briefly freeze, but I can easily start walking again. I do not need help from someone else or a walking aid (cane or walker) because of freezing.

2: Mild: I freeze and have trouble starting to walk again, but I do not need someone's help or a walking aid (cane or walker) because of freezing.

3: Moderate: When I freeze, I have a lot of trouble starting to walk again and, because of freezing, I sometimes need to use a walking aid or need someone else's help.

4: Severe: Because of freezing, most or all of the time, I need to use a walking aid or someone's help.

Thank you for your time and attention in completing this questionnaire!

Appendix 18: C-DTT and M-DTT Intervention Protocols

FREIC Code:3332

C-DTT Protocol

Instruction for the Standard Warm-up Session for Participants

Time Stamp per session	Tasks (under the comfortable standing position)
45 sec	Imagine you have songbirds on your shoulders, lift the birds up to chirp in your ear, both raising up at the same time once every 2 seconds for the 45 sec duration.
15 sec Rest	
45 sec	Imagine you have songbirds on your shoulders, lift the birds up to chirp in your ear, one at a time this time but once every second now for the 45 sec duration.
15 sec Rest	
45 sec	Imagining you have a shopping bag in each arm, please raise and lower them (both at the same time) at about a rate of one lift every 2 seconds second for the 45 seconds.
15 sec Rest	
45 sec	Imagining you have a shopping bag in each arm, please raise and lower this, alternating each arm at about a rate of one lift every second for the 45 seconds.
1 min rest	

Week 1-2

Equipment: exercise mat, tablet

Time Stamp per session	Balance task (Weeks 1-2)	Secondary cognitive task (Week 1)	Secondary cognitive task (Week 2)
Warm-up			
Block A			
90 sec	Standing on individualised green line	Looking at the shapes on the screen and answering the questions (e.g., which side has more squares?)	Looking at the shapes on the screen and answering the questions (e.g., which side has more squares?)
70 sec	Toe tapping with right foot – forward, middle, back	Counting upwards from 0 but every time when reached a number that has a 0 or 5 in it, instead of that number saying the word ‘Happy’!	Counting upwards from 0 but every time when reached a number that has a 0 or 5 in it, instead of that number saying the word ‘Happy’!

70 sec	Toe tapping with left foot – forward, middle, back	Counting upwards from 0 but every time when reached a number that is divisible by 3, instead of that number saying the word 'Happy'!	Counting upwards from 0 but every time when reached a number that is divisible by 3, instead of that number saying the word 'Happy'!
30 sec rest			
2 min	Marching in comfortable position	Reading carefully two tongue twists in 30 seconds and repeat it twice in 45 sec each.	Looking at the pictures and answer the questions about each picture.
1 min REST (if needed-seated rest)			
Block B			
2 min	Standing on individualised green line	Listening 1 min-mini stories and answering the questions about it in 40 sec.	Looking at the pictures carefully to memorise details and answer the relevant questions.
2 min	Heel dig right foot – forward, middle	Listening 1 min-mini stories and answering the questions about it in 40 sec.	Looking at the pictures carefully to memorise details and answer the relevant questions.
30 sec			
2 min	Heel digging left foot – forward, middle	Listening 1 min-mini stories and answering the questions about it in 40 sec.	Looking at the pictures carefully to memorise details and answer the relevant questions.
2 min	Knee bending	Listening 1 min-mini stories and answering the questions about it in 40 sec.	Looking at the pictures carefully to memorise details and answer the relevant questions.
Cool down			

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Week 3-4

Equipment: Exercise mat, tablet

	Week 3			Week 4	
Time stamp	Balance task	Secondary task	Time stamp	Balance task	Secondary task
Warm-up					
Block A					
90 sec	Standing individualised yellow line (if decided to progress)	looking at the shapes and colours on the screen and answering the questions (e.g., which side has more squares, which side has more red shapes?)	90 sec	Standing individualised yellow line (if decided to progress)	looking at the shapes and colours on the screen and answering the questions (e.g., which side has more squares, which side has more red shapes?)
70 sec	Toe tapping in clock circle with right foot	Counting backwards from 100 but every time when reach a number that has a 0 or 5 in it, instead of that number saying the word 'Happy'!	70 sec	Toe tapping in clock circle with right foot	Counting backwards from 100 but every time when reach a number that has a 0 or 5 in it, instead of that number saying the word 'Happy'!
70 sec	Toe tapping in clock circle with left foot	Counting backwards from 100 but every time when reach a number that is divisible by 3, instead of that number saying the word 'Happy'!	70 sec	Toe tapping in clock circle with left foot	Counting backwards from 100 but every time when reach a number that is divisible by 3, instead of that number saying the word 'Happy'!

30 sec rest			30 sec rest		
2 min	Marching-feet are together	Reading carefully two tongue twists in 30 seconds and repeat it twice in 45 sec each.	2 min	Marching-feet are together	Looking at the pictures carefully for 30 sec and answering the questions about it.
1 min rest (seat option)			1 min rest (seat option)		
Block B					
2min 40 sec	Standing individualised yellow line (if decided to progress)	Listening 90 sec-mini stories and answering the questions about it in 40 sec.	2 min	Standing individualised yellow line (if decided to progress)	Looking at the pictures carefully for 40 seconds. Then, trying to remember as much details as and saying to training partner for 1 minute.
15 sec rest			2 min	Face to wall-partial side lunge with right leg	Looking at the pictures carefully for 40 seconds. Then, trying to remember as much details as and saying to training partner for 1 minute.
2min 40 sec	partial lunge with left leg (leave the wall on right hand side)–	Listening 90 sec-mini stories and answering the questions about it in 40 sec.	30 sec rest		
15 sec rest			2 min	Face to wall-partial side lunge with left leg	Looking at the pictures carefully for 40 seconds. Then, trying to remember as much details as and saying to training

					partner for 1 minute.
2 min 40 sec	Face right (leave the wall on your left-hand side)- partial forward lunge	Listening 90 sec-mini stories and answering the questions about it in 40 sec.	2 min	Face to wall- partial side lunge with both left and right leg consecutively	Looking at the pictures carefully for 40 seconds. Then, trying to remember as much details as and saying to training partner for 1 minute.
Cool Down					

Weeks 5-6

Equipment: Exercise mat, tablet

	Week 5			**Week 6**	
Time stamp	Balance task	Secondary task	Time stamp	Balance task	Secondary task
Warm-up					
Block A					
90 sec	Standing individualised pink line (if decided to progress)	looking at the words and colours on the screen and answering the questions (e.g., how many you see word “Red”? how many you see “red words”?)	90 sec	Standing individualised pink line (if decided to progress)	looking at the words and colours on the screen and answering the questions (e.g., how many you see word “Red”? how many you see “red words”?)
70 sec	Stepping left foot- forward-middle-back-initial position	counting backwards from 100 but every time when reach a number that has a 0 or 7 in it, instead of that number saying the word ‘Happy’!	70 sec	Stepping left foot- forward-middle-back-initial position	counting backwards from 100 but every time when reach a number that has a 0 or 7 in it, instead of that number saying the word ‘Happy’!

70 sec	Stepping right foot- forward-middle-back-initial position	Counting backwards from 100 but every time when reach a number that is divisible by 3, instead of that number saying the word 'Happy', and a number that is divisible by both 3 and 5 (divisible by 15), instead of that number saying the word 'Birthday'!	70 sec	Stepping right foot- forward-middle-back-initial position	Counting backwards from 100 but every time when reach a number that is divisible by 3, instead of that number saying the word 'Happy', and a number that is divisible by both 3 and 5 (divisible by 15), instead of that number saying the word 'Birthday'!
30 sec rest			30 sec rest		
2 min	Marching-feet are together	Reading carefully two tongue twists in 30 seconds and repeat it twice in 45 sec each.	2 min	Marching-feet are together	Looking at the pictures carefully for 30 sec and answering the questions about it.
1 min rest (seat option)			1 min rest (seat option)		
Block B					
3 min	Standing individualised pink line (if decided to progress)	Watching the video clips carefully and answering the questions about it.	3 min	Standing individualised pink line (if decided to progress)	Watching the video clips carefully and answering the questions about it.
15 sec rest			15 sec rest		

3 min	Face right (leave the wall on your left-hand side)- full forward lunge with right leg	Watching the video clips carefully and answering the questions about it.	3 min	Face to wall- full side lunge with right leg	Watching the video clips carefully and answering the questions about it.
15 sec rest			15 sec rest		
3 min	Face left (leave the wall on your right-hand side)- full forward lunge with right leg	Watching the video clips carefully and answering the questions about it.	3 min	Face to wall- full side lunge with right leg	Watching the video clips carefully and answering the questions about it.
Cool-down					

N. B= video clips were brought from the YouTube Channel "Summit or Nothing" with the permission of the channel owner https://www.youtube.com/@SummitOrNothing .

FREIC Code:3332

Instruction for the Standard Cool-down Sessions for Participants

Time Stamp per session	Tasks (under the comfortable standing position)
30 sec	take your first arm and hold out your hand and gently bring your other hand in and stretch very gently along the whole length of your arm. Just keep it there for another 10 to 15 seconds. Relax. Do the same for other hand.
15 sec Rest	
30 sec	stretching the arms now by taking one arm up and bringing the other on the back of your head. Just keep it there for another 10 to 15 seconds. Relax. Do the same for other side.
15 sec Rest	
30 sec	gently bring your arms around, bring your hands together, and create a nice, big shape with your arms stretching out all of those back muscles, especially the position to try and really drop your shoulders down as you do this, if you can. keep it there for another 10 to 15 seconds. Relax. gently touch your hands to the front of your shoulders. And imagine a force pushing back those shoulders, not physically, but just imaginary. Try and bring your shoulder blades at the back here down and together.
15 sec Rest	
30 sec	bring your chin down to your chest. And gently up trying to come up to. Just a gentle movement of the head now. Up and down for 10 to 15 sec. And just a gentle turn of the head from side to side for 10 to 15 sec.
15 sec rest	
30 sec	Just give your ankles a little wiggle. And tap your toes on the floor and just roll back.

FREIC Code:3332

M-DTT Protocol

Instruction for the Standard Warm-up Session for Participants

Time Stamp per session	Tasks (under the comfortable standing position)
45 sec	Imagine you have songbirds on your shoulders, lift the birds up to chirp in your ear, both raising up at the same time once every 2 seconds for the 45 sec duration.
15 sec Rest	
45 sec	Imagine you have songbirds on your shoulders, lift the birds up to chirp in your ear, one at a time this time but once every second now for the 45 sec duration.
15 sec Rest	
45 sec	Imagining you have a shopping bag in each arm, please raise and lower them (both at the same time) at about a rate of one lift every 2 seconds second for the 45 seconds.
15 sec Rest	
45 sec	Imagining you have a shopping bag in each arm, please raise and lower this, alternating each arm at about a rate of one lift every second for the 45 seconds.
1 min rest	

Week 1-2

Equipment: Exercise mat, tablet, two soft balls, Lego plates (placed on the wall x5)

Time Stamp per session	Balance task	Secondary motor task
Warm-up		
Block A		
90 sec	Standing	Alternating a soft ball (e.g., stress ball) between hands in a comfortable position.
70 sec	Toe tapping with right foot – forward, middle, back	Alternating same object between hands over your head.
70 sec	Toe tapping with left foot – forward, middle, back	Alternating two soft balls holding one in each hand in a comfortable position.
30 sec rest		

2 min	Marching in comfortable position	Alternating two soft balls holding in each hand over your head.
1 min REST (if needed-seated rest)		
Block B		
2 min	Standing	Touching on the target 1 mounted in the middle of the wall with respectively your right and left hands.
2 min	Heel dig right foot – forward, middle	Touching on the target 2 mounted in the upper-right hand side of the wall with your right hand.
30 sec		
2 min	Heel digging left foot – forward, middle	Touching on the target 3 mounted in the upper-left hand side of the wall with your left hand.
2 min	Knee bending	Touching on the target 4 mounted in the lower-right hand side of the wall with right hand and target 5 mounted in lower-left hand side of the wall with your left hand, respectively.
Cool down		

Week 3-4

Equipment: exercise mat, tablet, soft ball, one shelf (placed on the wall), Lego plates (placed on the wall x5), Lego bricks (4x2 sized) in the shelf.

