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Investigating the nature of body representations and their use in pair matching and mental rotation tasks

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Abstract
Two computer based stimulus-response experiments were conducted with the aim of finding whether Body Representations aid pair matching and mental rotations of ‘same’ or ‘different’ Bodies in comparison to Bicycles. Also to find whether ‘disconnecting’ Body Stimuli would disrupt the BSD and increase RTs. Sixteen different University of Plymouth students took part in each experiment, 32 overall. No significant effects were found for pair matching alone. Body Stimuli were rotated significantly more quickly than Bicycle Stimuli in Experiment 2. This effect was attributed to participants utilising their Body Representations to perform the rotations in a more holistic way. No effect of Connection was found. The researcher proposed that this was due to stimuli limitations and other theories are presented.

Ethical Statement

The current research was conducted in an ethically sound manner. Participants read a brief explaining the stimulus-response task. Participants were informed that they would take part in a computer based task where they would be required to view images of Body and Bicycle stimuli and (1) make same or different judgements about stimuli pairs (2) make same or different judgements about stimuli pairs some of which would require mental rotation. It was explained that all personal information would be confidential and data received would be anomalous. Participants were informed of their right to withdraw at any point before, during or following completion of the experiment. Following this, participants gave informed consent by signing a consent form. On completion of the task, participants were given a debrief form, which included the necessary details (participant number and contact details of the researcher and the supervisor) should they wish to withdraw their data or receive further information about the study.

In order to ensure anonymity, participant numbers rather than names were attached to the data. Consent forms were kept confidential and no individuals outside of those directly involved with the study had contact with them. No deception was required and participants were not exposed to any increased risk of harm as a result of participating.

All data collection in this study was performed by the author.

Introduction

Creating a mental image occurs through the activation of an inner representation (Ionta, Fourkas & Agloki 2010). This image can be mentally transformed for problem solving or the mental production of goal oriented activities (Ionta et al., 2010; Shepard & Cooper 1982). In a study by Shepard and Metzler (1971), participants determined whether image pairs of fixed structure 3D cubes (S-M cubes) were identical or mirror image (Shepard & Metzler 1971). The authors found increased RTs linearly with angular difference (Shepard & Metzler 1971). This implicated the use of a mental 3D object which we can internally transform (Shepard & Metzler 1971).

The current experiment is focused upon the internal representations of the body and the way in which they are used in the mental rotation of body stimuli in comparison with bicycle stimuli. To recognise an object the visual information is mapped onto an internal representation; therefore, to see a human body triggers our own body representations (Parsons & Fox 1998).

One suggestion of embodied cognition is that the body may play an important role in shaping the mind (Wilson 2002). The human sensorimotor system may serve to embody and comprehend abstract ideas and concepts (Amorim, Isableu & Jarraya 2006). Embodying an object had been shown to increase ease of mental rotation; embodiment can be spatial where body axes are mapped out onto the target object or motorically organised (Amorim et al., 2006). Motoric embodiment is supported by theories of imagined action increasing muscular force (Decety 2002) and involves sensorimotor body knowledge triggered via mental imagery (Amorim et al., 2006). Feeling as if we are inside our bodies, restricted within the boundaries, and are distinct from other objects, is our embodied self (Carruthers 2008).

The visual system reacts specifically to biological stimuli in motion, or inferred motion, and treats it differently to other visual targets (Corradi-Dell'Acqua & Tessari 2009). Seeing a body effector perform a goal directed action evokes the resonating Mirror Neuron System, which can be used for imitation (Borghi & Cimatti 2010). The actions of others are interpreted using the Body Schema (BS) through a method of self-other comparison (Reed & Farah 1995; Shiffrar 2006). This convergence allows for a physical and empathetic response to others. For example to observe emotion in others can trigger a similar feeling in the observer (Carr et al., 2003; Singer et al., 2004; Shiffrar 2006). We visually experience bodies regularly and gather much information from them; sensory information about the body (own and others) is combined with information about our own movements in the Cerebral Cortex (Corradi-Dell'Acqua & Tessari 2009).

The unconscious imitation of gestures is associated with the activation of the observers own body representation and action planning (Shiffrar 2006). Mirror Neurons are selectively responsible for the observation and production of observed plausibly imitable, goal orientated actions (Shiffrar 2006). Mirror Neurons have been identified in the Ventral Premotor Cortex and the Inferior Parietal Lobule, and seem to be concerned with the understanding of action (Felician & Romaiguère 2008). Research by Schwoebel, Buxbaum and Coslett (2004) found that the imitation of meaningless gestures relied on the Body Schema, whilst body semantics were also involved in the production and imitation of meaningful gestures (Schwoebel et al.). Amorim et al., (2006) suggest that imitating an action requires understanding of that action, and its intention through the extraction of postural information from different angles (Amorim et al.).

Body Representations

Using a Simon-like task to study handedness recognition, Ottoboni, Cubelli, Tessari and Umiltà (2005) found that participants automatically encoded the position of the hand in relation to the body (Ottoboni et al., 2005). Because as no effect was found when the hands were cut at the wrists, it was assumed that this was a 'sidedness' effect, as opposed to handedness; the hand and the forearm may have triggered the activation of the Body Structural Description (BSD) (Ottoboni et al., 2005). Perception of body parts triggers body representations (Ottoboni et al., 2005) when that part has a connecting area (Borghi & Cimatti 2010). Further research found that when hands were attached to the body 'inappropriately' breaking bio-mechanical constraints, a 'sidedness' effect was not found; an effect was only observed when the stimulus configuration matched the BSD (Tessari, Ottoboni, Symes & Cubelli 2009).

The human body is distinct from other non-human objects, which is evidenced by inversion effects. When inverted, body images take longer to recognise because a part-by-part process is used, rather than the usual holistic method (Reed, Stone & McGoldrick 2006; Bosbach, Knoblich, Reed, Cole & Prinz, 2006). In a study by Reed, McGoldrick, Shakelford and Fidopiastis (2004) involving a sorting task using stimulus cards of bears, humans and bicycles, results indicated that the human body was represented on its ability to perform actions (Reed et al., 2004). Bodies may be special objects of perception causing activation of the Extrastriate Body Area in the Lateral Occipitotemporal Cortex when observed (Astafiev, Stanley, Shulman & Corbetta 2004).

The visual system provides global knowledge about the body. Without the visual system, mental representations of the body would largely be acquired from somatosensory or motor experience (Corradi-Dell'Acqua & Tessari 2009). Somatosensory perception is often more local and provides less information about the body in its entirety, particularly information about the connection between different body parts (de Vignemont, Tsakiris & Haggard 2006). Schwoebel et al., (2004) described three distinct body representations, the Body Structural Description, which codes information about body parts, Body Image/ Body Semantics, which codes body knowledge, and the Body Schema, which codes the current posture (Schwoebel et al.,).

The plastic nature of the Body Schema can be illustrated using the rubber hand illusion. Bodvinick and Cohen (1998) placed a rubber hand next to participants hidden real hand, and stroked and tapped the two in synchrony; finding that participants incorporated the rubber hand into their BS, feeling the touch in the rubber hand (Bodvinick & Cohen). This illusion is related to the phantom limb phenomena, where an amputee feels sensations in their amputated limb (Shiffrar 2006). It has been argued that this phenomenon arises as a result of the BSD but some researchers oppose this view. Carruthers (2008) argues that this cannot be the case, as some patients describe experiences changes in their phantoms (Carruthers).

Another theory is provided by Carruthers (2008), who describes Anosognosia for hemiplegia, a disorder which is characterised by an inability to recognise one's paralysis in one side of the body, in terms of online and offline representations. (Carruthers). The online body representation reflects the body as it is at that moment in time (Carruthers 2008). Offline body representations describe what the body is usually like, gaining information from the online representation, including movement capability; therefore visual and emotional aspects can shape these representations (Carruthers 2008). The patients are both able and unable to recognise their condition. They perform actions as if they are not paralysed but do learn for the short term from their failures. However, their offline representations do not seem to be being updated as they soon forget their paralysis (Carruthers 2008).

