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The Relationship Between Preference and Performance Measures of Handedness

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Abstract

There is great debate as to the way in which preference and performance measures of handedness are related. Some suggest that they are separable dimensions (e.g. Porac & Coren, 1981), however a bulk of evidence suggests otherwise (Annett, 1970b; 1976; 1985). The study aimed to discover whether any of three tasks were better captured by the EHI (Oldfield, 1971). Participants completed all three performance tasks and the EHI. Results suggest that performance measures tapping more practiced abilities may be better captured by preference inventories. Implications of the findings and how preference and performance measures might be related are discussed. How performance measures relate to different types of handedness dichotomies derived from the EHI are also discussed.

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Ethical Compliance

There were no major ethical concerns linked to the proceeding investigation; the tasks undertaken by the participants were judged to pose no risk over and above that normally experienced in everyday life and standard health and safety rules were adhered to. The experiment was passed by the schools ethics committee.

In order to comply with ethical guidelines informed consent was gained by briefing each participant of the aims of the study and by explaining the tasks they would be required to complete, they were also given the opportunity to ask any questions before proceeding and told that they had the right to withdraw at any time. Following the experiment each participant was fully debriefed as to the nature of the investigation and given both the experimenters and supervisors contact details should they have wished to find out more or withdraw their data from the study. They were also given a second opportunity to ask any questions they may have had.

All data reported was collected by the author and was kept confidential at all times. Only the author viewed the data and participants were identifiable only by number.

Introduction

Being the most obvious behavioural asymmetry in humans, it is hardly surprising that researchers have long been fascinated by handedness and its relationship with a range of behaviours. Despite wide investigation into handedness and its behavioural correlates, how to best define and measure the concept remains an area of debate.

The traditional definition of handedness refers to the preferred or superior use of one hand over the other (Porac & Coren, 1981). Hand preference is often used to divide samples into handedness groups in order to study lateralized behaviours (Corey, Hurley & Foundas, 2001). The quickest and simplest way for researchers to obtain a quantitative measure of hand preference is to administer a questionnaire. Such questionnaires provide a direct subjective measure of an individuals hand preference, generally asking participants to imagine or demonstrate how they would perform a number of tasks where one or both hands are used, and recording which hand is preferred in each task. Examples of tasks include which hand is used when writing and which hand is on top when sweeping (Annett, 1970a; Oldfield, 1971). Questionnaires of hand preference are not used simply because of the ease with which they can be administered, but the bimodal “J” shaped distribution (Annett, 1970a; Oldfield, 1971) yielded by preference measures, where the majority of respondents produce strong right-hand preference, almost none show “equal” preference, and few show strong left-hand preference, also enables researchers to divide samples into two distinct handedness groups.

Measures of hand performance are also used to assess handedness in research. In contrast to the bimodal distribution yielded by preference measures, measures of hand performance generally produce a unimodal distribution with a mean shift to the right of zero (Annett, 1985; 2002). Exactly how, or even *if* the two are related is an area of great debate. Many researchers advocate a relationship between measures of preference and performance (e.g. Annett, 1985; Bishop, 1989; Brown, Roy, Rohr, Snider & Bryden, 2004; Rigal, 1992; Triggs, Calvanio, Levine, Heaton & Heilman, 2000). Such researchers have frequently found significant relationships between the two types of measure, for example, Triggs *et al* (2000) found that three performance tasks tapping differing forms of manual skill (finger-tapping, the Purdue Pegboard and grip strength) each correlated significantly with preference measures. Prior to this, after repeatedly demonstrating a consistent relationship between performance on a peg-moving task and preference measures and discovering that manual proficiency remains unchanged throughout childhood (Annett, 1970b), Annett (1985) suggested that hand preference follows hand performance; early experiences teach us that one hand can be relied upon over the other to carry out tasks more efficiently, leading to greater confidence in the more efficient hand and consequently a preference.