	Week 3			**Week 4**	
Time stamp	Balance task	Secondary task	Time stamp	Balance task	Secondary task
Block A					

90 sec	Standing	Fully grip the soft ball with your right hand- hold 5 sec-loose it.	90 sec	Standing	Fully grip the soft ball with your left hand-hold 5 sec-loose it.
70 sec	Toe tapping in clock circle with right foot	Gripping with your right index finger and right thumb the soft ball-hold 5 sec-loose it. Do the same with your other right-hand fingers respectively.	70 sec	Toe tapping in clock circle with right foot	Gripping with your right index finger and right thumb the soft ball-hold 5 sec-loose it. Do the same with your other right-hand fingers respectively.
70 sec	Toe tapping in clock circle with left foot	Gripping with your left index finger and left thumb the soft ball-hold 5 sec-loose it. Do the same with your other left-hand fingers respectively.	70 sec	Toe tapping in clock circle with left foot	Gripping with your left index finger and left thumb the soft ball-hold 5 sec-loose it. Do the same with your other left-hand fingers respectively.
30 sec rest			30 sec rest		
2 min	Marching-feet are together	press the soft ball with your left-hand thumb-hold it 5 sec-loose it	2 min	Marching-feet are together	press the soft ball with your right-hand thumb-hold it 5 sec-loose it
1 min rest (seat option)			1 min rest (seat option)		
Block B					
2min 40 sec	Standing	Picking up the 4x2 dots Lego bricks from the shelf mounted on the wall with your right hand. Then put them **randomly** onto the target 1	2 min	Standing	Picking up the 4x2 dots Lego bricks from the shelf mounted on the wall with your right hand. Then put them in **a line starting the upper left or right corner** of the target 1 mounted

		mounted in the middle of the wall with your right hand. And do the same thing with your left hand. Continue to do this task right hand and left hand respectively.			in the middle of the wall with your right hand. And do the same thing with your left hand. Continue to do this task right hand and left hand respectively.
15 sec rest			2 min	Face to wall- partial side lunge with right leg	Picking up the 4x2 dots Lego bricks from the shelf mounted on the wall with your right hand. Then put them **in line starting the upper right corner** of the target 4 mounted in the lower-right hand side of the wall with your right hand.
2min 40 sec	partial lunge with left leg (leave the wall on right hand side)–	Picking up the 4x2 dots Lego bricks from the shelf mounted on the wall with your left hand. Then put them **randomly** onto the target 4 mounted in the lower-right hand side of the wall with your right hand.	30 sec rest		
15 sec rest			2 min	Face to wall- partial side lunge with left leg	Picking up the 4x2 dots Lego bricks from the shelf mounted on the wall with your left hand. Then put them **in line starting the upper left corner** onto the target 5

					mounted in the lower-right hand side of the wall with your left hand.
2 min 40 sec	Face right (leave the wall on your left-hand side)- partial forward lunge	Picking up the 4x2 dots Lego bricks from the shelf mounted on the wall with your left hand. Then put them **randomly** onto the target 5 mounted in the lower-right hand side of the wall with your left hand.	2 min	Face to wall- partial side lunge with both left and right leg consecutively	Picking up the 4x2 dots Lego bricks from the shelf mounted on the wall with your right hand. Then put them **in line** onto the target 5 mounted in the lower-right hand side of the wall with your right hand whilst doing right leg lunge. Do the same thing with left hand onto target 4 whilst left leg lunge. Continue to do this task with this order.
Cool Down			Cool down		

Week 5-6

Equipment: exercise mat, tablet, fidget (popping) toy, one shelf (placed on the wall), Lego plates (placed on the wall x5), Lego bricks (2x2 sized) in the shelf.

Time stamp	Balance task	Secondary task
Block A		
90 sec	Standing	Holding a fidget toy with your right hand and popping the bubbles with your left hand.
70 sec	Stepping left foot- forward-middle-back-initial position	Holding the same fidget toy with your left hand and re-popping the same fidget toy with your right hand.
70 sec	Stepping right foot- forward-middle-back-initial position	Holding the same fidget toy with your right hand and popping the same fidget toy with your left hand.
30 sec rest		

2 min	Marching- foot are in shoulder width		Holding the same fidget toy with your right hand and re-popping the same fidget toy with your left hand.	
1 min rest				
Block B				
	Week 5	Week 6	Week 5	Week 6
3 min	Standing	Standing	Picking up the 2x2 dot Lego bricks from the shelf mounted on the wall with your right hand. Then put them **randomly** onto the target 1 mounted in the middle of the wall with your right hand. And do the same thing with your left hand. Continue to do this task right hand and left hand respectively.	Picking up the 2x2 dot Lego bricks from the shelf mounted on the wall with your right hand. Then put them in **a line starting the upper left or right corner** of the target 1 mounted in the middle of the wall with your right hand. And do the same thing with your left hand. Continue to do this task right hand and left hand respectively.
15 sec rest				
3 min	Face right (leave the wall on your left-hand side)- full forward lunge with right leg	Face to wall- full side lunge with right leg	Picking up the 2x2 dot Lego bricks from the shelf mounted on the wall with your left hand. Then put them **randomly** onto the target 4 mounted in the lower-right hand side of the wall with your right hand.	Picking up the 2x2 dot Lego bricks from the shelf mounted on the wall with your right hand. Then put them **in line starting the upper right corner** of the target 4 mounted in the lower-right hand side of the wall with your right hand.
15 sec rest				

3 min	Face left (leave the wall on your right-hand side)- full forward lunge with right leg	Face to wall- full side lunge with right leg	Picking up the 2x2 dot Lego bricks from the shelf mounted on the wall with your left hand. Then put them **randomly** onto the target 5 mounted in the lower-right hand side of the wall with your left hand.	Picking up the 2x2 Lego bricks from the shelf mounted on the wall with your left hand. Then put them **in line starting the upper left corner** onto the target 5 mounted in the lower-right hand side of the wall with your left hand.
Cool down				

Instruction for the Standard Cool-down Sessions for Participants

Time Stamp per session	Tasks (under the comfortable standing position)
30 sec	take your first arm and hold out your hand and gently bring your other hand in and stretch very gently along the whole length of your arm. Just keep it there for another 10 to 15 seconds. Relax. Do the same for other hand.
15 sec Rest	
30 sec	stretching the arms now by taking one arm up and bringing the other on the back of your head. Just keep it there for another 10 to 15 seconds. Relax. Do the same for other side.
15 sec Rest	
30 sec	gently bring your arms around, bring your hands together, and create a nice, big shape with your arms stretching out all of those back muscles, especially the position to try and really drop your shoulders down as you do this, if you can. keep it there for another 10 to 15 seconds. Relax. gently touch your hands to the front of your shoulders. And imagine a force pushing back those shoulders, not physically, but just imaginary. Try and bring your shoulder blades at the back here down and together.
15 sec Rest	
30 sec	bring your chin down to your chest. And gently up trying to come up to. Just a gentle movement of the head now. Up and down for 10 to 15 sec. And just a gentle turn of the head from side to side for 10 to 15 sec.
15 sec rest	
30 sec	Just give your ankles a little wiggle. And tap your toes on the floor and just roll back.

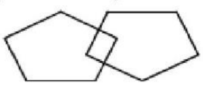
Appendix 19: Mini Mental State Examination Test (MMSE)

FREIC Code:3332

Mini-Mental State Examination (MMSE)

Patient's Study Code:______________________________ Date: ____________

Instructions: Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now? State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then the instructor asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible.
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

Appendix 20: Safety Report

FREIC Code:3332

NHS
Health Research
Authority

Report of Adverse or Serious Adverse Event (For all studies except Clinical Trials of Investigational Medicinal Products) – adapted for use in "The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: a feasibility study of a randomised clinical trial".

The Chief Investigator (CI) should report any AE/SAE that is both related to the research procedures and is unexpected. The report should be emailed to the Research Ethics Committee that gave a favourable opinion of the research within 15 days of the CI becoming aware of the event.

ADVERSE EVENT (AE): Any untoward medical occurrence in a patient or clinical trial subject administered [an intervention] and which does not necessarily have a causal relationship with this treatment.

SERIOUS ADVERSE EVENT (SAE): Any adverse event or adverse reaction that results in death, is life-threatening, requires hospitalisation or prolongation of existing hospitalisation, results in persistent or significant disability or incapacity.*

https://www.ct-toolkit.ac.uk/glossary/?letter=S&postcategory=-1

Details of the Chief Investigator

Question	Answer
Name:	Nesibe Cakmak
Address:	
Telephone:	
Email:	nesibe.cakmak@plymouth.ac.uk

Details of the study

Question	Answer
Full title of study:	The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: a feasibility study of a randomised clinical trial.
Name of REC:	University of Plymouth FREIC

FREIC Code:3332

REC reference number:	3332
IRAS ID:	n/a
Research sponsor:	University of Plymouth, Sarah Jones (rep)
Sponsor's reference for this report: (If applicable)	PEOS 3332

Type of event

Please categorise this event, ticking all appropriate options:

SERIOUS ADVERSE EVENT

Death ☐

Life threatening ☐

Hospitalisation or prolongation of existing hospitalisation ☐

Persistent or significant disability or incapacity ☐

Other ☐

ADVERSE EVENT

Near miss fall ☐

Fall ☐

Dizziness ☐

Other ☐

FREIC Code:3332

Circumstances of event

Question	Answer
Date of AE/SAE:	
Location:	
Describe the circumstances of the event: (Attach copy of detailed report if necessary)	
What is your assessment of the implications, if any, for the safety of study participants and how will these be addressed?	

Declaration

Signature of Chief Investigator:

Print name:

Date of submission:

Acknowledgement of receipt by FREIC (please insert name):

The [ ] Research Ethics Committee acknowledges receipt of the above.

Signed:

Name:

Position on FREIC:

Date:

Signed original to be sent back to Chief Investigator (or other person submitting report) Copy to be kept for information by FREIC.

Appendix 21: 5-point Likert Scale

FREIC Code:3332

We would like to learn your opinion about the training programme at the end of Week 2, Week 4 and Week 6. This is the first questionnaire asking your opinions for your first two weeks training experience. Completion of the questionnaire takes approximately 10 minutes. Your name will be removed and replaced with a random pseudonymous code so that all of the information about you can linked by the research team. You will not be identifiable in any of the information that we analyse or in the results shared.