This theory, however, cannot explain phantoms in those who congenitally lack limbs (Tsakiris & Fotopoulou 2008). The Phenomenon on phantom limb was initially understood as a form of 'body memory'; however, structural body changes are unlikely to be the cause because this phenomenon can occur in those who congenitally lack a limb (Brugger et al., 2000; Shiffrar 2006). Furthermore, mental rotation of congenitally absent hands has shown that even unilaterally amelic patients showed increased reaction times (RTs) for mental rotation of hands if in an unnatural orientation (Funk & Brugger 2008). Research on infants has also provided evidence of preferential looking at scrambled bodies in 18 month olds, suggesting early knowledge of 'abnormal' bodies (Slaughter, Heron, & Sim, 2002). Slaughter & Heron (2004) suggest that visuo-spatial knowledge about the body is present in the second year of life and becomes more detailed and specific with development (Slaughter & Heron). This is evidence of an innate body representation (Tsakiris & Folopoulou 2008).

Further information regarding the nature of body representations can be gathered from studies of brain damaged patients. Autotopagnosia is a deficit resulting in patients' inability to locate body parts in the context of a whole body, despite intact object recognition and spatial ability (Reed, Stone & McGoldrick 2006). Buxbaum & Coslett (2001) reported a patient who was impaired in matching body parts when viewed from different angles (Buxbaum & Coslett). This suggests that localisation of body parts is performed by the BSD (Buxbaum & Coslett 2001). This theory can be supported by evidence that errors seem to present the deficit as involved with spatial, not categorical, organisation (Corradi-Dell'Acqua, Hesse, Rumiati & Fink 2008).

The neural mechanisms which underlie the BSD have been highlighted using functional MRI data (Corradi-Dell'Acqua et al., 2008). Judging the distance between body parts resulted in activation of the Left Posterior Parietal Sulcus, which seems to process information specifically about the spatial relationship between parts; showing dissociation between the BS and the BSD (Corradi-Dell'Acqua, et al., 2008). Further research found specific activation of the Left Angular Gyrus whilst mapping the location of parts of the human body (Felician et al., 2009). Therefore, research into imitation and biological motion may reflect our mental representations of others, rather than of our own body (Corradi-Dell'Acqua & Tessari 2009).

Mental Rotation of Objects and Bodies

To mentally compare whether two objects that are mirror images of each other (or very similar) are the same, the objects are internally rotated to reach corresponding viewpoints; a process that is action dependent even when imagined (Shepard & Cooper 1982; Parsons & Fox 1998). Previous studies have found that, in mental rotation of objects, RTs correspond to the size of the angle (from the viewer) (Shepard & Metzler 1971; Shepard & Cooper 1982). However, a different process is utilised for mentally rotating body parts (Parsons & Fox 1998).

Overney, Michel, Harris & Pegna (2005) conducted a study in which participants were required to perform mental rotations of anatomically plausible and implausible body stimuli, measuring Event-related Potentials (ERPs) in order to identify neural mechanisms (Overney et al., 2005). Results suggested that anatomically implausible postures were recognised prior to rotation and implied implausible body stimuli activated the Left Occipital, Bilateral Frontal and two Medial areas of the brain where, during mental rotation, the Left Parietal areas were activated (Overney et al., 2005). This suggests separate neural areas are involved in the mental representation of body parts and the mental rotation of objects (Overney et al., 2005).

Interactions between vision and body representations are involved in the mental rotations of body parts (Fink & Brugger 2008). In a left-right hand judgement task, participants reported imagining their own body in an upright position and then mentally rotating it to match the reference stimulus (Parsons 1987a&b). Research shows that imagined movement is related to actual muscles (Decety 1996), and suggests that properties are shared between imagined and executed actions, and that mental rotation of body postures may be executed with reference to that persons own body (Petit & Harris 2005). Sirigu et al., (1996) found that damage to the Parietal Lobe disrupts this concordance between imagined and actual movement (Sirigu et al., 1996). Where an actual movement does not occur, an implicit movement, which is often outside of the observers awareness, is used to make a recognition judgement (Parsons & Fox 1998). Details of imagined movements may be constrained by the placement of actual joints reflected in concordance RTs to perform imagined and actual movements, and implicates the use of the Body Schema to create mental representations (Parsons & Fox 1998; Parsons 1987b; Parsons 1994).

In multiple studies of handedness recognition, Parsons (1987a, 1987b 1994) found that participants were likely to imagine their own hand or body when performing mental rotation of that part. It was found that the more difficult a movement is to perform, the more difficult it is to reproduce mentally, showing evidence of structural constraints on imagined action (Parsons 1994). Where the position of the participant's hand matches the observed hand, reaction times reduce suggesting the body's position may be used as a reference (Parsons 1987b).

Researchers have measured the effect of breaking body structural restraints in imagined rotations. In a study of embodiment, authors proposed that, where plausible, participants embody the object, mapping body parts onto it, and rotate it mentally to align it with the comparison posture (Amorim et al., 2006). Rotation is likely to be performed more holistically for human posture than for non-body stimuli, unless body postures violate biomechanical constraints (Amorim et al., 2006). Petit and Harris (2005) reached similar conclusions, finding that mental rotation rates were slower for implausible body stimuli. The experimenters hypothesised that this implausible stimuli was recognised using local representations, whereas plausible postures were represented using more global representations (Petit & Harris 2005).

Reed, Grubb, McGoldrick and Stone (2006) investigated the presence of the inversion effect in relation to body parts, scrambled and halved bodies in comparison to whole bodies, also corresponding conditions for houses and faces, all of which have a clearly defined hierarchical structure (Reed et al., 2006). Processing of the configural relations between parts seemingly relies on the hierarchical structure and the attachment to the torso rather than only the positions of parts in space (Reed, Grubb, McGoldrick, & Stone 2006; Bosbach et al., 2006). This connection to the body may be an important aspect as it remains the same despite differences in posture (Bosbach et al., 2006). Inversion effects were found for bodies and body halves but not for body parts (which contained no information regarding their connection to the body) or scrambled body postures (Reed, Grubb, McGoldrick, & Stone 2006).

The Current Study

This research consists of two studies comprising of computer based tasks where participants decided whether image pairs of Body and Bicycle stimuli were the same or different. Experiment 1 assumed that the BSD, but not the Body schema would be used for the recognition (with no rotation) of static bodies (not posed to infer action), and should not require an active mental image of the body (Bosbach, et al., 2006). Previous studies have suggested that when performing mental rotation of body-like stimuli a mental image of those persons own body or part is used, which would require the use of the Body Schema (Parsons 1987a, 1987b 1994; Amorim, et al., 2006).

Experiment 2 required participants to mentally rotate the comparison image in order to make this judgement. The present study further explored whether the BS is reliant on the BSD. The effects were measured through comparison of RTs. Bicycle stimuli were used as a control in order ensure that, if an increased RT was found for separated bodies, this was not just the case for objects generally.

The main hypothesis was that Body stimuli would be matched more quickly in Experiment 1, and rotated more quickly in Experiment 2, due to the use of mental representations of the body. Previous research has demonstrated inversion effects of Body stimuli in comparison with other stimuli, with a similar solid mechanical structure e.g. bicycles and bears (Reed, et al., 2004). The human skeleton controls what movements the body can make; the hinged movements makes it dissimilar to most objects, other than animals, in the way in which it is constructed (Shepard & Cooper 1982). Therefore, it is hypothesised that RTs will be greater for Bicycle stimuli (despite its solid mechanical structure) in comparison to Body stimuli, as the former should be represented less holistically (Amorim et al., 2006; Petit & Harris 2005). In Experiment 2 RTs should increase with angular difference. This slope should be greatest for Bicycle stimuli as this process should be more cognitively demanding due to the piecemeal process of rotation (Shepard & Metzler 1972; Amorim et al., 2006; Overney et al 2005; Petit & Harris 2005).

Previous studies have suggested that mental imaging of bodies is disrupted if a visual image does not respect normal bodily biomechanical constraints (Overney et al., 2005; Petit & Harris 2005; Amorim et al., 2006). Others have shown that changing the way in which parts connect to the torso adversely affects RTs (Reed, Grubb, McGoldrick, & Stone 2006). It has not, however, been researched in detail whether disconnecting Body Stimuli will effect a pair matching process or Mental Rotation. Disconnections will separate the head and limbs from the torso, but they will still be placed appropriately in coordination with their attachment point. The authors proposed that this will disrupt the BSD and cause increased RTs, but this should not occur for bicycle stimuli. In body stimuli the distortions should cause piecemeal recognition, but in bicycles this process of recognition should already be in place (Reed, Grubb, McGoldrick, & Stone 2006). It is postulated that in order for a mental representation of a body to be created using the Body Schema anatomical constraints must not be violated; suggesting that the BS and BSD are required for the mental rotation of body postures. It is hypothesised that the BSD *underlies* the BS and is required to create a mental image. Therefore, separations to the BSD should disrupt the BS and show longer RTs.