However, Porac and Coren (1981) pointed to the bimodal distribution of preference measures and the unimodal distribution of performance measures as evidence that hand preference and performance are separable dimensions. As already mentioned, preference measures produce a bimodal “J” shaped distribution (Annett, 1970a; Oldfield, 1971); performance measures on the other hand produce a unimodal distribution with a mean shift to the right of zero (Annett, 1972). Porac and Coren (1981) also pointed out that, although significant, correlations between preference and performance measures are often far from perfect.

There is no escaping the fact that preference and performance measures do produce different distributions, and in some cases, though significant, correlations are weaker than may be preferred. But does this mean that measures of preference and performance really are separable dimensions? Surely the two must be related in some way. It would be a rather odd situation if they bore no relation whatsoever, after all, they are both undoubtedly related to hand *use*.

Bishop (1989) has developed a model that not only accounts for the differences in preference and performance distributions but also the imperfect correlations between preference and performance measures, thus signifying a relationship between the two types of measure. Of course, there are a number of different performance measures that have been adopted by researchers to assess hand skill and it has been found that some are much more highly correlated with preference measures than others. For example, in a review of studies, Porac and Coren (1981) found that one measure of performance, steadiness, was highly correlated with preference whilst another, grip strength, produced a poor correlation. More recently similar results have been published (e.g. Brown *et al*, 2004; Triggs *et al*, 2000).

So hand preference is almost certainly related to hand performance, yet findings suggest that this relationship varies depending on the performance measure of choice (Brown *et al*, 2004; Porac & Coren, 1981; Triggs *et al*, 2000). As performance tasks provide an objective measure of handedness, in contrast to preference tasks that arguably provide a more subjective measure, determining which tasks more accurately predict preference is clearly important in facilitating handedness research based on distinct handedness groups (Brown *et al,* 2004). The current study was interested in determining what type of manual performance was best captured by a preference measure.

To obtain a measure of hand preference for each participant the Edinburgh Handedness Inventory (Oldfield, 1971) was used. The Edinburgh Handedness Inventory (EHI) is one of the most widely used preference measures and can be used to assess degree of handedness or be used to divide participants two distinct into handedness groups based on the scores produced. The method suggested by Oldfield for deriving handedness scores from the Edinburgh Handedness Inventory (EHI) involves asking participants to indicate their degree of preference by placing ++ in the appropriate column (left or right) where the preference is so strong that the other hand would never be used, + in the appropriate column where the other hand may occasionally be used and + in each column when both hands are used equally for the task. A laterality quotient is then calculated from these scores using the formula [(R-L)/(R+L)]100, where “R” refers to the number of “+”s in the right column and “L” refers to the number of “+”s in the left column. This produces scores ranging from +100 (totally right-handed) to -100 (totally left-handed). With a large enough sample, EHI distributions produce the traditional bimodal distribution of preference measures.

As with other preference measures, two methods for deriving handedness groups using the EHI are frequently used. Perhaps the most common method involves dividing the sample arbitrarily between consistent right-handers and nonconsistent right-handers. Where this divide is made varies remarkably between investigations but is generally made in the higher scoring half of "+" scores. The other method is a far more simple intuitive divide at zero so that all those with a "+" score are classed as right-handed and all those with a "-" score are classed as left-handed.

Participants were also asked to complete three measures of manual performance each of which being modelled on tasks developed by Annett (1970b; 1992). The first was based on the peg-moving task (Annett, 1970a), the other two on the DOTS and LINES tasks (Annett, 1992). As already mentioned, previous research has shown the peg-moving task to be consistently related to preference measures (Annett, 1970b; 1976; 1985), despite the peg-moving task producing a unimodal distribution. In an attempt to find a group alternative to the peg-moving task Annett (1992) developed and trialled a number of tasks including two pen and paper tasks, DOTS and LINES. Both tasks use the same apparatus and require participants to accurately aim for a target; the DOTS task requires that the participant lift a pen from the paper between each target, whereas the LINES task requires the participant to draw one continuous line, this time passing accurately through each target.