Intervention Acceptability Questionnaire

At the end of 2nd week

For the following statements, think back over the PAST TWO WEEKS and please answer the questions posed, using a tick in the checkbox to the side of your question that best represents your opinion:

How enjoyable did you find training in your home environment?	Not enjoyable at all ☐	Mostly not enjoyable ☐	Unsure ☐	Mostly enjoyable ☐	Completely enjoyable ☐
How enjoyable were the balance tasks?	Not enjoyable at all ☐	Mostly not enjoyable ☐	Unsure ☐	Mostly enjoyable ☐	Completely enjoyable ☐

How enjoyable were the secondary tasks?	Not enjoyable at all ☐	Mostly not enjoyable ☐	Unsure ☐	Mostly enjoyable ☐	Completely enjoyable ☐
How confident were you to train in your own home?	Not confident at all ☐	Mostly not confident ☐	Unsure ☐	Mostly confident ☐	Completely confident ☐
How understandable was the training videos?	Not understandable at all ☐	Mostly not understandable ☐	Unsure ☐	Mostly understandable ☐	Completely understandable ☐
How understandable was the training workbook to complete?	Not understandable at all ☐	Mostly not understandable ☐	Unsure ☐	Mostly understandable ☐	Completely understandable ☐

How challenging was it to set-up the wall-tablet?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging was it to use the technology?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging did you find to keep your feet in the correct position?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging were the balance tasks?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging were the secondary tasks?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐

How safe did you feel training in your own home?	Not safe at all ☐	Mostly not safe ☐	Unsure ☐	Mostly safe ☐	Completely safe ☐
How tiring were the tasks?	Not tiring at all ☐	Mostly not tiring ☐	Unsure ☐	Mostly tiring ☐	Completely tiring ☐
Would you recommend this training programme for people with PD?	I would not recommend this at all ☐	I would mostly not recommend this ☐	Unsure ☐	I would mostly recommend this ☐	I would completely recommend this ☐

Please add any comments and suggestions you may have about the training programme (optional):

At the end of 4th and 6th weeks

For the following statements, think back over the PAST TWO WEEKS and please answer the questions posed, using a tick in the checkbox to the side of your question that best represents your opinion:

How enjoyable did you find training in your home environment?	Not enjoyable at all ☐	Mostly not enjoyable ☐	Unsure ☐	Mostly enjoyable ☐	Completely enjoyable ☐
How enjoyable were the balance tasks?	Not enjoyable at all ☐	Mostly not enjoyable ☐	Unsure ☐	Mostly enjoyable ☐	Completely enjoyable ☐
How enjoyable were the secondary tasks?	Not enjoyable at all ☐	Mostly not enjoyable ☐	Unsure ☐	Mostly enjoyable ☐	Completely enjoyable ☐

FREIC Code:3332

How confident were you to train in your own home?	Not confident at all ☐	Mostly not confident ☐	Unsure ☐	Mostly confident ☐	Completely confident ☐
How understandable were the training videos?	Not understandable at all ☐	Mostly not understandable ☐	Unsure ☐	Mostly understandable ☐	Completely understandable ☐
How understandable was the training workbook to complete?	Not understandable at all ☐	Mostly not understandable ☐	Unsure ☐	Mostly understandable ☐	Completely understandable ☐
How challenging was it to set-up the wall-tablet?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐

FREIC Code:3332

How challenging was it to use the technology?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging did you find to keep your feet in the correct position?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging were the balance?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging were the secondary tasks?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐
How challenging did you find to do the tasks in the past two weeks compare to the previous two weeks?	Not challenging at all ☐	Mostly not challenging ☐	Unsure ☐	Mostly challenging ☐	Completely challenging ☐

How safe did you feel training in your own home?	Not safe at all ☐	Mostly not safe ☐	Unsure ☐	Mostly safe ☐	Completely safe ☐
How tiring were the tasks?	Not tiring at all ☐	Mostly not tiring ☐	Unsure ☐	Mostly tiring ☐	Completely tiring ☐
Would you recommend this training programme for people with PD?	I would not recommend this at all ☐	I would mostly not recommend this ☐	Unsure ☐	I would mostly recommend this ☐	I would completely recommend this ☐

Please add any comments and suggestions you may have about the training programme (optional):

I am very appreciative of the time you have taken to assist in our analysis and commit to utilizing the information gained to contemplate and implement worthwhile improvements.

Once again, I am extremely grateful for your contributing your valuable time, your honest information, and your thoughtful suggestions.

Appendix 22: Training Workbook

Training workbook and optional journal

Participant initials:

Training Workbook

Instructions page

Please put your score from each training task in the tables in this document. Each training day (session) relates to a different column in the table. We have added one day's worth of scores in our example table below as an exemplar set of scores to show you what this may look like. At the bottom of the column, we would like you to indicate how enjoyable you found today's tasks and how challenging they were.

How enjoyable have you found today's tasks? Choose a number that relates to how you feel and write in the table below: [ ]

How challenging have you found today's tasks? Choose a number that relates to how you feel o choose from and write in the table below: [ ]

Did you fall or stumble? If so, how many times did you fall during the sessions? Number of falls: How many times you stumble or nearly fall (lost your balance but did not fall)? Number of near falls:

		Week number:			Week number:		
	Session 0 (28th Feb, Tuesday)	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
Block A:	5						
Block B:	7						
Enjoyment rating:	6/10						
Difficulty rating:	2/10						
Number of falls:	0						
Number of near falls:	1						

Please note, your safety and wellbeing is of the highest importance. If you (i) are experiencing difficulties or (ii) have injured yourself or (iii) if the research is negatively affecting your health or life in any way, please contact the research team as soon as safely possible to do so: nesibe.cakmak@plymouth.ac.uk

Weeks 1-2

Please put your score from each training task in the table below.

YOUR SCORE CARD:

	Week number 1			Week number 2		
	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
Block A:						
Block B:						
Enjoyment rating:						
Difficulty rating:						
Number of fall:						
Number of near fall:						

Please note, your safety and wellbeing is of the highest importance. If you (i) are experiencing difficulties or (ii) have injured yourself or (iii) if the research is negatively affecting your health or life in any way, please contact the research team as soon as safely possible to do so:
nesibe.cakmak@plymouth.ac.uk

Optional journal weeks 1-2

Do you have anything else to note or tell the research team about? If so, please write it down next to today's date.

DATE:	JOURNAL ENTRY:
	…………………………………………………………………………………………
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Weeks 3-4

Please put your score from each training task in the table below.

YOUR SCORE CARD:

	Week number 3			Week number 4		
	Session 7	Session 8	Session 9	Session 10	Session 11	Session 12
Block A:						
Block B:						
Enjoyment rating:						
Difficulty rating:						
Number of fall:						
Number of near fall:						

Optional journal weeks 3-4

Do you have anything else to note or tell the research team about? If so, please write it down below next to today's date.

DATE:	JOURNAL ENTRY:
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Weeks 5-6

Please put your score from each training task in the table below.

YOUR SCORE CARD:

	Week number 5			Week number 6		
	Session 13	Session 14	Session 15	Session 16	Session 17	Session 18
Block A:						
Block B:						
Enjoyment rating:						
Difficulty rating:						
Number of fall:						
Number of near fall:						

Optional journal weeks 5-6

Do you have anything else to note or tell the research team about? If so, please write it down below next to today's date.

DATE:	JOURNAL ENTRY:
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Appendix 23: Mini Balance Evaluation Systems Test (MiniBESTest)

FREIC Code:3332

Mini-BESTest

Participant ID:
Researcher Name:
Date:

ANTICIPATORY ***SUB SCORE: /6***

1. SIT TO STAND

Instruction: ***"****Cross your arms across your chest. Try not to use your hands unless you must. Do not let your legs lean against the back of the chair when you stand. Please stand up now.****"***

(2) Normal: Comes to stand without use of hands and stabilizes independently.
(1) Moderate: Comes to stand WITH use of hands on first attempt.
(0) Severe: Unable to stand up from chair without assistance OR needs several attempts with use of hands.

2. RISE TO TOES

Instruction: *"Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I will count out loud to 3 seconds. Try to hold this pose for at least 3 seconds. Look straight ahead. Rise now."*

(2) Normal: Stable for 3 s with maximum height.
(1) Moderate: Heels up, but not full range (smaller than when holding hands), OR noticeable instability for 3 s.
(0) Severe: < 3 s.

3. STAND ON ONE LEG

Instruction: "Look straight ahead. Keep your hands on your hips. Lift your leg off of the ground behind you without touching or resting your raised leg upon your other standing leg. Stay standing on one leg as long as you can. Look straight ahead. Lift now."
Left: *Time in Seconds Trial 1:_____Trial 2:_____*
(2) Normal: 20 s.
(1) Moderate: < 20 s.
(0) Severe: Unable.
Right: *Time in Seconds Trial 1:_____Trial 2:_____*
(2) Normal: 20 s.
(1) Moderate: < 20 s.
(0) Severe: Unable
To score each side separately use the trial with the longest time.
To calculate the sub-score and total score use the side [left or right] with the lowest numerical score [i.e., the worse side].

REACTIVE POSTURAL CONTROL ***SUB SCORE: /6***

4. COMPENSATORY STEPPING CORRECTION- FORWARD
Instruction: "Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall."

(2) Normal: Recovers independently with a single, large step (second realignment step is allowed).
(1) Moderate: More than one step used to recover equilibrium.
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously.

5. COMPENSATORY STEPPING CORRECTION- BACKWARD

Instruction: "Stand with your feet shoulder width apart, arms at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall."

(2) Normal: Recovers independently with a single, large step.
(1) Moderate: More than one step used to recover equilibrium.
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously.

6. COMPENSATORY STEPPING CORRECTION- LATERAL

Instruction: "Stand with your feet together, arms down at your sides. Lean into my hand beyond your sideways limit. When I let go, do whatever is necessary, including taking a step, to avoid a fall."
Left
(2) Normal: Recovers independently with 1 step (crossover or lateral OK).
(1) Moderate: Several steps to recover equilibrium.
(0) Severe: Falls or cannot step.

Right
(2) Normal: Recovers independently with 1 step (crossover or lateral OK).
(1) Moderate: Several steps to recover equilibrium.
(0) Severe: Falls or cannot step.
Use the side with the lowest score to calculate sub-score and total score.

SENSORY ORIENTATION ***SUB SCORE: /6***

7. STANCE (FEET TOGETHER); EYES OPEN, FIRM SURFACE
Instruction: "Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Be as stable and still as possible, until I say stop."
Time in seconds: ________

(2) Normal: 30 s.
(1) Moderate: < 30 s.
(0) Severe: Unable.

8. STANCE (FEET TOGETHER); EYES CLOSED, FOAM SURFACE

Instruction: "Step onto the foam. Place your hands on your hips. Place your feet together until almost touching. Be as stable and still as possible, until I say stop. I will start timing when you close your eyes."

Time in seconds: ________
(2) Normal: 30 s.
(1) Moderate: < 30 s.
(0) Severe: Unable.

9. INCLINE- EYES CLOSED

Instruction: "Step onto the incline ramp. Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart and have your arms down at your sides. I will start timing when you close your eyes."

Time in seconds: ________
(2) Normal: Stands independently 30 s and aligns with gravity.
(1) Moderate: Stands independently <30 s OR aligns with surface.
(0) Severe: Unable.

DYNAMIC GAIT ***SUB SCORE: /10***

10. CHANGE IN GAIT SPEED

Instruction: "Begin walking at your normal speed, when I tell you 'fast', walk as fast as you can. When I say 'slow', walk very slowly."

(2) Normal: Significantly changes walking speed without imbalance.
(1) Moderate: Unable to change walking speed or signs of imbalance.
(0) Severe: Unable to achieve significant change in walking speed AND signs of imbalance.

11. WALK WITH HEAD TURNS – HORIZONTAL

Instruction: "Begin walking at your normal speed, when I say "right", turn your head and look to the right. When I say "left" turn your head and look to the left. Try to keep yourself walking in a straight line."

(2) Normal: performs head turns with no change in gait speed and good balance.
(1) Moderate: performs head turns with reduction in gait speed.
(0) Severe: performs head turns with imbalance.

12. WALK WITH PIVOT TURNS

Instruction: "Begin walking at your normal speed. When I tell you to 'turn and stop', turn as quickly as you can, face the opposite direction, and stop. After the turn, your feet should be close together."

(2) Normal: Turns with feet close FAST (< 3 steps) with good balance.
(1) Moderate: Turns with feet close SLOW (>4 steps) with good balance.
(0) Severe: Cannot turn with feet close at any speed without imbalance.

13. STEP OVER OBSTACLES

Instruction: "Begin walking at your normal speed. When you get to the box, step over it, not around it and keep walking."

(2) Normal: Able to step over box with minimal change of gait speed and with good balance.
(1) Moderate: Steps over box but touches box OR displays cautious behaviour by slowing gait.
(0) Severe: Unable to step over box OR steps around box.

14. TIMED UP & GO WITH DUAL TASK *[3 METER WALK]*
Instruction TUG: "When I say 'Go', stand up from chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair."
Instruction TUG with Dual Task: "Count backwards by threes starting at ___. When I say 'Go', stand up from chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair. Continue counting backwards the entire time."