Experiment 1 Method

Participants

Sixteen stage 1, 2 & 4 Students at the University of Plymouth participated in the study. The majority (12) of participants did so in order to gain credit in psychology courses. These participants were recruited via the University online Study sign-up management site, and the Researcher recruited the other four participants. Participants were aged 18-23, fourteen of which were female, and two were male. All participants gave their written consent after receiving their brief and standardised instructions from the experimenter before performing the task.

Materials

Briefs and standardised instructions were printed on A4 paper and given to participants prior to the commencement of the study. Instructions required participants to complete a short computer based task in which they were required to make matching/ non-matching judgements about figure and bicycle stimuli. Printed participant consent forms were used to gain informed consent. Participants were also given a printed debrief on A4 paper on completing the experiment. All printed documents were created using a word processor. All trials were held in the same room; a small open room with 6 computers, separated by dividers. Blinds were closed to prevent glare on the computer screens. Participants sat approximately 55 cm from a 20inch widescreen Samsung SyncMaster 2043BW monitor. The experimental program was created using a slide generator.

Stimuli

All stimuli were presented in pairs simultaneously. Stimuli consisted of two Types (Bicycle and Body) and within these types two Connection statuses (Separated or Intact). Stimuli included 3 Body Intact images, the same 3 Body images Separated; 3 Intact Bicycle images and the Same 3 Bicycle images Separated. Pairs were displayed within a white circle (Mask size 650 in Corel) on a grey background produced in Corel PHOTO-PAINT X4 (see figure 1.0). Image pairs were displayed only in pairs within their own category i.e. Intact Body pairs, Separated Bicycle pairs. Each possible combination was used and combinations were repeated. Images were 1024 by 768 pixel bitmaps. In total the experiment contained 144 trials.

Stimuli Type

Body Stimuli were comprised of three different male figures which were created using Blender software. Images were all greyscale placed in a white circle on a grey background (See Figure 1.0). Images were adjusted using Corel PHOTO-PAINT X4. The three images loosely represent the three different body somatotypes; ectomorph, mesomorph and endomorph. Facial features remained the same across the three Body figures in order to trigger the BSD and minimise the effects of face recognition. In order to ensure the task triggered the structural description, rather than simple recognition, somatotype variation was intended to be subtle. Images differed in the size of the stomach and muscles (e.g. arm and leg width). Height was not varied, as this would produce an obvious visual cue. Quicker RTs were expected between ectomorph and endomorph stimuli as these images are most obviously different from one another.

In keeping with previous studies (Reed, Grubb, McGoldrick, & Stone 2006), Control Stimuli (Bicycles) were chosen for their solid mechanical structure. Bicycle Type Stimuli were used as a Control and consisted of three different Bicycles. The most obvious information, such as written branding or decoration, was removed. White/grey bicycles were used all of which were adjusted to fit within a mask circle created on Corel PHOTO-PAINT X4 size 650. Bicycle images differed in terms of greyscale, wheel size, saddle shape, frame shape and handlebars. Bicycle stimuli were recovered from internet sources

Stimuli Connection

Stimuli Connection refers to the Connection of parts to the ‘main section’ in previous stimuli sets, which is whether images are disconnected or intact. Disconnected stimuli are implausible.

To create the Connection Stimuli original Body images were separated at five locations on the body, with the intention of disrupting the BSD. In order to disconnect body parts from the torso, the images were separated at the neck, shoulders and thighs, by a consistent distance using a Mask template in Corel PHOTO-PAINT X4, where possible, similar to a size 30 eraser, creating a total of 5 separations from the torso (See Figure 1.0, Image A.). In order to create these separations the connecting areas were removed from the image entirely.

A similar process was used for Bicycle images. Separations for Bicycles were created in a similar fashion to the Body stimuli to separate off all parts from the main structure (e.g. the torso of the Body figures and the main frame of the bicycle). Bicycles were separated at five different locations; the wheels, handlebars, pedals and saddle by a consistent distance of (size 30 eraser).

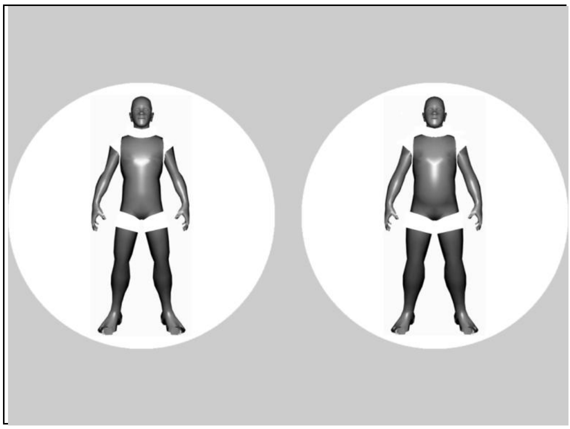

Image A: 'Different' intact Body pair trial, man 1 (Left) man 3 (right). Border added to illustrate the effect of the black screen on which images were presented.

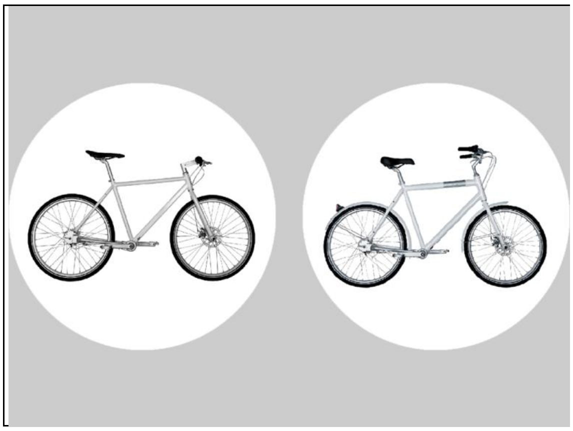

Image B: 'Different' Bicycle pair trial bicycle 2 (Left) bicycle 1 (Right).

Figure 1.0 Example stimuli

Design & Procedure
A 2 X 2 repeated measures experimental design was used. The two within-subjects factors were stimuli Type (Bicycle or Body) and Connection status (Separated or Intact). All participants took part in each condition as all Stimuli images were presented in a randomised manner combining all categories to prevent order effects.

The Experiment was computer based and participants were required to view a series of frames and produce an accurate, rapid, keyboard response. The program displayed 3 frames on repeat until the 144 trials were completed. Frame 1 consisted of a black screen with the words 'same or different' presented in white on the centre of the screen, and was presented for 2500ms. Frame 2 presented a black background with a grey central rectangle containing two white circles containing the Stimuli. This slide was shown for 10 seconds or until the participants responded. Frame 3 was a blank black screen presented for 250ms, to prepare participants for the next set of stimuli. Responses were recorded and coded in terms of RT, Response (Correct or Incorrect) and category of viewed stimuli. Additional information was inputted regarding participants' age and sex.

Participants took part in the task in groups of 1-6 in a room with 6 computers separated by dividers. The experiment ran from 13.00-16.30 in the afternoon of one day and each experimental trial lasted approximately 30 minutes (with the trial itself lasting up to 20mins). On entering the room, participants were allocated to any computer where there was a printed brief and standardised instruction on each desk. Participant numbers written on instruction sheets were in accordance with participant numbers inputted relating to that set of data (participant numbers were again given on debriefs). Participants were instructed to sit at a computer desk and fill in their age and sex (Participant numbers were already inputted) but not start the trial. Once all participants had arrived, this information was read out to them and the experimenter ensured that participants understood the task fully. Participants were informed that the experiment intended to gather knowledge about the nature of body representations. It was explained that the study involved pair matching of Body and Bicycle stimuli requiring a keyboard response. They were informed that they would be required to make decisions about whether sets of image pairs were the 'Same' or 'Different'. It was explained that image pairs would not mix content and would either be the same Type and Connection in each pair. Participants were asked whether they felt happy to continue and any questions were answered. Participants were fully informed of their rights to confidentiality and their right to withdraw at anytime. No participants withdrew at this time or at a later stage.