Past findings have shown these tasks to produce different distributions, DOTS producing a bimodal distribution more in-keeping with distributions of preference measures and the LINES and peg-moving task producing the unimodal distribution associated with performance measures (Annett, 1992). The same study showed that between hands differences vary for each task when hand preference is taken into account, DOTS producing the greatest difference and the peg-moving task the smallest. These findings suggest that the three performance measures above may be measuring different aspects of hand skill and that perhaps the dots task is more strongly related with preference measures than the other two tasks and therefore better associated with categorisation on the EHI. How either of the remaining two tasks would be associated with categorisation on the EHI was less obvious, though since past findings have shown both to be related to hand preference potentially strong relationships with the EHI were expected to be observed in both cases.

Method

Participants

Forty-one (34 female and 7 male) undergraduates participated as part of a course requirement. Of the participants, 30 were professed[1] right-handed individuals, the remaining 11 professed left-handed individuals.

Procedure and Materials

The 41 participants completed all four tasks. Order of task administration was randomised to avoid order effects; 20 participants received

[1] Participants were asked to indicate which hand they felt was dominant prior to completing any tasks.

the EHI followed by the Dots, Lines and Pegboard tasks, the remaining 21 received the Dots, Lines and Pegboard tasks followed by the EHI. Age and sex of each participant was also recorded. Participants were briefed prior to the experiment (see Appendix A), informed consent was gained and it was explained that participants had the right to withdraw from the study at any point. Following the study participants were fully debriefed as to the nature of the study (see Appendix A) and again reminded that they had the right to withdraw their data at any time.

The Edinburgh Handedness Inventory

The 20-item version of the Edinburgh Handedness Inventory (EHI) was used to indicate participants preferred handedness (see Appendix B). Instructions on how to complete the questionnaire were given in both written form with the questionnaire and verbally for clarification. Laterality quotients for the EHI were derived according to Oldfield (1971).

The Dots Task

The dots task was modelled on Annett's (1992) DOTS. As in Annett's DOTS, two parallel rows of ten circles were printed on plain A4 paper, each circle was 4mm in diameter and 64mm apart. The circles were linked by zigzag lines alternating between the upper and lower circles indicating the order in which participants were to mark each circle. Two such stimuli were printed one below the other on each page, one to be completed with the left hand, the other with the right (see Figure 1).

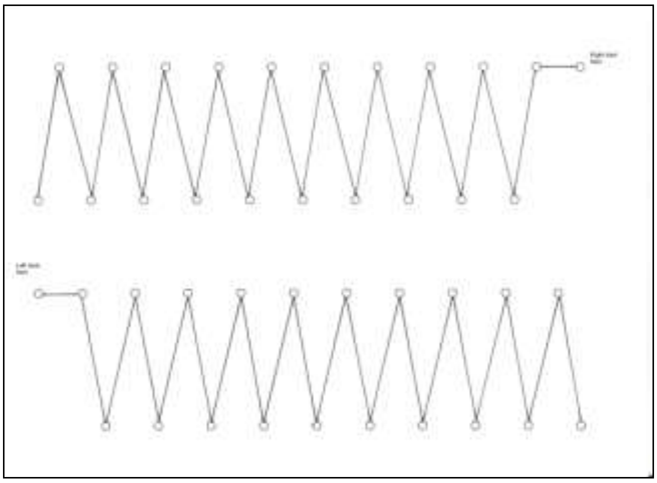

Figure 1. Apparatus used for both the dots and lines tasks.

Participants were given both written instructions (see Appendix B) and verbal instructions on how to complete the dots task. The apparatus was presented horizontally to all participants. They were asked to start by holding the pen in the start position (see Figure 1), and were then asked to mark the centre of as many circles as possible, as accurately as possible in 10 seconds[2].

Participants were given one practice trial followed by three test trials. The start hand was randomised for each participant regardless of professed handedness so that half of the participants completed the tasks in the order RLRLRL and the other half in the order LRLRLR.

The score was the total number of accurate marks made in the three test trials. Inaccurate marks were taken as any pen mark outside of the circle. A laterality quotient was derived from the number of circles accurately

[2] A pilot study had found that 10 seconds was the optimum time for the dots task; participants were able to mark a number of circles in this time, but mostly did not reach the end thus avoiding a potential ceiling effect.

marked; [(R-L)/(R+L)]100, where “R” is the number of circles accurately marked by the right hand and “L” the number of circles accurately marked by the left hand.