TUG: ________seconds; Dual Task TUG: ________seconds
(2) Normal: No noticeable change in sitting, standing or walking while backward counting when compared to TUG without
Dual Task.
(1) Moderate: Dual Task affects either counting OR walking (>10%) when compared to the TUG without Dual Task.
(0) Severe: Stops counting while walking OR stops walking while counting.

When scoring item 14, if subject's gait speed slows more than 10% between the TUG without and with a Dual Task the score should be decreased by a point.

TOTAL SCORE: /28

Mini-BESTest Instructions
Subject Conditions: Subject should be tested with flat-heeled shoes OR shoes and socks off.
Equipment: Temper® foam (also called T-foamTM 4 inches thick, medium density T41 firmness rating), chair without arm rests or wheels, incline ramp, stopwatch, a box (9” height) and a 3-meter distance measured out and marked on the floor with tape [from chair].
Scoring: The test has a maximum score of **28** points from **14 items** that are each scored from 0-2.
“0” indicates the lowest level of function and “2” the highest level of function.
If a subject must use an assistive device for an item, score that item one category lower.
If a subject requires physical assistance to perform an item, score “0” for that item.
For **Item 3** (stand on one leg) and **Item 6** (compensatory stepping-lateral) only include the score for one side (the worse score).
For **Item 3** (stand on one leg) select the best time of the 2 trials [from a given side] for the score.
For **Item 14** (timed up & go with dual task) if a person’s gait slows greater than 10% between the TUG without and with a dual task then the score should be decreased by a point.

1. SIT TO STAND
Note the initiation of the movement, and the use of the subject’s hands on the seat of the chair, the thighs, or the thrusting of the arms forward.

2. RISE TO TOES
Allow the subject two attempts. Score the best attempt. (If you suspect that subject is using less than full height, ask the subject to rise up while holding the examiners’ hands.) Make sure the subject looks at a non-moving target 4-12 feet away.

3. STAND ON ONE LEG
Allow the subject two attempts and record the times. Record the number of seconds the subject can hold up to a maximum of 20 seconds. Stop timing when the subject moves hands off of hips or puts a foot down. Make sure the subject looks at a non-moving target 4-12 feet ahead. Repeat on other side.

4. COMPENSATORY STEPPING CORRECTION-FORWARD
Stand in front of the subject with one hand on each shoulder and ask the subject to lean forward (Make sure there is room for them to step forward). Require the subject to lean until the subject’s shoulders and hips are in front of toes. After you feel the subject’s body weight in your hands, very suddenly release your support. The test must elicit a step. NOTE: Be prepared to catch subject.

5. COMPENSATORY STEPPING CORRECTION - BACKWARD
Stand behind the subject with one hand on each scapula and ask the subject to lean backward (Make sure there is room for the subject to step backward.) Require the subject to lean until their shoulders and hips are in back of their heels. After you feel

the subject's body weight in your hands, very suddenly release your support. Test must elicit a step. NOTE: Be prepared to catch subject.

6. COMPENSATORY STEPPING CORRECTION- LATERAL
Stand to the side of the subject, place one hand on the side of the subject's pelvis, and have the subject lean their whole body into your hands. Require the subject to lean until the midline of the pelvis is over the right (or left) foot and then suddenly release your hold. NOTE: Be prepared to catch subject.

7. STANCE (FEET TOGETHER); EYES OPEN, FIRM SURFACE
Record the time the subject was able to stand with feet together up to a maximum of 30 seconds. Make sure subject looks at a non-moving target 4-12 feet away.

8. STANCE (FEET TOGETHER); EYES CLOSED, FOAM SURFACE
Use medium density Temper® foam, 4 inches thick. Assist subject in stepping onto foam. Record the time the subject was able to stand in each condition to a maximum of 30 seconds. Have the subject step off of the foam between trials. Flip the foam over between each trial to ensure the foam has retained its shape.

9. INCLINE EYES CLOSED
Aid the subject onto the ramp. Once the subject closes eyes, begin timing and record time. Note if there is excessive sway.

10. CHANGE IN SPEED
Allow the subject to take 3-5 steps at normal speed, and then say "fast". After 3-5 fast steps, say "slow".
Allow 3-5 slow steps before the subject stops walking.

11. WALK WITH HEAD TURNS HORIZONTAL
Allow the subject to reach normal speed, and give the commands "right, left" every 3-5 steps. Score if you see a problem in either direction. If subject has severe cervical restrictions allow combined head and trunk movements.

12. WALK WITH PIVOT TURNS
Demonstrate a pivot turn. Once the subject is walking at normal speed, say "turn and stop." Count the number of steps from "turn" until the subject is stable. Imbalance may be indicated by wide stance, extra stepping or trunk motion.

13. STEP OVER OBSTACLES
Place the box (9 inches or 23 cm height) 10 feet away from where the subject will begin walking. Two shoeboxes taped together works well to create this apparatus.

14. TIMED UP & GO WITH DUAL TASK
Use the TUG time to determine the effects of dual tasking. The subject should walk a 3-meter distance.

TUG: Have the subject sitting with the subject's back against the chair. The subject will be timed from the moment you say "Go" until the subject returns to sitting. Stop timing when the subject's buttocks hit the chair bottom and the subject's back is against the chair. The chair should be firm without arms.

TUG With Dual Task: While sitting determine how fast and accurately the subject can count backwards by threes starting from a number between 100-90. Then, ask the subject to count from a different number and after a few numbers say “Go”. Time the subject from the moment you say “Go” until the subject returns to the sitting position. Score dual task as affecting counting or walking if speed slows (>10%) from TUG and or new signs of imbalance.

Bibliography: Franchignoni, F., Horak, F., Godi, M., Nardone, A. & Giordano, A. (2010) 'Using psychometric techniques to improve the Balance Evaluation Systems Test: the mini-BESTest'. *J Rehabil Med*, 42 (4), pp. 323-331.

Appendix 24: Interview Guide

FREIC Code:3332

Interview Guide

Thank you very much for spending your time for our study. I have few questions about your balance training which includes both balance and secondary tasks- dual-task training, and assessments.

1. How did you find the idea of performing dual-tasks as a way of training your balance?

Challenging? Easy? Meaningful?

2. What do you think about the difficulty level of each task? Do you think that the level of difficulty was different for the balance tasks and secondary tasks?
3. What do you think about the length of each session?
4. What do you think about how frequently you were asked to undertake the sessions?

If not already suggested by interviewees: Do you have any (more) ideas on how the balance of difficulty and challenge and timing of sessions could be improved?

5. What do you think about the enjoyment of performing the training tasks (balance and secondary tasks)?
6. What do you think about the progression of tasks at the end of each two-week period?
7. How did you find training in your own home?
8. How challenging was it to set-up the exercise area and equipment?
9. How did you feel about taking this training with your supporter/partner?

Prompt words in case interviewee responds with 'I don't know': Confident? Bored? Safe? Convenient?

10. How did you feel about taking this training without a professional's supervision?

Prompt words in case interviewee responds with 'I don't know': Confident? Bored? Safe? Convenient?

11. Do you have any ideas as to how the training programme could be improved?
12. How did you find accessing the Panopto link to the videos for your training?
13. How did you find following the videos?
14. How did you find completing the training workbook?

Prompt words in case interviewee responds with 'I don't know': Did you use it to provide self-feedback or to track yourself or see your progression?

15. Did you fall or almost fall during the training sessions?

If the interviewee responds with 'yes': How often did that happen? How did you feel about that? What did you do when that happened and how did you manage that situation? and Did you put anything in place to stop it happening again?

If the interviewee responds with 'no': Did the risk of falling concern you at all? How did you feel about that? Did you put any protective measures in place to stop a fall from happening?

16. What do you think about completing a questionnaire at the end of each two weeks?

Prompt words in case interviewee responds with ‘I don’t know’: Overwhelming? Good to see change/no change on your progression?

17. What do you think about the assessment that you undertook with the researcher in the University?

Prompt words in case interviewee responds with ‘I don’t know’: Difficult to drive to there? Difficult to arrange a transportation? How did you feel after the visit?

18. How do you feel after completing the training programme? Do you feel it affected your balance? If responds with ‘yes’: How? / In what way?

Did you observe any improvements in balance function?

19. Would you recommend this home-based dual-task training programme to other people who have PD? If responds ‘yes’: Could you please explain why? If responds ‘no’: Would you mind explaining why you wouldn’t recommend this to others with PD?
20. This is the end of today’s interview, before we formally stop the recording, would you like to add or comment about anything further?

Thank you for your time!

Appendix 25: Consent Forms for the Feasibility Trial

FREIC Code: 3332

UNIVERSITY OF PLYMOUTH
Faculty of Health

Consent Form for People with Parkinson's disease

Project Title: The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: a feasibility study of a randomised clinical trial.

Chief investigator: Nesibe Cakmak (Director of PhD studies for NC: Dr Lisa Bunn; Supervisors: Dr Camille Carroll, Prof Jenny Freeman)

Please amend all the boxes:

1. I confirm that I read and understood the participant information sheet. ☐
2. I confirm that I understood the possible risks of the dual-task balance training. ☐
3. I confirm that I have a safe training area in my home to undertake the dual-task balance training. ☐
4. I confirm that I have a supporter who can be my exercise buddy during the training sessions. ☐
5. I agree to complete training workbook with the report of adverse events. ☐
6. I confirm that I have had an opportunity to ask questions and answered satisfactorily. ☐
7. I understand that my participation is voluntary and that I can withdraw at any time without giving any reason. ☐

Consent Form Version 2.0 *21/02/2022*

8. I consent to storage of my data including my personal information for the purposes of this study on a password protected University of Plymouth licensed account. I understand that any information will be kept strictly confidential and no personal information will be included in the study report and/or any publication. ☐

9. I agree to participate above study. ☐

Name of Participants:

Name of Researcher:

Date:

UNIVERSITY OF PLYMOUTH
Faculty of Health

Consent Form for Supporters

Project Title: The effectiveness of motor-motor and motor-cognitive dual-task training interventions on balance in people with Parkinson's disease: a feasibility study of a randomised clinical trial.

Chief investigator: Nesibe Cakmak (Director of PhD studies for NC: Dr Lisa Bunn; Supervisors: Dr Camille Carroll, Prof Jenny Freeman)

Please amend all the boxes:

1. I confirm that I read and understood the participant information sheet. ☐
2. I confirm that I understood the possible risks of taking part to this study. ☐
3. I confirm that I understood my role during the study. ☐
4. I confirm that I have had an opportunity to ask questions and answered satisfactorily. ☐
5. I understand that my participation is voluntary and that I can withdraw at any time without giving any reason. ☐
6. I understand that no data will be collected from me. ☐
7. I agree to participate in the above study. ☐

Name of Supporter:

Name of Researcher:

Date:

Appendix 26: Body Sway Data: Angular velocities and Root Mean Square of angular velocities

Body sway-related data at baseline and post-test with the change for each participant.