Participants were free to sit at any computer. Each computer had a participant number that corresponded to the number on the instruction sheet placed in front of it. Participants inputted their age and sex. Participants read further brief instructions on screen which reiterated informed participants:

> "You will see a pair of images appear on the screen, and you will need to decide whether they are the same or different"

Participants were reminded that a 'same' response required them pressing the 'S' key on the keyboard, and a 'different' response required them pressing the 'D' key.

Participants were given 12 randomised trials to get used to the stimuli and key response (these trials were not included in analysis). Participants were never required to make a same-different judgement on a Bicycle-Body pair or intact-Separated pair.

The computer presented three frames which were repeated until all trials were completed. The trial began after initial instructions were shown on the screen, re-iterating which keys to press in response to the stimuli. The screen was cleared; following this Frame 1 was presented with the words "same or different?" on the screen for 2500ms. This was followed by Frame 2 presenting the bitmap image with a Body or Bicycle pair each displayed (floating) within a white circles on grey squares on a black screen. Participants were to determine as quickly and accurately as possible whether the images were the same (identical) or different. In order to compute their decision, participants pressed key "S" for 'same' and "D" for 'different' on the keyboard; keys were chosen so that they were memorable for the response No feedback was given after participants made a response. If participants took over 10 seconds to make a decision they're answer was disregarded. Frame 3 then followed, presenting a blank black screen for 250ms to prepare participants for the next trial. The sequence of displays was random for each participant (in both the experimental trials and practice) and image pairs were repeated throughout the experiment; Bicycle-pair and Body-pair (both Separated and intact) were displayed alternatively and randomly.

Each participant performed 144 experimental trials with 3 x different Intact Body figures and their separated counterparts, 3 x different intact Bicycles and 3 Separated ones. Displayed in pairs of all possible same-different bicycle or Body combinations (Bicycle-Body pairs did not occur). All possible combinations were producing not using Bicycle-Body combinations.

Once all participants had completed the task they were given a written debrief which they took with them. Participant numbers and contact information of the researcher and supervisor were included in order for them to contact the experimenter for further information about the study, with respect to their data or to withdraw their data.

Experiment 1 Results

Analysis was carried out using SPSS 17.0 Statistical software. Data was treated as within subjects as participants experienced all stimuli types therefore a 2 X 2 Repeated Measures ANOVA was used. One set of data was removed from analysis as it contained too many outliers. Results were filtered and RTs two standard deviations from the mean were removed. In keeping with previous research, analyses of variance (ANOVAs) were conducted for the RTs of correct responses to 'same' pair trials (Parsons 1987b; Amorim et al., 2006) and error rates were calculated. The significance level was set to $p<0.05$ for ANOVAs for all trials.

Table 1: Descriptive Statistics presenting statistics for 'same' response trials Mean RTs for correct responses, Standard Error (Std. Error) for correct responses and Mean error rates (%).

Type	Connection	Mean RT (ms)	Standard Error	Mean Error rates (%)
Bicycle	Separated	1792.12	160.46	7.78
	Intact	1783.96	175.05	6.71
Body	Separated	1858.49	151.54	8.52
	Intact	1794.98	167.52	13.33

Table 1 presents the mean reaction time (ms) for all participants over each trial responding to the above categories of stimuli. Mean RTs show that pair recognition generally in response to Body Stimuli was the more difficult than for Bicycle Stimuli; furthermore, the Separated Body Stimuli took slightly longer than Intact Stimuli. The Std. Errors show a wide spread of RTs, but not above that of other mental similar studies (Amorim et al., 2006). Mean error percentages show participants made more errors overall in the Body stimuli trials particularly in response to intact body stimuli.

Reaction Times

Repeated measures Analysis of Variance (ANOVA) was calculated for correct responses to identical pair trials.

The Stimulus effect of Type (Bicycle compared with Body) showed no significant difference in the RTs $F(1,14)=0.061$, $p<0.9$, any differences can only be attributed to chance factors. Mean RT for Separated Body condition was slightly larger (M=1858.49ms) than for the intact condition (M=1794.96 ms) (see Table 1) but this difference was not significant. There was no significant effect found for Connection status (Separated compared with Intact) across both Stimuli Types $F(1,14)=0.610$, *p*<0.5. Therefore separating the stimuli had no significant effect on RT. No significant effect of interaction between Type and Connection was found: $F(1,14) = 0.250$, $p<0.7$.

Error rates

Percentage error was computed to ensure accuracy. ANOVAs were run for error rates. No significant differences for error rates were found. More errors were produced for the Body stimuli but this difference was not significant $F(1,14)=2.313$, $p<0.2$. Error rates were not significantly larger in either condition: $F(1,14)=0.959$, $p<0.3$. Nor was there a strongly significant effect of interaction between Type and Connection $F(1,14)= 3.369$, $p<0.09$ however, this difference would be significant to a lower significance level ($p<0.1$) (see Figure 2). More errors were found for responses to Separated Bicycles (M=7.78ms) than Intact (M=6.67ms) and more errors were found for intact Bodies (M=13.33ms) than Separated (M=8.52ms). Participants seem to have made quite a few errors particularly in response to the Body stimuli.

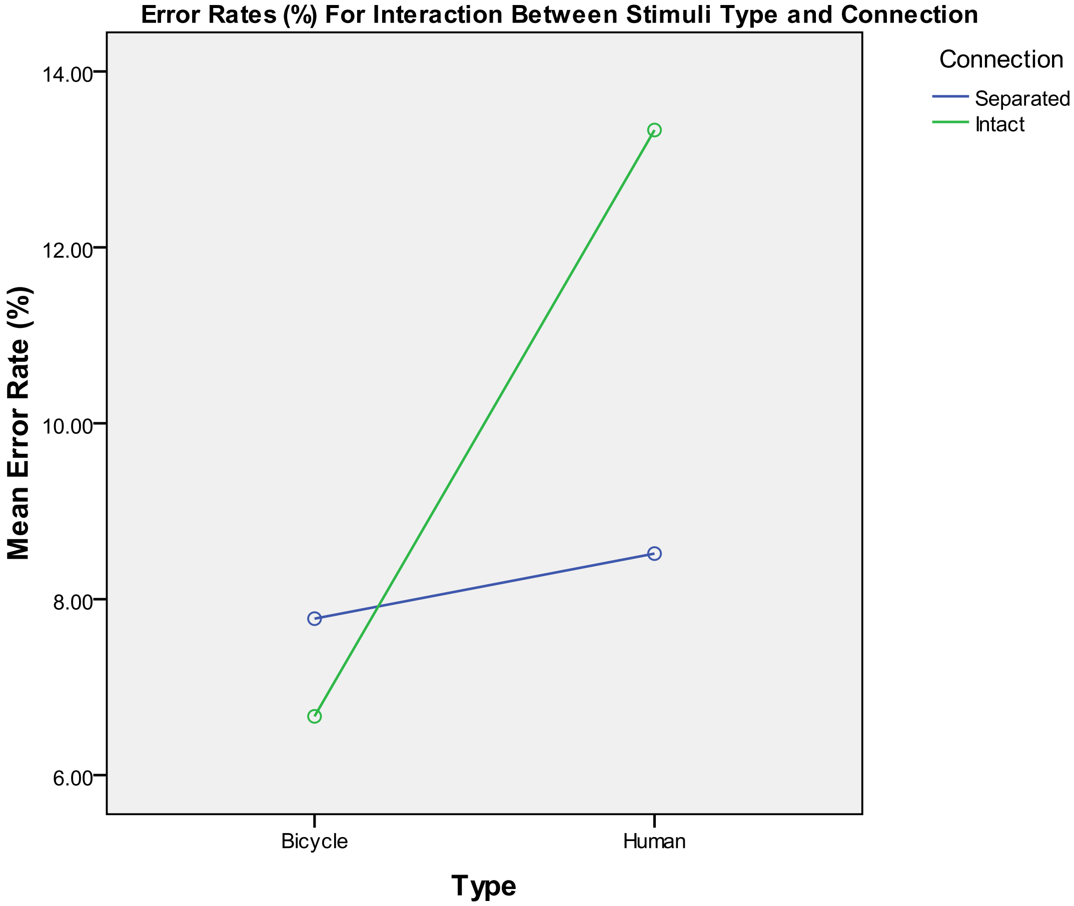

Figure 2: Plot displaying error interaction between connection and stimuli type.