The Lines Task

The lines task was modelled on Annett’s (1992) LINES. The same apparatus that was used in the dots task was used for the lines task (Figure 1). Again, participants were given both written (see Appendix B) and verbal instructions and the apparatus was presented horizontally.

Participants were instructed to draw one continuous zigzag line entering and leaving the circles as accurately as possible without overshooting. For this task, participants were given 15 seconds to pass through as many circles as they could[3].

One practice trial and three test trials were given to each participant. The start hand was randomised for each participant regardless of professed handedness so that half of the participants completed the tasks in the order RLRLRL and the other half in the order LRLRLR.

The score was the total number of circles passed through accurately. Inaccuracy was defined as any pen mark outside of the circle. The laterality quotient was derived from the number of circles accurately passed through; [(R-L)/(R+L)]100, where “R” is the number of circles accurately passed through by the right hand and “L” the number of circles accurately passed through by the left hand.

[3] A pilot study had shown that 15 seconds was the optimum time for the lines task in order to avoid a ceiling effect.

Pegboard task

The pegboard task was modelled on Annett's (1970a; 1992) peg-moving task (PEGS). As with Annett's (1970a; 1992) PEGS, participants were presented with a wooden board placed horizontally in front of them. Dimensions of the board differed from that of Annett's; the board used for the current experiment consisted of two parallel rows of ten holes, 20mm in diameter, 205mm apart, with 25mm between each hole (see Figure 2). The ten pegs were 17mm in diameter and 55mm in length.

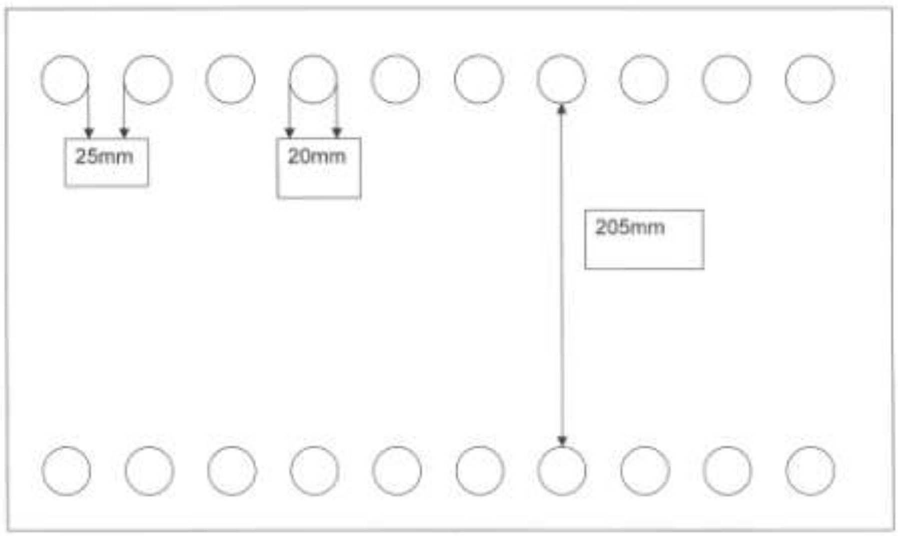

Figure 2. Pegboard layout and dimensions.

The participants were given both written (see Appendix B) and verbal instructions on how to complete the pegboard task. They were asked to move each peg in turn as quickly as they could from the furthest to the closest row. If the participant dropped a peg then the timer was reset and the trial restarted, avoiding potentially lengthened response times caused by events of no interest to the study. Participants began the task by holding the first peg; the experimenter signalled start time.

Each participant was given one practice trial and five test trials. Five test trials were recorded rather than three as in the previous two tasks so as to obtain a more accurate mean response time. The start hand was randomised for each participant regardless of professed handedness so that half of the participants completed the tasks in the order RLRLRLRLRL and the other half in the order LRLRLRLRLR.