		EO Condition														
		total sway speed (deg/s)			velocity in ML direction(deg/s)			velocity in AP direction(deg/s)			RMS of acceleration in ML direction (m/s2)			RMS of acceleration in AP direction (m/s2)		
	allocated group	T0	T1	change	T0	T1	change	T0	T1	change	T0	T1	change	T0	T1	change
P3	M-DTT	0.82	0.32	-0.5	0.79	0.32	-0.47	1.37	0.49	-0.88	3.765	4.926	1.161	0.4	0.263	-0.137
P11	M-DTT	0.52	0.57	0.05	0.52	0.59	0.07	0.45	0.57	0.12	7.225	8.44	1.215	1	0.282	-1.172
P1	C-DTT	0.74	0.9	0.16	0.73	0.89	0.16	0.75	0.73	-0.02	8.497	8.431	-0.066	0.133	1.163	1.030
P12	C-DTT	0.49	0.28	-0.21	0.48	0.27	-0.21	0.68	0.51	-0.17	5.103	5.093	-0.010	1.846	1.287	-0.560
P13	C-DTT	0.82	0.22	-0.6	0.8	0.22	-0.58	1.1	0.28	-0.82	5.745	5.67	-0.075	0.947	0.528	-0.419
P14	C-DTT	0.35	0.32	-0.03	0.34	0.32	-0.02	0.58	0.38	-0.20	2.297	2.304	0.007	1.841	3.087	1.246
		EC Condition														
		T0	T1	change	T0	T1	change	T0	T1	change	T0	T1	change	T0	T1	change
P3	M-DTT	0.93	0.33	-0.60	0.9	0.32	-0.58	1.36	0.55	-0.81	3.979	4.693	0.71	0.684	0.175	-0.509
P11	M-DTT	0.58	0.69	0.11	0.58	0.84	0.26	0.66	0.68	0.02	7.517	8.399	0.88	1.472	0.6	-0.872
P1	C-DTT	0.82	0.99	0.17	0.65	0.98	0.33	0.81	0.77	-0.04	8.669	8.298	-0.37	0.326	1.217	0.891
P12	C-DTT	0.35	0.25	-0.10	0.35	0.25	-0.1	0.64	0.45	-0.19	4.765	4.746	-0.02	1.775	1.755	-0.020
P13	C-DTT	1.51	0.31	-1.20	1.31	0.31	-1	2.9	0.52	-2.38	5.762	5.828	0.07	0.837	0.629	-0.208
P14	C-DTT	0.39	0.52	0.13	0.52	0.51	-0.01	0.39	0.76	0.37	2.32	2.048	-0.27	1.842	2.805	0.963
		Condition of feet are 4 cm apart														
		T0	T1	change	T0	T1	change	T0	T1	change	T0	T1	change	T0	T1	change
P3	M-DTT	1	0.37	-0.63	0.97	0.36	-0.61	1.29	0.46	-0.83	3.74	4.307	0.57	0.333	0.075	-0.26
P11	M-DTT	0.7	0.57	-0.13	0.54	0.57	0.03	0.7	0.49	-0.21	7.722	8.597	0.87	1.522	0.188	-1.33
P1	C-DTT	1.03	0.84	-0.19	1	0.82	-0.18	1.05	1.06	0.01	8.446	8.435	-0.01	0.311	1.2	0.89
P12	C-DTT	0.72	0.44	-0.28	0.71	0.43	-0.28	0.71	0.44	-0.27	5.324	5.067	-0.26	1.626	1.671	0.04
P13	C-DTT	1.91	0.26	-1.65	1.84	0.26	-1.58	1.89	0.25	-1.64	5.47	5.583	0.11	0.669	0.42	-0.25
P14	C-DTT	0.34	0.61	0.27	0.34	0.6	0.26	0.39	0.72	0.33	1.702	1.646	-0.06	1.853	2.361	0.51

Legend- ‘AP’=anteroposterior direction, ‘C-DTT’=cognitive-motor dual-task training, ‘EC’= eyes closed, ‘EO’= eyes open, ‘M-DTT’=motor-motor dual-task training, ‘ML’=mediolateral direction, ‘P’=participants, ‘RMS’=root mean quare, ‘T0’=baseline assessment, ‘T1’=end of training assessment.

Appendix 27: Themes/sub-themes of the Qualitative Data

Chart for themes/sub-themes with participant quotations and key consideration from themes for future studies.

	Theme 1: An acceptable DTT balances challenge and enjoyment.
	Sub-theme 1: Dual-task training is challenging because it includes coordination and multi-tasking
Quotes from M-DTT group	“I didn’t have any problem with balance to be perfectly honest, it's just the coordination of different tasks that I find hard.” (P11) “Stepping around the clock was the most difficult. The twelve, one, two, three, I found it really, really, hard to do that. …I had enough to do with coordinating the back from the side steps and doing whatever I did with the balls or the toy. I couldn't step one, two, three, four, five, six and whether I was closer or further apart, because I never really went back to that same position. If I had to really concentrate, then I probably wouldn’t have done the other tasks. But balance problems are really not a problem.” (P11) “The Lego ones weren't that bad; they were okay in general. I was very calm and just put them on. That wasn't a big problem in didn’t drop many and so it wasn’t a big problem. The lunging was okay.” (P11) “It is easy if I don’t have to do anything else.…it is not too difficult. I need to concentrate on it. Yeah, but I do it easier but if I have to use the hands that’s when it gets difficult.” (P11) “Of all the things we’ve done it's the only thing that is done with coordination.” (SoP11) “I find it very hard; I think I got better towards the end. I was trying to pay attention in the beginning definitely. I was so confused by the movements I had to do with my feet and with the hands at the same time that I just couldn't concentrate.” (P11) “I was trying to look at the end at week five and six I was getting a bit better because I was more aware of the yellow line. Yeah, but as I said it's hard.” (P11) “It was challenging, but yeah, that’s all I can say it was challenging but I managed to do them. Yeah, that was okay… It helps with co-ordination, I think.” (P3) “It was challenging, but yeah, that’s all I can say it was challenging…it helps. It helps with co-ordination, I think.” (P3)
Quotes from C-DTT group	“I had three things going on at one time, steps, looking at pictures, counting to one hundred, all sorts of things.” (P14) “…it was a complete surprise when we started to do the exercises, which you outlined because they became mind bogglingly difficult, physically very demanding. I found that I either had to do something, I had to concentrate on moving my feet, clock pattern.” (P14)

	"When I threw in exercise movements as well that was really difficult when combined together. The first day I think I tried this I was like jelly; I couldn't do anything at all. I just stopped. I had a little wobble." (P14) "It's difficult to do these specific types of exercises in a group because it would be multitasking, not just dual tasking." (SoP14) "…So, I had three things going on at one time, steps, looking at pictures, counting to one hundred, all sorts of things... So, I threw that away, that gave me two things to look at. The two things I did much better. I felt I did better." (P14) "No, it was fine. I mean. It's just that right really, I mean, if it was, I think we'd put off doing it or it would take longer…We had a bit of a challenge, and it was footwork, but it was fine. It was okay to me." (P13) "The actual physical thing seemed like a very easy thing to do. But in fact, it's not as soon as you had a cognitive test as well." (P1) "For example, things like marching, it may be quite easy with me but yeah the things that lunges like when you have to look away and then just turn your head back, It was quite challenging." (P1) "The marching actually helps you do things. The lunges make it a lot worse…Well, it does when it counts thing. I mean, it can do. But unluckily the marching was with the tongue twisters... It's like two separate things." (P1)
	Sub-theme 2: Dual-task training is challenging but it is interesting and enjoyable
Quotes from M-DTT	"Some of the exercises I have found extremely challenging although quite simple…I mean positively hard." (P11) "I mean, that was just a personal frustration that takes away the enjoyment. But yeah. Overall, the score to 6 to 7 and 8. So it was fine, well it was a challenge, but you know, what are they cooking up the week, what are the challenges next week? it was all well-designed and engaging." (P11) "No, that's okay. Tolerable." (P3)
Quotes from C-DTT	"it was an interesting approach to doing it…it's definitely a challenge." (P12) "I enjoyed the challenge of it. Yeah. I mean, when I didn't have much time and it was frustrating, apart from that I enjoyed it. (P1) "…that was more enjoyable, and I could do those and still do activities reasonably well…the video and the man talking that really touched my brain. And I think I can control the balance well." (P13) "This is actually a good idea. It's something that you could do maybe as A treatment as well as an exercise is something that you have to do every day to keep your brain." (P13)

	"Dual tasking is a really interesting concept for me. Quite clearly when I'm doing two things at once something has to give. I'm completely unable to do both at the same time or do something I do slowdown in some aspect. So there this competition for the way my brain works in some way. It's very interesting to see what happens." (P14) "It was very challenging, absolutely very, very, very much so…the balance exercises, no problem. They were easy. But when I hit the challenges you gave me then it opened all the cracks, all the weaknesses. That is how you are stuck, good." (P14) "That really woke me up this much more to this and so really really difficult to know. And I didn't know where it was going because I have never ever faced in my exercises. So, I was dealing with it very slowly, very badly. But yes, it's a real, real wakeup call and then you start to think what else, what other impacts does it have." (P14) "I thought it was quite interesting and something I had a little bit experience with before, and so I knew that the idea challenges of cognitively just doing exercise was very important. And so, I was quite interested." (P1) "Generally, I found it. Yeah, I liked it all the challenges and, and, and it was quiet, it was quite good it just in the way for Parkinson's." (P1) "I enjoyed the challenge of it. Yeah. I mean, when I didn't have much time and it was frustrating, apart from that I enjoyed it. And. Yeah, and it's just quite interesting to see what it suddenly got a lot harder when you have something that backwards and that was like wow, counting forward was quite easy and that they were not very easy, but you know it's much easier and then suddenly counting backwards." (P1) "Generally, I just quite like all this challenge. And anything that's. I sort of saw it as a bit playful, so which is why it was quite nice. Horrid Henry (a character within the audio story) things like…" (P1) "a lot of the exercises seem to be repetitive. You're doing the same at the end as you'd been doing at the beginning. So frustrating, tedious and boring. "(P12) "…in a way because the sessions were very similar, they got a little bit boring. I was doing some of the things with her, when you're trying to pick out which picture it was on the screen or which of the items in a particular, pick them all out that's interesting. The chap doing his walk across Dartmoor was sort of interesting in itself because that was different each time, so that was interesting. But by and large each session was a repeat of the previous one." (SoP12)
	Sub-theme 3: Sustaining motivation and challenge is needed to gain benefit
Quotes from M-DTT	"it is sometimes difficult to keep motivated, but. I think you have to make the effort if you're going to reap the benefit…I think with Parkinson's you've got to think that way or you just deteriorate" (P3)

	"Well, a lot of people say, oh, you're very good you do this and do that. And my answer is, it's not being very good it's fear of what will happen if I don't do it. If I don't do it, I'm going to deteriorate. But if I make the effort, I can feel the benefit. So, it's fear driven, fear of what will happen if I don't exercise." (P3) "…but I think to benefit from it, you've got to get your mind in the right mindset to do things that you don't really enjoy doing if you're going to have benefit from it afterwards." (P3)
Quotes from C-DTT	"it's constantly building up. So, I mean, six weeks, you can tell that how much did you know, it does help you, but it is the sort of thing that would be very good to build and, you know, have something that you'd be able to keep doing. But definitely it can help." (P1) "So, I would have thought that was about the only thing you could do to improve your balance, is to keep practising." (P12) "This is doing better…. It is not over strenuous and causing you to get tired quickly and you can work on both, but let's say, yeah, good." (P13) "I hate to feel that I couldn't do it. So maybe it might encourage me to think harder because the day before that I hadn't done very well. And I was determined then to look at it more closely and concentrate more to see if I could improve on it." (P13) "I think it makes you close and alert it because I seem to be losing my leg, my brain works a bit harder. And I think it sort of woke me up and make me sort of think quicker. It is not spooky, I think is making me…It's more alert, yes. Definitely. It's a little bit more challenged." (P13) "…people with PD tend to for the cognitive and not the physical thing. And I tried to let go of the cognitive and think, it doesn't matter if you don't get it right, you are testing yourself. So, I try and concentrate on the movement…. I was actually really concentrating on them on the physical." (P1) "…I decided that what was the thing that was causing me the most problem. The most problem at any one time was always moving my feet while watching the clock's sequence. But I decided that it was a no brainer I was not going to do that. So, I threw that away, that gave me two things to look at. The two things I did much better. I felt I did better." (P14) "As soon as I got a strategy in my head, I felt valuable for me that made life a bit easier, caught up with the problems. So, I got the pictures, then I said, well, what's causing you problems from looking at the pictures, doing these stupid exercises. So doing the stupid exercises, cut those down. (P14)
	Sub-theme 4: Individual situations and interests can affect the level of acceptance
Quotes from M-DTT	"…the lunges were not too bad. It was the leg exercises that I felt were more challenging because of the balance issue there." (P3)