The above plot shows a reasonably stable level of error over Stimuli Type for the Separated Connection, it however shows a great increase of error for Intact Body Stimuli despite a slight reduction in error for Intact Bicycle Stimuli. This shows that separating stimuli has produced only a slight difference on error over the two stimuli types. However intact stimuli has produced largely more errors than intact bicycle stimuli, the larger number of errors shown for human stimuli shows that this stimuli was more difficult to match.

Experiment 1 Discussion

Descriptive statistics show only small variation of Mean RTs across Stimuli differences. The greatest Mean RT is found for Separated Body Stimuli but this is not significantly larger than any other. High standard error does not affect experimental validity as a repeated measures design was used.

No significant effects were found in Experiment 1. There were no significant differences in the RTs for matching Bicycle in comparison to Body Stimuli ($p<0.9$), therefore the prediction that Body Stimuli would be matched more quickly due to the BSD cannot be accepted. This may have been a consequence of stimuli limitations. Stimulus Connection had no effect on either Stimulus Type; therefore disconnecting Stimuli had no significant affect on RTs. It was predicted that the BSD would aid recognition, this effect was not shown, it follows that disrupting the BSD in Body Stimuli had no effect on pair matching; therefore the null hypothesis is accepted. The lack of difference in Connection type in Bicycles is as expected, but this is not noteworthy as no effect was found for Body Stimuli. This could suggest that pair matching may not require the use of the BSD, or that separating the connections simply has no distorting effect on the BSD. Slightly quicker mean RTs for intact stimuli suggests that the way in which separations were created and/or the differences in difficulty between Bicycle and Body Stimuli may have caused no effect to be seen.

Limitations and Implications for Further Research

The main limitation seems to be stimuli. In order to compare effects of pair matching due to object type the two sets of Stimuli are of similar ease of general recognition. This is in terms of colour depth, complexity, number of possible cues etc. Stimuli issues include markings on the bicycles, which may have made them more identifiable and particularly may have provided visual cues for recognition. Bicycle Stimuli may be easier to decipher from one another, as there are differences in the depth of the greyscale and markings on the bicycles themselves. Which is reflected in the lower error rates for bicycles, for example, mean error percentage for intact bicycles was M=6.67 and for Intact Bodies was M=13.33 although the difference in error between conditions was not significant. The Bicycles were also more distinctive from the backgrounds.

The Body stimuli were very difficult to decipher from one another and this seems to have caused a random response effect. Differences between stimuli were very subtle particularly between endomorph and mesomorph figures. The Separated bodies may have been recognised more easily than intact (see Figure 2) as a slightly greater number of errors in the intact condition were recorded; therefore the way in which these bodies were separated could have provided a visual cue for recognition. It could perhaps be that in Separated Stimuli a different percentage of the Body as some were larger than others.

Further research could provide interesting findings in this area; the BSD would be highly implicated if differences were found for disconnected or simply implausible stimuli in recognition only. The stimuli limitations in this research provides a possible improvement area where less subtle human differences could be created and a control stimuli should perhaps be more similar to the body. Animal stimuli such as bears (Reed et al., 2004) would be more similar and would give more knowledge into the animate/ inanimate question of recognition. General experimental limitations and further research will be discussed in the generalised discussion.

Experiment 2 Method

Participants

Sixteen stage 1, 2 and 4 students at the University of Plymouth participated in the current study. As in Experiment 1 the majority (15) did so in order to gain credit in Psychology Courses and signed up via the University online experiment management system. The researcher recruited one participant. Any participants who took part in the previous study were prevented from taking part. Of the 16 students, 13 were female and 3 were male, ranging from age 18-35 years old. Two sets of female data were not used for analysis. All participants gave informed consent before taking part in the study.

Materials

Materials and apparatus were the same as those used in Experiment 1, except that Experiment 2 provides different content of Brief and Standardised instructions, and Debrief.

Stimuli

Three new Body and Bicycle images were produced with a concordant separated set, mirror images for these 12 images were created and all 24 were rotated to 7 different orientations. All stimuli were in the canonical view for that image (e.g. Bodies facing the Observer, Bicycle from the side on) and were created for the present experiment. Stimuli were similar to Experiment 1 except for only one Bicycle and one Body was used, these single sets of stimuli were presented in three separate poses. Each stimuli type was presented with another within its own category. The posed stimuli were either presented in Identical or Mirror image pairs for similarity. Mirror images were produced from the reference stimuli. Where the mirror image was placed on the left as the reference the original image could be placed on the right as the comparison for ‘different’ stimuli trials. Stimuli consisted of 3 Intact Body images, 3 Separated Body Images, 3 Intact Bicycle images and 3 Separated Bicycle images, (and mirrors) images in the separated connection type were identical, apart from their connection status, to their intact counterparts. Stimuli pairs were 1024 by 768 pixels as in Experiment 1.

Stimuli Type

Body Stimuli consisted of postured human male figures created in Blender software, three Bodies were created using the same figure in different poses, changing only the arms (See Figure 3, Image E). As in Amorim et al., (2005) one or two arm bends were created at the elbow and/or shoulder in one arm. Body 1 had the hand and forearm raised and across the chest, Body 2 had the arm behind the back and Body 3 had the arm up in a ‘shaking hands’ style pose. The individual characteristics of the Body Stimuli were kept the same so that the differing factors were the poses only.

Control Stimuli consisted of three similarly ‘postured’ Bicycle images, using the same bicycle in each, only the handlebars (and attached front wheel) were positioned for consistency with human stimuli. Postures of the Body stimuli were as closely replicated as possible. Bicycle 1 was positioned against a flat wall with the wheel turned slightly away from the observer. Bicycle 2 had the handlebars turned towards the observer with the wheel twisting towards the rest of the bicycle. Bicycle 3 had the handlebars again facing the observer with the wheel turned slightly away from the body of the bicycle.

Connection Stimuli

As in Experiment 1 each Stimuli Type (Body or Bicycle) had a further level which was Connection. Each had a set where 5 separations were made to produce the Connection Stimuli using Corel PHOTO-PAINT. Again the same images were used for Bicycle and Body types but images were separated at each area which connected to the main section (torso in Body and main frame in Bicycle). As in Experiment 1 a mask was used to remove certain areas of the Body stimuli, when possible consistent with a size 30 eraser. For bicycle stimuli a distance was removed in consistence with a size 30 eraser.

Stimuli Rotation

For each trial, two Body or Bicycle pairs were presented simultaneously with the Reference image (Left) always in the upright orientation and the Comparison image (Right) at orientations that differed by picture-plane. Rotations were given from 0-180° in 30° increments as in previous studies (Amorim et al., 2006; Overney et al 2005; Petit & Harris 2005). Angular differences were created by rotating the reference stimuli whether normal or mirror image, by rotating it by the required amount in Corel PHOTO-PAINT software. Upright Reference figures always appeared on the left side of the screen; half the trials used identical pair stimuli, and half contained mirror image pairs. All images were created separately and centrally aligned to the display circle and background and then placed next to another image to create pairs.

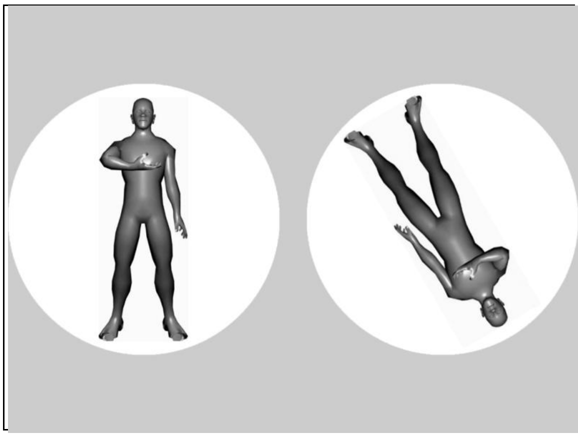

Image E: 'Same' Intact Body 1 stimuli pair. 150 degree angle on Comparison image (right). Border added as Images were presented on a Black background.

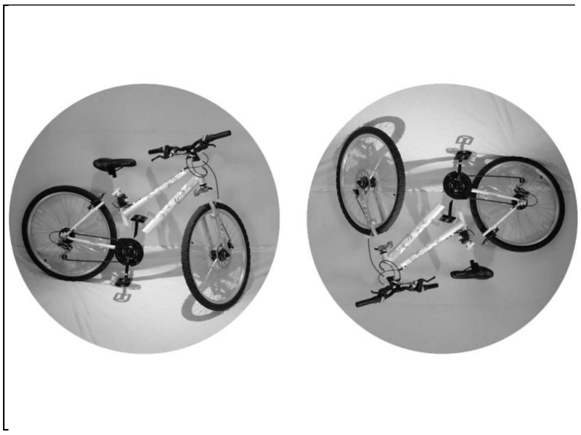

Image F: 'Same' separated Bicycle 2 Stimulus pair, comparison figure presented at 180 degree angle.