The score was the mean time it took each participant to move all ten pegs across the five test trials to an accuracy of 1/100 seconds. For the pegboard task laterality quotient was derived in a different way to that of the dots and lines task; [(L-R)/(L+R)]100, where "L" refers to the mean response time of the left hand and "R" refers to the mean response time of the right hand. The measure L-R is used for the pegboard task as most people take longer to complete the task with their left hand (Annett, 1992).

Results

Preference and Performance Distributions.

Figures 1a-d show the distributions plotted using the laterality quotients derived from the scores on the preference and performance measures. As predicted, the Edinburgh Handedness Inventory and dots task produced bimodal "J" shaped distributions whereas the pegboard and lines task produced unimodal distributions

Measure of association.

In order to analyse the association between handedness groups categorised according to either a divide at zero or an arbitrary divide at +75 eta² was used. The independent variable was taken as the EHI handedness groups, the dependent variable being the laterality quotients derived from the performance tasks.

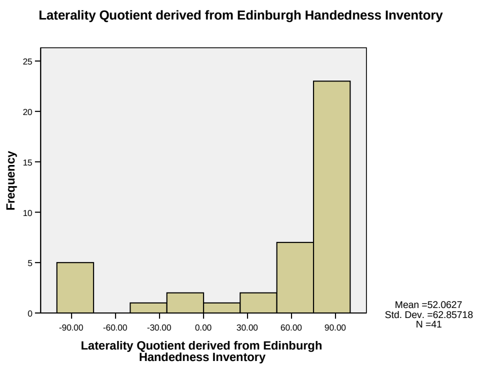

Figure 1a. Distribution of laterality quotients derived from the EHI.

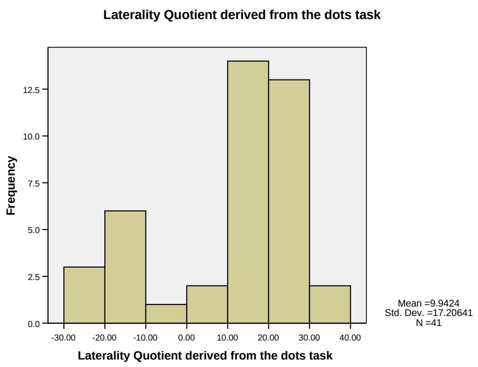

Figure 1b. Distribution of laterality quotients derived from the dots task.

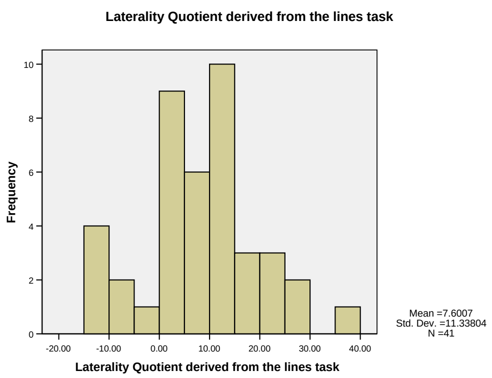

Figure 1c. Distribution of laterality quotients derived from the lines task.

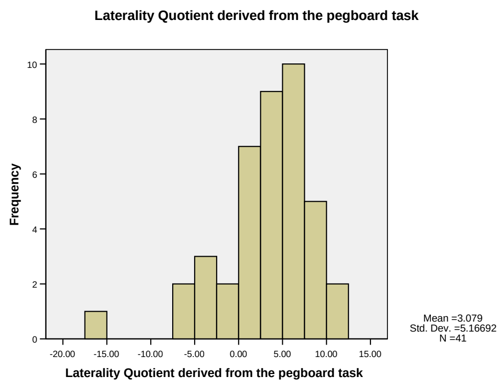

Figure 1d. Distribution of laterality quotients derived from the pegboard task.

Table 1a shows the extent of association between each performance task and the EHI according to eta^2 when participants are divided at zero so that all those with a "+" score are in the right-handed group and all those with a "-" are in the left-handed group. Table 1b shows the eta^2 when participants are divided according to consistency of right-handedness so that all those scoring +75 or above on the EHI are classed as consistent right-handers and all those scoring below +75 are classed as nonconsistent right-handers.