	"Well, I can't say I enjoyed them, but they're not particularly unpleasant, but it isn't the sort of thing I would choose to do by choice, but I feel I need to do those sort of things to keep on a level." (P3) "I've always been a very outdoor person, so I don't. Things that are indoors have never interested me very much. I've always been active, so I used to ride horses and did dog training and stuff like that, but I never spent much time indoors. So those sorts of exercises didn't even enter my head until somebody said that might do you a bit of good. But now I've had to give up the exercises that I used to do I've got to substitute it with something else." (P3) "I was just heading towards my off phase, and it gets more difficult and very slow." (P11)
Quotes from C-DTT	"But it's funny, the picture ones, just because I'm very tend to be very visual. So, I found them much easier. It was video one struggling with." (P1) "The only thing I would say is with Parkinson's is this so many of the things that you would tell…And then if there's a week when I haven't done so much, like, you know, in the time that since I last saw you, you know, I've had, like, a bad shoulder. Yeah, I had a really bad cold, flu thing, for like a week. And that means that all my things come back, like. I mean, all my symptoms are like 100% worse." (P1) "…my kids don't really know about Parkinson's, they don't. And so, I like for example, I had two weeks was the Easter holiday. And so, I can't because I get upset if you do anything that shows weakness. Uh, yeah, it's a problem with the children. And so, I didn't really do it when they were around." (P1) "because of the need to be medicated, sometimes just because of the time of the day, I didn't want to be doing at the same time of the day. Sometimes I was more medicated than other times. And so obviously that would be successful." (P1) "Some were more difficult than others. Don't like the lunges." (P12) "There is certain things I found easier than others I found pictures and I enjoyed that…The math side completely go to pieces, and I couldn't really concentrate on the numbers or keeping my balance and moving very difficult…But yes, generally it was, it was good fun." (P13) "I did find the lunges. It's quite difficult to do it efficiently and look at the pictures. But yes. It was just it wasn't it wasn't too taxing… And. This, umm…Numbers. It was one of the most intense." (P13) "And then the wonderful thing for me I had photographs. Sure, there was something I understood and liked using wonderful images. So, I focussed on the images that are terrific. In concentration I could look at a picture and I could see what it was, and picture learn it and regurgitate it quickly. Much more difficult the more things you have to remember but that's deliberate, obviously when you fail." (P14)

	"The most amazing thing for me was the photos, it was like a sanctuary because there I was, I could stare at something. And I couldn't say goodbye. Right, so I enjoyed looking at them. So, this comforted me but the other ones the other ones are not. If I had done the other exercises on that challenge, because I think I probably could have done them. But having two other things piled on top and the difficulty of that was undoable for me." (P14) "So, I started off on a high level of difficulty, enjoyment, and I imagine it was trying to cross over and go the other way around so the enjoyment because it was easier. But it didn't because it was then wrapped up the next round next week was more difficult. So, the little bit of comfort I felt had gone because it was faster, quicker, more content." (P14) "…that may well be a reflection of my age and all the other bits and pieces. A younger person newly diagnosed with probably laugh." (P14) "The balance exercises, no problem. They were easy. But when I hit the challenges you gave me then it opened all the cracks, all the weaknesses. That is how you are stuck, good. when I was trying to do that sums cognitive stuff. I'm not, I knew I wasn't very good at that anyway. "(P14) "None of the exercises were taking numbers away from a hundred. And I think your anxiety about doing cognitive testing with clinical cognitive testing waylaid your thinking." (SoP14) "Not taking. No, automatically, you came to take them away and all we were doing was counting back. Okay, so there are some exercises that caused anxiety." (SoP14) "The other difficulty was that P14 had a poor response to his medication and once that was fixed and that was only fixed last week, his ability and his willingness to do those exercises was much better. So, I think medication status is very important." (SoP14) "And with all physiotherapy exercises that JW has done, he starts off enthusiastic and then it just peters out because of doing it on your own and doing exercises in front of the mirror is not as much fun as having a cup of coffee with friends afterwards. So, I think you've got intrinsically a problem with dual tasking that solitary activity and those people that don't want to mix with others will do well and those people who get nothing out of solitary exercise probably wouldn't benefit from a longer course because they would only sustain it for a short time." (SoP14)
Key points and considerations	**KP1** Some primary balance tasks are cognitively too demanding. **C1** For future DTT structure, these balance tasks (clockwise stepping, stepping forward and backward in order) may be introduced very late weeks of the training programme. **KP2** Some balance and cognitive task combinations make the dual-tasking undoable rather than challenging or helping to perform it.

	C2 some of the future task combinations within DTT may need to be changed to keep the level of the effect of individual task on the other task minimal. **KP3** medication status is important when undertaking the training. **C3** future study may set rule to undertake the home-based DTT in "on" period. **KP4** individual interests and skills influence perceived challenge level, enjoyment, and engagement with the training. **C4** mixing the elements from a wider range for individual tasks would be considered for future DTT design.
	Theme 2: A home-based programme has both advantages and disadvantages
	Sub-theme 1: A safe environment offering flexibility.
Quotes from M-DTT	"When you gave us instructions, you were always there. We checked up a few on a couple of occasions and then we had the video calls. It was not a problem. It was easier to choose a time of day without the reliance on someone." (P11) "I didn't record because it wasn't worth recording but there were a couple times at the beginning, I don't know why, you did a little step, but I wouldn't call it a fall or a near fall." (SoP11) "My balance isn't too bad going from side to side. It's from forward to back that I have difficulty with the balance. But the lunges were all right because I have the security of the wall on that side although I wasn't touching it, but I knew it was there." (P3) "I'm happy to have somebody there, but I'll still do them with nobody there." (P3) "They are challenging when you do them but once I've done them you don't feel any aftereffects." (P3) "I think you're more relaxed in your own home. You do it when you feel you can do it whereas if you're outside, you have to do it when somebody else wants you to do it. And when you've got things that come and go you choose to do it when you feel at your best." (P3) "You can fit it into your daily routine and do it when it best suits you." (P3) "Yes, you can do it when you feel it best. So, you do a better job than if you were made to do it at a different time." (P3) "I don't know if some people might not put the effort in if they're home, if they're not being watched. You know, you can say I've done it when I haven't. But yeah, we were pretty strict with the way we did it. My supporter didn't let me cheat or anything." (P3)

Quotes from C-DTT	"Yeah. Yeah. I only once wobble. One day I wobble, nearly fall but the dog joined. Yeah, I learned to get rid of." (P1) "I stumbled a few times, but I didn't fall…" (P12) "I think it was more unsteadiness rather than the near fall." (SoP14) "And obviously with things like Covid, you know, obviously things on Zoom … you have challenges to do and. Yeah. I mean, it could easily be the sort of thing that could be delivered as separate things in, you could, like online or something. But I think it's the right thing to do." (P1) "The thing is you can do like something in an outside like fast walking stuff like this, but, you know, like this time of the year, Well, so muddy everywhere if you were doing it, there will be consequences." (P1) "I feel perfectly comfortable doing the exercises in my own home it wasn't a problem." (P12) "You could fit that in any time of the day. Really. It didn't have any strict timescale. That was good. I like doing them at my own time, my own place, it was good, wasn't it? Don't have to go anywhere. It suited that lifestyle because you could fit it in, and it didn't do impeding anything all." (P13) "You can choose when to do it but it's also very easy to choose not to do it. So if you were doing like group exercise then you would feel more obliged…So, I think group exercises gives you a sense of teamwork and depending on other people as well and not letting them down but working at home gives you the choice. So, there's a balance there, I think." (SoP14) "…And as a group, I think that's not gonna work well together with some people. Making people comfortable, that's made a huge difference." (P14) "So certainly, in some of the process I didn't have a clue what to do at the beginning. I had no idea. So, I didn't know what the tests were for, what they were trying to look for. So, I had to do a complete learning experience to find out what seemed to be the rationale behind it, what was actually required. So, I spent a lot of time, the first two sessions, the first series of sessions trying to think of how I can do something." (P14)
	Sub-theme 2: Finding a training area can be difficult.
Quote from M-DTT	"That was all right because we just moved the table up the end and used that space. So, we didn't play table tennis for six weeks." (P3) "Your balance is very good anyway, I'm not sure if your balance wasn't so good and there was a risk of falling whether we want it somewhere s bit more. There are obstacles around. If you thought, you were going to fall you wouldn't want to do it there. "(SoP11)

	"You would want an empty room. So, for me, it was fine, but for somebody with balance problems it might be difficult to find a safe place in the house. It is not always difficult, but you need to check. So, possibly okay." (P11)
Quote from C-DTT	"I only say about that the mat was quite big. Yeah. Quite Hard to find a space." (P1) "It (available space) was easy for me to find. I think it might be difficult for a lot of people. Fortunately, we have a spare bedroom, so I had enough space and the right sort of place to put the iPad. It could be difficult for some people I would have thought. You need quite a big space, don't you, to do those exercises." (P12) "We picked a place that was right and light. And wasn't probably let the mat roll off. So, we just put the iPod there, no problem. I mean, the mat is quite big, isn't it? That I think some people might struggle with manoeuvring that. But it means, I don't know, that, that was finding a place for that, because it was the most difficult part of setting up, wasn't it?" (P13) "I think one problem I found was the mat was very large and if we left it down it caused me a trip hazard. So, we had to roll it up afterwards… But certainly, needed a large space and people who are furniture walking were probably freezing because they have got their furniture too close together. You would have trouble with that space. we were lucky we have a larger of space and it's just a wooden floor." (SoP14)
	Sub-theme 3: Finding a suitable time can be difficult.
Quotes from M-DTT	"I just sort of fitted it in when my supporter was there and you know, there was nothing else happening. We would do it to say, should we go and do the exercises now?" (P3)
Quotes from C-DTT	"…one of the worst things is the one time when I didn't have very much time, I tried speeding up, and that was that was a nightmare trying to move on, because I didn't enjoy that one moment." (P1) "it's surprisingly difficult to find the time to do it. When you're busy. I mean it needs both of us to be available." (P12) "The biggest problem was finding a run of time where we weren't trying to do other things at the same time. P14 had three visits to Derriford in the last six weeks, nothing urgent just routine appointments. And then we've had Zoom calls and such like this. So, our days structured around what we have to do and sometimes it was oh we have got to do this as well." (SoP14)
	Theme 3: Dealing with the technology
	Sub-theme 1: Accessing and streaming the movies whilst training.
Quotes from M-DTT	"It is fine I am used to working with a tablet and navigating windows. So yeah it is fine." (P11)

	"It was quite straightforward in the first place, and then it seemed to disappear and then I found it turned up in the bin. Yeah, but I found it again. So probably when you open it up now you probably have to go into the bin to find it." (P3) "I don't know what I did, it must be something I pressed but it's all right because I had it on my other tablet anyway, so I could have used that if I couldn't find it. But it did start by fumbling a bit, but we got it sorted come the end." (P3) "I'm rubbish with computers anyway. It's a bit of a lottery whether I'm pressing the right things or not." (P3) "The tablet's fine yeah. You showed us how to do it well." (P3)
Quotes from C-DTT	"No trouble my supporter did it." (P12) "It (setting up tablet) was easy." (SoP12) "Once I found the right email it was easy because we've got quite a list of emails between us. I couldn't always find the right one, but when I picked the right email, it wasn't any trouble." (P12) "It (navigating) wasn't difficult." (P12) "That (accessing the link and navigating) was fine." (P1) "And again, being able to pause the program if somebody came to the door or a postman or a delivery man and this sort of thing. sort of come up and we do the warmup and then we go press done. And we go back to the back to the link and became the week and the session. And then doing up." (SoP13) "It wasn't a problem, you just need pressing a few more buttons and maybe in some cases, they have to join the group and some people seem to have quite a bit of difficulty getting to the right place like am I there and pressing buttons and things. It just depends on how much skill people have." (P13) "it's not smooth it's very clunky. when I was pressing, I expected it to do what it was supposed to do. We spent a long time losing you, losing those videos, hunting around they weren't even in the right order. So, it was a cumulative effect. This was supposed to be a very simple thing to just push a button and it works, so that worry is taken away. That was a real problem because we all argued about what time we were getting ready to go and do these things because it's took us so long to log on." (P14) "Using iPad was smoother P14. I found it better to take over that bit because otherwise we would have been ages and with frustration probably have not got to the exercises." (SoP14) "That would be okay if that ran on its own completely. You put that in somewhere or the other, that was it, everything worked. That's what it is, you put in, it works. It's like Zoom meetings are a nightmare when they are not working properly. Team meetings are terrible, and everyone hates them because of that" (P14)