Figure 3: Example stimuli Experiment 2

Design & Procedure

The general design is the same as that in Experiment 1 the same slide generator was used with the same frames displaying the relevant bitmap images for Experiment 2. Factors were treated as a repeated measures design as each participant experienced all stimuli types. The procedure, apparatus (Including the room, test times and numbers in each test) and experimental design were the same as that used in Experiment 1.

Participants were required to decide whether Identical or Mirror image pairs were the same or different. Mirror image is used as mental rotation studies require similar stimuli (Shepard & Metzler 1971). The mirror image or original image could be presented as the reference. Images were presented with the left image as the reference which was always presented upright, the image on the left was rotated by 0-180° in 30° increments and was either identical (same) or mirror image (different) of the Reference image. Therefore where the comparison image was not presented at 0° a mental rotation needed to be performed. Stimuli were presented randomly to prevent order effects.

Ethical considerations were in place and participants were informed of what they would be required to do. On entering the room participants were provided with a brief and standardised instructions, it was explained that to respond ‘same’ meant the trials were identical and to respond ‘different’ meant the stimuli pair was mirror image. If participants were happy to continue they gave informed consent and took part in the task. No participants withdrew at this time or at any point following the experiment. Participants performed 12 practice trials and then the full experiment. Practice trials were not included for analyses. After task completion participants were given a copy of the debrief to take with them which contained their participant number, the researchers and supervisors contact details. Thirty minute timeslots were used and the study generally lasted up to 25 minutes.

Each participant performed 168 trials which contained 2 stimuli sets, Type (Bicycle or Body) and Connection (Intact or separated). There were 2 trial types (Identical or Mirror image) and 7 angular differences (0°, 30°, 60°, 90°, 120°, 150° or 180°). Trials could be presented with original or mirror counterpart as the reference. The order of stimuli presentation was randomised each time to prevent order effects.

Experiment 2 Results

Analysis was carried out using SPSS 17.0 Statistical software.

Table 2: Descriptive Statistics: Statistics for ‘same’ response trials, Mean RTs for correct responses, Standard Error for correct responses, Mean error rates (%) and Mean RTs as a function of angular difference (Slope).

Type	Connection	Mean Reaction Time (ms)	Standard Error	Slope ms/degrees	Mean Error (%)
Bicycle	Separated	1818.73	231.22	25.08	4.42
	Intact	1912.98	227.03	25.28	3.79
Body	Separated	1540.26	109.37	21.54	3.06
	Intact	1505.34	119.92	20.1	3.4

Table 2 displays the mean RTs for all participants over each trial in response to the specific condition. The mean results show initial indications that bicycle stimuli have taken longer to mentally rotate (1818.73ms separated, 1912.98ms intact) in comparison to Body stimuli (1540.26ms separated, 1505.34ms intact). Larger Standard Error can be seen in the bicycle trials which show that there was greater variation in RTs for this stimuli type. Standard errors show a large spread of data over all trial types. Error rates show that very few errors were made.

In keeping with the previous research on mental rotation analysis of variance (ANOVAs) were conducted for the RTs of correct responses to ‘same’/ identical pair trials (Parsons 1987b; Amorim et al., 2006). Also, error rates were calculated for same-pair trials. The significance level was set to $p<0.05$ for ANOVAs for all trials. Two participants results contained too many outliers and therefore they’re data was not used for analysis.

Reaction Times (RTs)

Mean reaction times were analysis using a 2 X 2 Repeated measures ANOVA with Stimulus type (Body, Bicycle) and Connection (Separated, Intact) as the within-subject factors. The main effect of Stimuli Type was significant: $F(1,13)=6.2$ $p<0.05$ ($p=0.027$), means show that greater RTs were recorded for Bicycle pairs as compared with Body pairs. Therefore in Bicycle pairs to rotate and match the comparison image to the reference took significantly longer than it did for Body pairs. No significant effect of connection (Separated, Intact) was found across Stimuli Types: $F(1,13)=0.284$, $p<0.6$. There was no significant effect found for the interaction between stimulus type and connection: $F(1,13)=0.892$, $p<$ 0.4. However, although insignificant, quicker RTs were found for Separated bicycle trials (M=1818.73 ms) than for Intact Bicycle trials (M=1912.98 ms). For Body stimuli the RT for the Separated condition (M=1540.26 ms) was longer than for the intact condition (M=1505.34 ms) although the differences were not significant.

Slope

RTs increased linearly with angle for both stimulus types (see figure 1). ANOVA for effect of angle produced no significant differences between means for any condition. Comparing Means for Stimuli Type showed slopes for Bicycles were steeper than for Bodies $F(1,13)=3.983$, is not highly significant $p<0.07$ but differences are notable to a lower significance level of $p<0.1$. This suggests that as angular difference between the comparison and reference stimuli increases RTs increase more rapidly for Bicycle Stimuli in comparison to Body Stimuli. The mean overall slope was larger for bicycles (M=25.18 ms/deg) than for Bodies (M=20.82ms/deg) suggesting that the increased angle of rotation of the bicycle stimuli had a larger effect on RTs than for Body stimuli. No difference in slope for connection was found $F(1,13)=0.716$, $p<0.4$, however Separated Body stimuli produced slightly slower RTs at most rotation angles (see figure 4). Nor was any effect of slope found for the interaction between type and connection $F(1,13)=0.716$, $p<0.4$.

Figure 4 shows mean response times regulated by angular difference. Mean performances are displayed for stimuli type (Bicycle and Body) over both connection conditions as a result in angular differences in comparison stimuli. The graph shows a general increase in RT linearly as angular difference of the reference to comparison image increases. Therefore as the angle of the reference stimuli

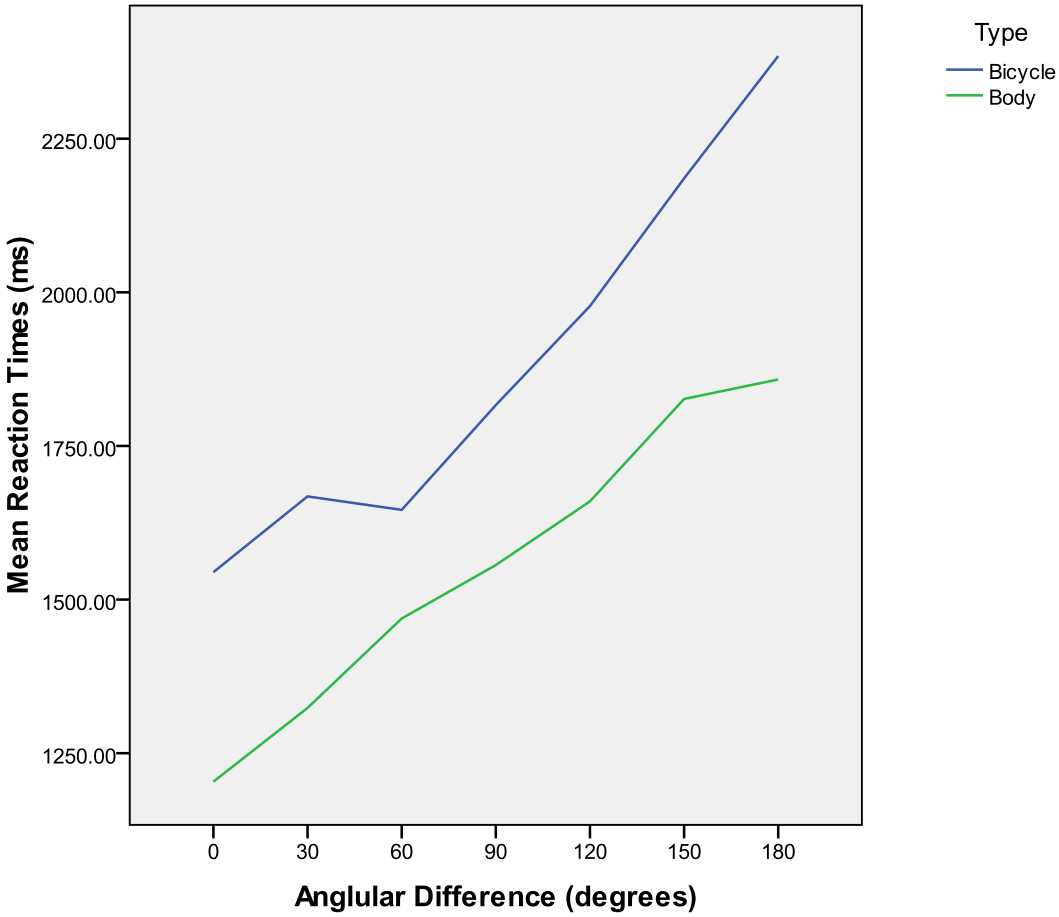

Figure 4.0: Line Diagram displaying the Mean slope (ms/degrees) for correct responses to same trials to both Body and Bicycle Stimuli.

diverges further from the comparison stimuli (always 0°) the time taken to rotate and match that image increases. The top line, which represents Bicycle stimuli is visibly consistently higher as Mean RTs were greater for these pairs. The Bicycle line also seems to increase more steeply consistently after 60 degrees this effect is not highly significant (p<0.7) but the effect is noteworthy.