Table 1a.
Eta^2 values when sample divided at zero.

	Eta^2
Dots task	.55
Lines task.	.50
Pegboard task	.47

Table 1b.
Eta^2 values when sample divided at +75.

	Eta^2
Dots task	.25
Lines task	.29
Pegboard task	.12

As can be seen, far more of the variance in each of the performance measures is explained when the sample is divided intuitively at zero than when divided according to right-hand consistency. However, the extent of association even when dividing participants at zero is still far from perfect.

Exploring Interactions.

A mixed analysis of variance (ANOVA) was used to explore any interactions between handedness categorisation according to the EHI and scores on the performance measures. Again, analyses were run with the sample classified according to a divide at zero and then with the sample classified according to an arbitrary divide at +75. The handedness groups were the between subject variable. The within subject factor being the hand used; for each task participants had two sets of scores, one for the right and one for the left hand. In order to meet the assumptions of ANOVA laterality quotients were not used, instead number of accurate marks on the dots and lines tasks and response time on the pegboard task were used.

Table 2.
Means and standard deviations of accurate marks/mean response time when sample divided at zero. (right-handers N = 33; Left-handers N = 8).

	Handedness	Mean	Standard Deviation
Dots; accurate marks with right hand.	Right Left	43.27 29.12	7.35 6.03
Dots; accurate marks with left hand.	Right Left	32.12 40.13	7.25 8.69
Lines; accurate passes with right hand.	Right Left	41.42 29	9.09 7.07
Lines; accurate passes with left hand.	Right Left	33.36 34.63	8.11 9.66
Pegboard; mean response time with right hand (secs).	Right Left	9.87 11.35	.89 1.45
Pegboard; mean response time with left hand (secs)	Right Left	10.84 10.43	.99 1.05

An Intuitive Divide at Zero.

Means and standard deviations for the dots, lines and pegboard task when the sample was divided at zero are presented in Table 2. Analysis of variance revealed a significant interaction between handedness group and each of the tasks; dots, $F(1, 39) = 33.43$, $p < .001$, lines $F(1, 39) = 36.47$, $p < .001$, and pegboard task, , $F(1, 39) = 36.47$, $p < .001$.

Follow-up analysis with an independent measures t-test revealed four significant differences; in the dots task the right-handed group accurately marked more circles when using their right hand (*M* = 43.27, *SD* = 7.35) than did the left-handed group (*M* = 29.13, *SD* = 6.03). This difference was significant, $t(39) = 5.04$, $p < .001$. Further to this, the t-test revealed that the left-handed group accurately marked more circles in the dots task when using their left hand (*M* = 40.13, *SD* = 8.69) than did the right-handed group (*M* = 32.12, *SD* = 7.25). This difference was also significant $t(39) = -2.70$, $p < .01$. In the lines task the right-handed group accurately passed through more circles when using their right hand (*M* = 41.42, *SD* = 9.09) than did the left-handed group (*M* = 29, *SD* = 7.07). This difference was significant $t(39) = 3.6$, $p < .001$. Finally, in the pegboard task the right-handed group were faster when using their right hand (*M* = 9.87, *SD* = .88) than those in the left-hand group (*M* = 11.34, *SD* = 1.45). This difference was significant $t(39) = -2.77$, $p < .05$. It should be noted however that a Levene's test for equality of variances indicated that equal variances could not be assumed therefore results for the pegboard task should be taken with some caution. No significant differences were found between the two-handedness groups when the left hand was used for either the lines or pegboard task.

It should be noted that in each of the analyses of variance reported above Mauchly's Test of Sphericity was significant therefore the Greenhouse Geiser adjustment was used.

Means and standard deviations for the dots, lines and pegboard tasks when the sample was divided into groups according to consistency of the right hand are presented in Table 3. Analysis of variance again revealed a significant interaction between handedness group and each task; dots, $F(1, 39) = 12.02$, $p < .001$, lines, $F(1, 39) = 21.35$, $p < .001$, and the pegboard task, $F(1, 39) = 11.81$, $p < .001$.