	Sub-theme 2: Interacting with the movies
Quotes from M-DTT	"The 'Go' sign came up quite a while before the voice said Go. So, there's a bit of confusion about when you should have started. But apart from that, it was great." (P3) "At the end, you don't need all the information you can fast forward through that so that's not a problem. I'm not really moving that fast. So, I think it's the right pace." (P11)
Quotes from C-DTT	"There are actually a few errors in the instructions…there's a difference between when the screen comes says go. Yes. And then what? And then when it said go. And so, I got very confused. And so sometimes I started when the go came up and carried on the way through. And then then and then I go. I mean, there are tiny things but generally they were good." (P1) "I have difficulty with the video. It has a lot of mistakes in it. So sometimes it was, I didn't really know what it was asking me to do, or I couldn't hear what was being said. That was the difficulty, the level of difficulty of the tasks given were not too bad. I mean, even the later ones where we had the chap walking on Dartmoor, he was an English speaker, but he didn't speak very clearly, and my hearing is going anyway. So, it was sometimes quite difficult to hear what he said so then I couldn't answer the questions because I hadn't heard what was said. So that is where the difficulty came in. Actually, doing the tasks itself by being able to understand clearly what was going on would have been quite easy. It's just not being able to hear clearly what's being said. The two things together weren't a problem." (P12) "it's tedious and I did have difficulty in understanding what was being said, particularly in the first part of the exercises when I think you were reading out from Horrid Henry. I couldn't understand what you were saying. I'm sorry. I just find your accent difficult to comprehend. So, it was things like that that was tedious. So frustrating, tedious and boring." (P12) "The instructions were clear enough, sometimes they didn't coincide with what was written on the screen, so the narrator would be saying something different." (P12) "I mean, we actually almost gave up on some of the similar practice stories where it was different because we couldn't actually understand enough, and we were really concentrating." (SoP12) "The voiceover was saying the same instructions, but the written instructions were three and seven. So, we followed the written instructions." (P13) "But success. But. But then. I think. Really apart from the sort of technical glitches. It's gone very well." (SoP13)

	"I didn't know what I was doing. I didn't know what to expect. Brain training exercises is how I interpret the first bits. I'd never seen anything like that. I didn't realise that's what they were. I needed more examples. I couldn't work the rules out. When someone said, take something away from a hundred that just, alarm bells went off because I've got to do that, and I couldn't prepare myself or anything for that." (P14)
	Sub-theme 3: Using online approach as an assessment method
Quotes from M-DTT	"It (online questionnaire) was clear from the start. Yeah, I didn't have any difficulty with it (online questionnaire) at all." (P11) "I think it's good to keep face to face contact because you get more feel for what's happening don't you. Yeah, that's good (video conferencing)." (P3)
Quotes from C-DTT	"Yes, that (online questionnaire) was easy" (P12) "Yeah, it's okay." (P13) "It (the online questionnaire) was completely too vague. Every question it had I could write much more because it needed a specific answer itself. So it was something needs to be another thing. It wasn't well-structured, and you didn't have anything to put in at the beginning to know what the correct thing was." (P14) "That (Zoom meetings for progress assessment) is good. definitely. That works. Yeah." (P1) "I think it's a necessary thing to do when two people are coping to work has together." (P14) "it's nice to catch up. You don't actually always write down or remember things. When you do that, it's nice to go over and you were asking questions and giving our response. I think it's a good idea, the meeting, because we wouldn't surprise that in one episode." (P13)
Key points and considerations	**KP1** technical glitches (voice delay, inconsistency between the written and voice instruction) within the DTT movies leads to confusion and can affect engagement and enjoyment. **C1** improvement in the technical design is necessary and should be held with a professional third-party (e.g., app/software designers). **KP2** accessing and navigating the DTT movies appears acceptable amongst most of the current study participants but is dependent on the user's technical skill. **C2** it may be valuable to screen potential participants tech-use skills before enrolling them to the study for future study. **KP3** the online method for the questionnaire is acceptable but the design and the context of the questionnaire may need to be improved.

	C3 current questionnaire is adapted and self-created. It would be valuable to assess its reliability and validity before use in a future study. **KP4** Assessment sessions are considered necessary and remote delivery is acceptable.
	Theme 4: There are advantages and disadvantages to training with a buddy
Quotes from M-DTT	"My supporter was always there when I did those exercises because he had the scores, so I think I could do them by myself, but you can't because you can't count and do it. "you've got to have somebody there to actually see if you're improving or not." (P3) "I'm happy to have somebody there, but I'll still do them with nobody there." (P3)
Quotes from C-DTT	"I thought it was a great idea. And I think that, you know, I mean, I just know that lots of people do go to classes with somebody with them, which is if you have got someone, it's great. If not, it's horrible, but it's prohibitive? if you don't have a buddy." (P1) "So, I think the idea that you could do something, that you have a possibility of doing it with someone else, I mean, a buddy is encouraging that, to go on. You don't want to do it yourself, really. But I don't, I found it very, not found good with someone else to do them. So, the way that you could do it, do it by self." (P1) "I know that some people go to my class, and they have a partner who says 'come on, come on, stand up straight. Now, you're not doing that very well.' Then, maybe it's quite often it's because they've got to the point where they have some problem, so they really benefit from what someone says to them. But I haven't got to that point yet. And I push myself. Not anyone. But I don't need someone to push, and I push myself. So, I think it's always good to have the option you know. If they had someone who they could relate to I mean to get feedback how they are doing that thing okay." (P1) "He was entirely supportive. What else can I say." (P12) "It was a bit of a competition to my husband myself as to how he got right. And I said, good competition." (P13) "The last two weeks, the video in the back on the moor. When it was lunging, I was quiet. I was standing very close because I was worried that you were going to fall on the number of a catch." (SoP13) "I mean, used to find, we need somebody there just to give hand, really. training buddy is a really important point." (P13) "Having my supporter to take records was quite interesting because I assumed she would take records and be completely neutral but there was scope within the work that you gave us to have a different interpretation to one another in the same room, looking at the same things, and it brought some discussion." (P14)

	"I felt the whole thing was set up to be competitive. My supporter said do the best you can, go as fast as you can, keep going. Very, very competitive. I don't like that particularly, it's not my style. I do it because I can do it and have been successful doing it when I choose to." (P14) "My supporter is trying very hard to make sure that I do that sort of exercises and I am on a project which is looking at it regularly falls off the bottom of the list to do because it's in my control and I don't have to. And I'm trying to make it beneficial though, because I know I don't want to do it. I want to rest sometimes. When I rest, I want to do what I want to do." (P14) "I don't need any more social interactions with my supporter. I have plenty thank you." (P14) "Stranger (as a training buddy) because they're both going through the same exercise. You haven't got the baggage." (P14)
Key points and considerations	**KP1** training with a buddy may be necessary for some, but he/she does noy have to be their partner for some pwPD.
	Theme 5: Training characteristics are manageable
	Sub-theme 1: Duration and the frequency of the sessions
Quotes from M-DTT	"That's fine yeah. No, it is the right one. It is good, yeah. It was the perfect to warm up and warm down. It is fine, yeah." (P11) "At the end, you don't need all the information you can fast forward through that so that's not a problem. I'm not really moving that fast. So, I think it's the right pace." (P11)
Quotes from C-DTT	"I thought that sometimes at the beginning of every section, I went through the whole thing. And I thought it could be shorter. Mm hmm. But then I obviously realised that. No, you know, like everyone has said, I mean, I tend to have not that much time. If I know that I'm listening to something, I struggle to focus on that very much anyway. So, I don't really listen to the instructions properly. So, I quite like to review instructions maybe once a week or something." (P1) "Like being able to do it in, say, 20 minutes. I mean, if I could do it, it tended to take over half an hour. If it was taking 20 minutes, I'd probably be doing it more. Yeah. Sometimes what I did was exercising, and I moved straight on to the next slide, so I did not do the warm-up. That made it easier to do." (P1) "I suppose as time went on, you get so, so used to doing it. They need lengthy explanation, like for the first couple of sessions it's good to keep repeating. But then after that, by, by, you know, by session 18, it's, you know, it's like I Skip this one. But obviously can't because of the sales that's driving that. But yeah. And then I think in the. More or less a rest time between the two sections, it's quite good." (P1)

	"That (frequency of the sessions) was fine." (P1) "The actual length of time for each of the exercises was okay. There seemed to be a big gap between the end of the exercise and having to do the next one. So, there was a lot of downtime because there was a space between the two. It could have been speeded up." (P12) "When you're busy. I mean it needs both of us to be available. And it's a good half an hour, it's more than half an hour actually by the time you've done the cool down it's a good forty-five minutes three times a week for the two of you" (P12) "Once or twice a week would be easier than three times, but probably once a week wouldn't be enough to have reasonable results." (P12) "We tended to. Skip past them a little bit because we knew it was just instructions, so we shouldn't lose it when we did that. And it took a half an hour to get through. Which is which is which is fine. It's fine. Wouldn't impede on anything." (P13) "The longest time I ever did any of the exercises was 45 seconds. These exercises were going on for 45 seconds and more than 45 seconds. I was much more tired as I went through each time. And for me it actually became, it built up so sometimes because of the other things that I do, I still do exercise, move around the house and that sort of thing all the days. So sometimes I had conflicts of interest or pressure to do your stuff on top of the other things that couldn't be moved. That was very difficult." (P14) "The warmups and the cool downs, I know you're supposed to do it, most of the time I felt warm enough, so I didn't do it. I was so fed up come the end I never did any cool downs. So that was cut off either side." (P14)
	Sub-theme 2: Seeing the benefits of it in 6 weeks is difficult.
Quotes from M-DTT	"I could do it, but I'm not sure I haven't done this for six weeks. I'm not sure what's the goal, yeah. Is it because I'm supposed to improve balance, am I trying to improve coordination between the balance task and the hand task. Or am I looking for improvement in my general health. It's hard to see from here, where we start, where are we heading for, what is the purpose of the trial, what are you trying to achieve here." (P11) "Not after six weeks. It's a steep, steep journey, I guess. Yeah, but I mean, I like the way they challenge you to try and coordinate these different things…. But if you get proficient in these tasks, I'm pretty sure it will have an impact. Or you would have to do them more consistently over a longer period of time. "(P11) "I don't think so. Not specifically in the last six weeks or so. My balance is reasonably good." (P11) "I mean, obviously, the more often you do them, you work out, the tricks that make it easier. You concentrate better if you just get used to the different challenges. So, by nature you get better. And then you have to assess whether it has an impact on your overall balance, say, the six weeks. I personally can't see

	any change, but then again, I wasn't so bad at the beginning. You might want somebody who has major balance problems and a faller on this. But yeah, I can see the principle of the exercise model." (P11) "Mind you we didn't challenge your balance either. I wonder whether you don't do anything when you need to test your balance like climbing the ladder. You generally don't climb a ladder. So, was it easier to put the Christmas presents up in the loft before or after?" (SoP11) "After." (P11) "You felt better going up the ladder after than you did before?" (SoP11) "Yes." (P11) "That's an improvement." (SoP11) "I think you have to be doing it regularly for it to benefit you." (P3) "It focuses your mind. It makes you think what you're doing. I think it probably would, yeah. that's difficult to say because sometimes you have good days and sometimes you have bad, and you don't know if it's the exercise or not. So, you can't really specifically say yes or no really. I think you'd have to do it (the DTT programme) for a long time to see if you're stay stable with it. Yeah. I think it does help you." (P3) "I think to improve it you'd have to be doing them every day or over a longer time." (P3)
Quotes from C-DTT	"Especially when you have Parkinson's and so, and so what happens is you know, for six weeks it's very easy to know that you can keep going, keep going, whereas maybe for 12 weeks people might struggle a bit more. But on the other hand, with anything that way, you can see the improvement. I mean, like, for example, my classes I get into in person and usually ten weeks, by the end of it very different than beginning." (P1) "I have generally done as much other exercise. I feel like the last two weeks my balance is slightly worse. But then I had a bit. I noticed that it was improving in first couple, maybe three weeks, and then it's only because then I got a cold. I couldn't exercise as much; at that moment my balance was not that good. I mean, it probably isn't that bad because I could do most of the tasks. But I just felt a bit more wobbly and that it's just all to do with the issue of trying to find something different. It's such a hard sort of thing to, you know, do to quantify what's happening in your body." (P1) "I don't think it's (my balance) changed. I can't determine any particular change with balance. It's still not good." (P12) "I mean, I said to you earlier, I do Pilates twice a week and we do balancing there. We do a much more difficult exercises there than you gave me to do, and I don't do them very well. Some of them I can't do... So, I would have thought that was about the only thing you could do to improve your balance, is to keep practising. And it would take more than six weeks I would have thought." (P12)