Figure 5 presents Mean performances in response to Body stimuli only, as a result of angular differences in comparison stimuli. The graph shows a difference of approximately 800ms between the times taken to rotate Body Stimuli at 0° to 180°. The above graph shows the line for separated Body Stimuli is generally higher over the majority of rotation angles in comparison with intact Body Stimuli. This effect however showed no significant difference.

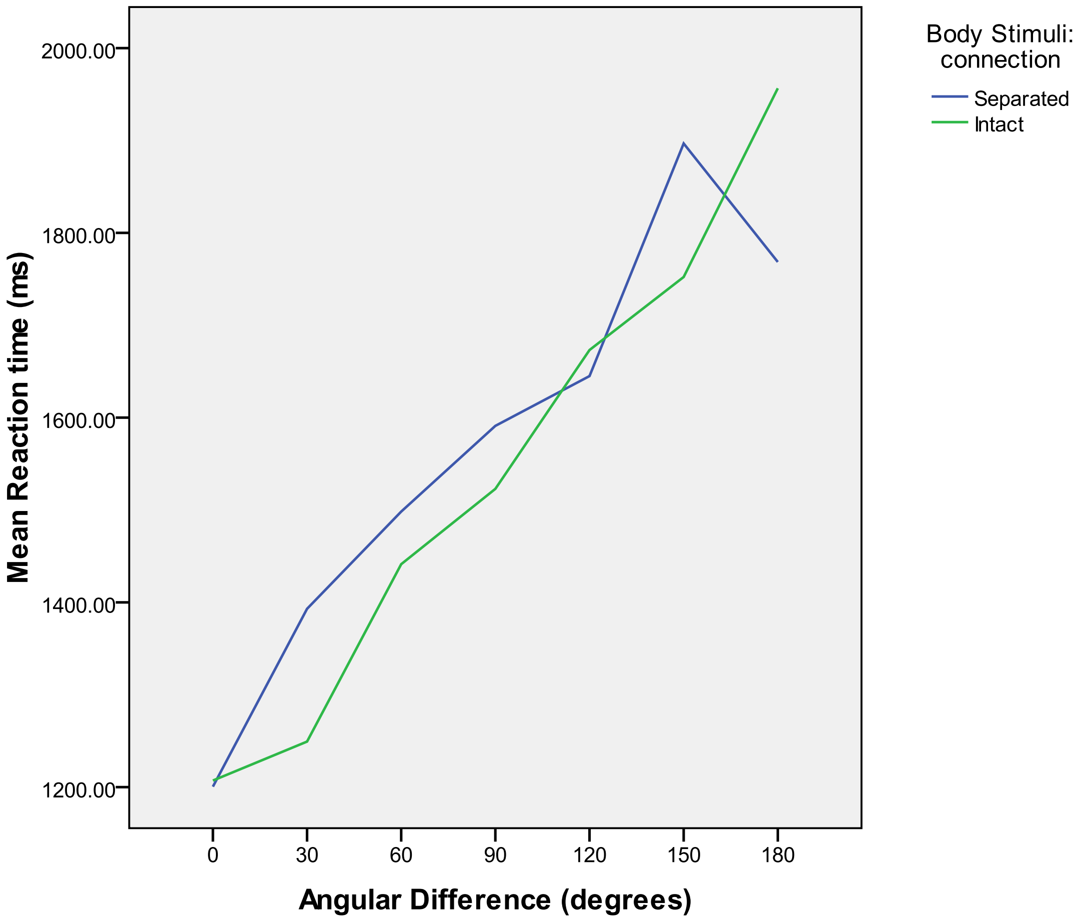

Figure 5.0: Line Graph displaying Mean slope (ms/degrees) for Body Stimuli for correct responses to same Stimuli Trials.

Error rates

No significant effects were found for error rates however very few errors were made in the results used for analysis, only two participants made errors in all conditions and seven made errors in only one. There was no significant effect of stimulus type (Body, Bicycle) on compared mean error rates: $F(1,13)=0.379$, $p<0.6$ or connection types (Separated, Intact) $F(1,13)=0.75$, $p<0.8$, nor for any interaction between type or connection: $F(1,13)= 0.207$, $p<0.7$.

Experiment 2 Discussion

Descriptive statistics showed larger mean RTs, standard errors and Slope for Bicycle Stimuli. Analysis of variance shows Bicycles took significantly longer to mentally rotate than Body stimuli ($p<0.05$); supporting previous findings that the human body is represented more holistically and therefore mentally rotated more easily than other objects (Amorim et al., 2006). This suggests that mentally rotating body stimuli is easier even when an inanimate object has a solid mechanical structure, therefore the hypothesis that Body stimuli should be represented more holistically and therefore rotated more quickly than Bicycle Stimuli can be accepted. The increased time taken to match Bicycle Stimuli suggests, as expected, that this task was more cognitively demanding and should occur in a piecemeal fashion. Therefore, this evidence supports and extends that of (Amorim, et al., 2006 & Reed et al., 2004). Previous evidence from Reed, et al., (2004) found no inversion effects for bicycle and bear stimuli, this research has evidenced that this Body-Bicycle difference could be extended to mental rotation (Reed et al.,).

This assumption is reinforced by the increased slope for Bicycle stimuli, the effect was not significantly different to p<0.05 to that for Body Stimuli, however it was not far off p<0.07. The Mean RTs for Bicycle stimuli increased more with the angle of the comparison stimuli than it did for Body stimuli (See figure 4.0). This suggests that when task difficulty increases with rotation angle responses to Bicycle stimuli are most adversely affected. As cognitive load of the task increases (with angle of rotation) difficulty of task has a greater effect, thus increased slope can be seen to coordinate with increased RTs in the bicycle trials. This supports previous research which suggests that matching takes longer the further the Comparison Stimuli has to be rotated to match the Reference image (Shepard & Metzler 1971; Amorim, et al., 2006; Overney et al 2005; Petit & Harris 2005). This suggests that the mental image of the Body or Bicycle is created and that mental image is internally transformed until it concords with the orientation of the comparison stimuli (Shepard & Cooper 1982). Therefore the greater the angular difference between the reference and comparison stimuli the further the internal image must be rotated to judge whether the two match.

Distorting the Stimuli by creating separations overall had no significant effect on mean RTs across both Stimuli Types (p<0.6) this may have been due to the distortions having been too subtle, therefore the experimental hypothesis that separating the connections would disrupt the BSD resulting in increased RTs must be rejected and the null accepted. Figure 3.0 demonstrates that although no significant difference was found overall for the effect of Connection Status on Stimuli Type, Body stimuli trials produced reasonably consistent slower RTs in the Separated status, as this is not significant the hypothesis must be rejected however it suggests that with less subtle stimuli differences an effect could be found.

Two participants were removed from data analysis as they results contained too many outliers which suggests that they may have been incorrectly applying the rule. It is also possible that certain individuals are much better than others at performing mental imagery tasks. Research suggests that individuals with low spatial ability are slower at performing mental transformations of SM cubes as they are less affective at adopting the required strategies than those with higher spatial ability (Just & Carpenter 1985). This explanation may suggest that those who performed particularly poorly may have had low spatial ability. The diversification between those who performed well and those who performed poorly was interesting as most made very few errors, but a minority made many, (e.g. one data set showed over 50% error in each trial) results with a high number of errors were not used for analysis. There were also large differences in the times taken for participants to perform trials. This individual difference was consistent over trial type as a repeated measures design was used, therefore any individual differences do not reduce treatment validity.