	Sub-theme 3: Progression may work in different ways.
Quotes from M-DTT	"There was a bigger challenge as it went on, especially the clock one that is difficult…my balance isn't too bad going from side to side. It's from forward to back that I have difficulty with the balance. But the lunges were all right because I have the security of the wall on that side although I wasn't touching it, but I knew it was there." (P3) "I must say, I didn't notice much difference depending on the foot position whether it was green, yellow or red. Didn't make any difference to me because, to be honest, when I did the side steps I find it impossible to always get back to the same position." (P11) "Weeks one and two were probably easier. Week 3, then introduce the round clock. And that I found hard yeah. And then it got easier again. There was a fidget toys that was difficult with one hand. I'd say probably weeks three and four were the trickiest ones." (P11) "I did feel it was getting better towards the end but then again week three and four because they were the most challenging combination of leg and hand movements. Yeah, I guess I felt the best during the last couple of weeks or maybe because the exercises were less challenging." (P11) "I didn't think it made any difference to me because I just find it impossible to stick to it. I don't think during the week 6 came back to the yellow lines. I just found it really hard to do. So, in that respect, I think, yeah." (P11) "The only way it worked was when you stayed still and there weren't many of those. There were some where you didn't move your feet but there weren't many of those." (SoP11) "it's just maybe in week six two inches so it doesn't make any difference, not to me, but maybe to somebody with balance problems it may be more difficult and might be closer together. I think it's kind of, because of the circumstances and the kind of exercise you do, I don't think it plays a big role." (P11)
Quotes from C-DTT	"For example, the foot tapping wasn't too bad. Some of the lunges I found really difficult, especially in week five and six. You carried on looking at screen. And that made it easier for lunging to the side." (P1) "And. Yeah, and it's just quite interesting to see what it suddenly got a lot harder when you have something that backwards and that was like wow, counting forward was quite easy and that they were not very easy, but you know it's much easier and then suddenly counting backwards." (P1) "Was it (first progression) week three, no I didn't really notice that one…No I didn't really notice that." (P12) "As you know, in the early part of the course of trying to listen to your friends with a strong accent was it was frustrating, mostly because neither of us could pick up on the information that we would look." (SoP13)

	"But it was very noticeable in the last two weeks with the patterns left, right, equal, counting the different words that got progressively hard. But the harder, the harder the brain tasks, the more I had to think about keeping my feet. the early ones, I could probably do anything with it, you know, just concentrate on the brain." (P13) "Yes, I could perform them, but only in a very limited manner in comparison with what was required. That must reflect the fact that the easiest thing was standing there. Then some sections were more difficult." (P14)
Key points and considerations	**KP1** session durations are acceptable but seeing same instructions every time may not be effective. **C1** frequency of the instructions for the same or similar tasks may be reduced in future design. **KP2** 6 weeks-training programme is acceptable but it may not be beneficial to improve balance. **C2** in future training design may be changed to 8-10 weeks, as they are also used in other effectiveness studies. **KP3** progression in the stance position makes not any difference, especially it is too difficult to keep that position in certain tasks (e.g., stepping forward, backward, stepping in clock-side). **C3a** coaching by training buddy would be considered to keep alert pwPD in terms of the priority of the performing dual-tasking. **C3b** progress assessment would be undertaken not only in standing still in new stance position but also, while stepping position, and then decide to progress or not to the new stance position. **KP4** the progression from Week 3-4 to Week 5-6 was not work for pwPD as planned because of the task combinations within different intervention groups: clock-side stepping was found more challenging in week 3-4 than lunging in Week 5-6 in M-DTT group. However, in C-DTT group forward lunging while watching video and answering questions on the screen in Week 5-6 was found very challenging. **C4** task combinations need to be reconsidered to keep the standardisation in progression level in each group.
	Theme 6: Research assessments are familiar but are they acceptable?
	Sub-theme 1: Face-to-face assessments are acceptable, but travel may be a burden.
Quotes from M-DTT	"it's alright. I have been part of other tests before and they all do something similar. So, I was really familiar with it. It was fine." (P11) "No, it's just that as long as I've got someone there as a safety blanket. I feel quite happy to do them." (P3) "I just hate travelling around Derriford because of the traffic. Well, yeah. I mean, you got no choice, really. Unless you want to come to us." (P3) "It was alright. It's an easy enough drive for us, just three quarters of an hour for us. So, it's fine." (P11)

Quotes from C-DTT	"Well, we've only been twice. It feels as if we've done more this time than you did before, but that could be my memory at fault, but the assessments are fine. I have had most of them done before. The various neurologists I've seen have done exercises with me or I've taken part in several other studies and so I've had that kind of procedure before so it's quite familiar to me." (P12) "I mean, the thing is quite hard it's otherwise. Well, obviously, we know that you're doing research, but otherwise it's quite hard to gather whether you've actually improved and what the difference is. So, I assume, you know, it's quite important." (P1) "Umm, it was very straightforward, I think, yeah." (P13) "The assessments that we do here are easy to do it is only the process of coming here and I don't quite see what the difference between doing it at home and doing it here." (P14) "And travelling down here. It depends on where you live. If you live down here it is not so difficult." (P12) "People have now begun to accept video conferencing and I don't think it's ever going to go back to face to face. Nearly for everyone it's too expensive, time and that sort of thing. It (face-to-face assessment) is lovely because you can see a person but functionally (shaking head)" (P14)
	Sub-theme 2: Training workbook is acceptable.
Quotes from M-DTT	"it's quite straightforward, actually (completing the training workbook)" (P3) "I was making tally marks. He was moving too quickly so I was counting in my head and marking down every ten. … That was fine, absolutely, great." (SoP11)
Quotes from C-DTT	"It was fine. I was doing it on the side. I had a piece of paper and write down to this paper and transfer into it, generally that was easy." (P1) "I mean, within that week it's quite similar. And then I feel like, (murmuring). So, it was fine, as I said, because I have had some obvious things, but then I might do at the end of week or something, I do not remember. I'm better at this one and that one." (P1) "I did that (completed the training workbook). That was easy." (SoP12) "But filling in the scores were fine but there were only two things to write and how many times did P14 fall over and that was zero. But P14 had to score enjoyment and initially we couldn't decide how to score that, so we just picked a number and stuck to that consistently. So, enjoyment was a high number if he enjoyed it. So, there were other things as well, so maybe a bit of guidance on the scale." (SoP14)

	Theme 7: Suggestions from pwPD and supporters
	Sub-theme 1: DTTs content and delivery
Quotes from M-DTT	"I think you have to do targeted exercises like you've got in the program. But I still think you need to get outside. I mean to walk and stuff like that. Because those things don't demand precise movements, do they, outside exercises, but the inside one's are more." (P3) "It just depends on how you're feeling on the day I think. Some days, you know, maybe if the weather's not very good when you're in the indoor activity. If you're home, you can tailor that to the conditions on the day. You know, if it's like this then if it's something you can do outside then I would be outside." (P3) "You're right and say it gives you focus to know what you shouldn't just step here; it should be somewhere close. Yeah, but don't expect that somebody can distinguish between this way and this way." (P11) "It was a bit confusing also because it was a big problem too. I only managed one side (of the popping toy) or managed one and a half side. So, I got nearly through the second one, but it didn't count. So that was difficult. The Lego was okay and didn't really want too hard." (P11)
Quotes from C-DTT	"Say to people sometimes this time maybe put your emphasis on physical. Yeah. Because it makes quite a lot of difference, I found it if I was actually really concentrating on them on the physical." (P1) "When you are multi-tasking, you don't really multitask properly. And so, what happens is you always prioritise one. I'm trying to say for this one time, prioritise the physical. It's quite good sometimes I like, for example, because I have to do it alone. So, what I realised was that it's possible if you had someone with you, they tell you to come on, put more effort into it. You could also you could video yourself, that I'm trying to make myself concentrate more on physical." (P1) "What you could do is split the screen and have that video review going like this at the same time that you could read it depending what you needed to focus on." (P1) "What would be very good is to have something with a few variations in it and then work with a therapist to go through it. Start with just so that we set it up for each individual person. I mean, so that you could try different things. And, you know, that may be slightly different that someone with you if you didn't have someone with you. So, the person wants to do it with buddy so that they could." (P1) "When you were showing, you were demonstrating the lunges, when you were demonstrating the lunges like that way you tell where you have to do, you didn't have a screen there and it would have been good to have the screen." (P1)

	"The videos need tidying up and making more accurate. And the instructions are repeated every time and the narrator tells you exactly what to do and it's the same words every time. You go "Oh, come on, we've been through this". (P12) "Maybe you would like the, umm, tongue twisters are quite challenge. I had good or bad in those, but it's nice to have a variety of activities" (P13), "probably to get away with half of that" (SoP13). "There was one thing I was unsure of, how much coaching to give JW about the instructions for example because especially in that section, when he wasn't understanding word blue or word written in blue, that sort of thing, I mean I could see where he was going wrong, but if it had been left up to him, he would not have seen it. So, I (the buddy) I didn't know if I was allowed to coach him (the person with PD) or to point out what the instructions meant. So that would have been helpful for the coaching." (SoP14)
	Sub-theme 2: Assessments and scoring
Quotes from M-DTT	"Would it be better the scores that you put down are the totals. Would it be better to itemise (the scores) them because you don't know which ones that you've improved on and which you haven't rather than the whole total. So, he's put the daily things that we did on the back as I was doing them. With the individual score on as well." (P3)
Quotes from C-DTT	"It (dual-tasking) gives you a way of measuring things at the moment you need something that is quantitative so that you can see how things change over time from place to place. But if you don't have a quantitative way of measuring how the brain operates, it must be an example of what the brain is doing with dual tasking. So, if you have two tasks, they interact over time. Maybe you can pick something up from that. So, I don't know but I think it's a good idea." (P14)
Key points and considerations	**KP1 and C1** giving an instruction in terms of focusing/prioritizing of the tasks (like 'focus on hand task/cognitive tasks' or 'this time focus on your feet') by the training buddy or within the pre-recorded movie would be considered as a strategy.

Legend- 'C=considerations for future studies, 'C-DTT'=cognitive-motor dual-task training, 'KP'=Key points from the themes, 'P'=participants, 'SoP'=Supporter of participant.