Limitations and Suggestions for Further Research

The Body Stimuli is more distinct from the background than the Bicycle Stimuli; it could be argued that this reduces the validity of these findings as it may have improved the recognition process of Body Stimuli. However it could be arguable also that mirror image bicycles would be more obvious than mirror image humans as the front wheel and handlebars are prominent cues.

Quicker RTs for Separated Bicycle Stimuli in comparison to Intact Bicycle Stimuli (M= 1818.73ms < M=1912.98 ms), suggest that there may have been an issue with the way that the separations were produced. There may have been some visual cue where part of the bicycle was erased to create the separations which aided mental rotation. Conversely, there was a very slight increase in RTs for Separated Body stimuli M=1540.26 ms in comparison to intact Body stimuli M=1505.34ms although insignificant this suggests that the expected effect may have been there but was not recorded due to these visual cues. It is possible that with more sophisticated stimuli a research effect could be achieved.

As experiment 2 demonstrated that Body stimuli are recognised more quickly than Bicycle stimuli, it may be interesting to do this with two animate objects of perception such as Bicycle and Bear stimuli (e.g. Reed, Grubb, McGoldrick, & Stone 2006).

Further limitations and suggestions for further research will be presented in the General Discussion.

Generalised discussion

In Experiment 1 it is likely that Body stimuli was too difficult to decipher and the Bicycle stimuli too easy. This would have led to an imbalance and diminished any expected effects (e.g. bicycles taking longer to match) as found in Experiment 2. Furthermore, increased error rates were seen in Experiment 1 which seems to reflect a stimuli problem (Body stimuli was too difficult to decipher).

Experiment 1 showed no significant effect of Stimulus Type. The intention of performing Experiment 1 was partly to find whether a distorted BSD alone was enough to disrupt pair matching. This was also intended to perform as a control in Experiment 2 to ensure any effect of separation could be attributed to the BSD not the BS. As this effect was not found, it is assumed that Bodies were rotated faster than Bicycles due to the combined effect of the BS and the BSD. However, the nature of the interaction between these two body representations is unsure and this effect could be attributed to the BS alone. Particularly as no effect of Separation was found no direct result of structural constraints on the body was measured.

No significant effects of Connection type were found across either condition, this may have been due to stimuli limitations but it could also suggest that the way in which stimuli was manipulated did not affect the BSD. Ottoboni et al., (2005) provided evidence that when presented with hand stimuli including the attached forearm a mental representation of the body is triggered (Ottoboni et al.,). The disconnected Body Stimuli may have provided enough information for the BSD to function normally.

Amorim et al., (2006) have demonstrated that by adding a head to S-M cubes participants use embodiment to improve their mental rotation; the ability of the mind to map its parts onto a set of cubes in a body-like posture may suggest that the BSD is malleable within skeletal constraints (Amorim et al.,). The results of the current study showed no significant difference between connected and separated stimuli, this may suggest that the BSD is malleable and subtle distortions have no effect.

Therefore the results may show that disconnecting human figures does not disrupt our body representations.

Limitations and Suggestions for Further Research

One limitation of this study may be the way in which the separations were produced; the experimenter separated the images in order to remove areas which connected to the torso (or main frame in bicycles). These separations removed part of the stimuli which may have been useful for recognition. As suggested earlier the way in which these separations were produced may have created some sort of visual cue for mental rotation. Particularly in Experiment 1 disconnections may have been slightly different on each Body as they were different sizes, as images in Experiment 2 were mirror image the effect should not have been so prominent. This would explain the greater diversion from the expected result in Experiment 1. Therefore the validity of results with reference to Separated Stimuli, as this may have resulted in the Experiment not only measuring the question at hand, but also the effect of the cue. Particularly with some of the figures the muscular areas around the shoulder and thigh differed greatly and may have been an important area for recognition in Experiment 1. With different Disconnections an effect of Connection may have been found in both experiments. Previous studies have shown the effect using less subtle methods such as body part scrambling (Reed, Grubb, McGoldrick, & Stone 2006) therefore it is possible that in order to deviate from the BSD more obvious means are required.

If further studies attempt this method again it may improve the study to create separations by moving the part away from the main section so the entire body still remains. This was not done in this experiment as the grey background on the Bicycles in Experiment 2 became distorted when the sections were moved.

Further research into the nature of the BSD could investigate whether changing the proportions of different parts have an effect. It may disrupt the BSD if the body is distorted, keeping limbs placed next to the body correctly but connecting them incorrectly. More research in this general area would provide evidence of to what extent the BSD is malleable and the ways in which it can be disrupted. As the BSD is only one Body representation, further research could also focus on the relationship between representations.

The difference between our own and others representations may be a key area for further research. Carruthers (2008) suggests that our body representations are influenced by experience of others bodies, this theory would suggest the way we see other bodies could influence the way in which our own body is represented (Carruthers). Evidence from Heterotopagnosia, a disorder where patients are able to locate parts of their own but not others bodies; suggests the presence of two independent body models, one, drawing information from visual experience of others and another from sensorimotor signals (Felician et al., 2003). With these patients it was also found that the more similar the target was to a body, the worse their ability to point to a part (de Langavant, Trinkler, Cesaro & Bachoud-Lévi 2009). Suggesting the deficit is related to bodies specifically.

In further research authors proposed differential neural networks associated with the representation of the own and others bodies (Corradi-Dell'Acqua, Tomasino & Fink 2009). When comparing a visual stimulus of a hand to their own participants Left

Parietal Operculum was implicated, when to a visual template the Posterior Left Intraparietal Sulcus was active (Corradi-Dell'Acqua et al., 2009). This could suggest two separate neural systems encoding spatial organisation of ones own body and the bodies of others which could explain our ability to feel that we are distinct from others (Felician & Romaiguère 2008). Dissociation between the two may cause an unrealistic representation of the body and proposes that more research should be conducted into the effect ones own BSD and BS have upon the Body Image. If it was found that a manipulated BSD affected Body Image this could give insight into disorders such as anorexia where this is distorted.

Research by Felician and Romaiguère (2008) suggests that representations of others bodies is separate to the representation of our own so perhaps this dissociation is important (Felician & Romaiguère). If we use separate structures to represent our own and others bodies it may be a deficit in either of these areas which could account for a distorted body image. The anorexic views her extremely thin body as overweight experiencing a dissociation between the reality of the body and the perception of that body (Knockaert & Steenhoudt 2005). The skeletal anorexic body is similar to a representation of death and shows that the anorectic has a strong desire to be in control of the way in which others perceive that body (Knockhaert & Steenhoudt 2005).

If an individual is born with a different body to those of the general population, the question arises of whether their BS or BSD would be different to that of others, and what effect would this have on self other analysis and the development of a body image (Corradi-Dell'Acqua & Tessari 2009). As research suggests this BSD may be innate (e.g. Slaughter & Heron 2004) this framework may be different in different people, or it may simply provide a skeletal structure. Further research could aim to discover what interaction the BSD has with the Body Image and why some individuals have a desire to reconnect with the skeletal form of the body Knockhaert & Steenhoudt 2005).

Conclusion

This paper has comprised of two studies, which investigated the way in which we utilise our Body Representations to perform pair matching and mental rotation tasks. The effects of Bicycle and Body Stimuli on RTs were compared. The first study was intended to tap into the BSD only, using pair matching. No significant effects were found. This was attributed to stimuli issues. The second study was similar but required participants to use mental rotation to match posed stimuli. This study has supported previous evidence in that the body is represented differently to inanimate objects and is mentally rotated more easily. With increased angular difference between pairs of stimuli the times taken to rotate increased also, furthermore this effect was more prominent with Bicycle stimuli. These results suggest that the Body is rotated in a more holistic way due to the Body representations. Bicycle stimuli are rotated in a piecemeal manner which requires more cognitive effort. The body representations contribute to our ability to create a mental image of and internally transform body stimuli. Disconnected stimuli were compared with intact to find whether this would disrupt the BSD and if so, what effect this would have on the BS, however no effect of Connection Status was found. This was attributed to issues in the way that separations were produced. Further research should produce disconnections in a way less likely to produce visual cues.

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