Table 3.
Means and standard deviations of accurate marks/response time when the sample was divided at +75 (consistent right-handers N = 23; nonconsistent right-handers N = 18).

	handedness	Mean	Standard Deviation
Dots; accurate marks with right hand.	Consistent right Nonconsistent right	43.3 34.39	5.25 9.27
Dots; accurate marks with left hand.	Consistent right Nonconsistent right	31.91 35.91	4.27 11.01
Lines; accurate passes with right hand.	Consistent right Nonconsistent right	42.22 34.89	9.62 9.11
Lines; accurate passes with left hand.	Consistent right Nonconsistent right	33.04 34.33	8.02 8.87
Pegboard; mean response time with right hand (secs)	Consistent right Nonconsistent right	9.72 10.72	.82 1.31
Pegboard; mean response time with left hand (secs)	Consistent right Nonconsistent right	10.67 10.89	.97 1.06

Follow-up analysis using an independent measures t-test revealed three significant differences; in the dots task the consistent right-handed group accurately marked more circles with their right hand (*M* = 45.30, *SD* = 5.25) than did those in the non-consistent right-handed group (*M* = 34.89, *SD*

= 9.67). This difference was significant $t(39) = 4.47$, $p < .001$. It should be noted however that a Levene's test for equality of variances indicated that equal variances could not be assumed therefore results for the dots task should be taken with some caution. In the lines task the consistent right-handed group accurately passed through more circles when using their right hand (*M* = 42.22, *SD* = 9.62) than those in the non-consistent right-handed group (*M* = 34.89, *SD* = 9.11). This difference was significant $t(39) = 2.48$, $p < .05$. Finally, in the pegboard task the consistent right-handed group were faster when using their right hand (*M* = 9.72, *SD* = .82) than those in the non-consistent right-handed group (*M* = 10.72, *SD* = 1.31). This difference was significant, $t(39) = -2.82$, $p < .01$. It should be noted however that a Levene's test for equality of variances indicated that equal variances could not be assumed therefore results for the pegboard task should be taken with some caution. No significant differences were found between the two groups when the left hand was used for any of the three performance measures.

Again, in each of the analyses of variance reported Mauchly's Test of Sphericity was significant therefore the Greenhouse Geiser adjustment was used.

All statistical data and output are contained on disk in Appendix C.

Discussion

Categorising samples using the EHI.

Hand preference inventories generally produce bimodal distributions allowing researchers to divide samples into two distinct handedness groups. The Edinburgh Handedness Inventory (Oldfield, 1971) is no exception and as predicted results replicated this pattern despite a relatively small sample.

The current study addressed to some extent the question of how handedness dichotomies derived from the EHI relate to performance measures. Two ways of dividing samples were investigated; a simplistic intuitive divide at zero and the more commonly used arbitrary divide between consistent and nonconsistent right-handers. Interestingly, it was the less widely used, far more simplistic divide at zero that produced the stronger association between hand preference group and performance on each of the three manual tasks. When the sample was divided arbitrarily at +75 to distinguish between consistent and nonconsistent right-handers hand preference category was only very weakly related to performance on each of the three tasks; the lines task showed the greatest association but still only 29% of its variance could be explained by the EHI when groups were derived in an arbitrary way. Further to this, when the sample was divided at zero the performance measure most strongly associated was the dots task, however when the sample was divided at +75 the lines task was most strongly associated. This suggests that the two different types of dichotomies derived from hand preference measures are reflecting different aspects of hand performance. Indeed, an arbitrary divide appears to reflect very little in the way of hand performance (see Table 1b).

These findings have clear implications for researchers choosing an arbitrary divide as criteria for hand preference classification. Although it cannot be disputed that such a dichotomy distinguishes between those who more frequently prefer the right hand over the left, it appears to have very little predictive value when considering hand performance. In contrast, the simplistic divide at zero provides much more predictive power when considering hand performance. One must bear in mind though that the score used as criteria for an arbitrary divide varies greatly across research studies. The current study only examined the association between hand performance and a relatively high cut-off criteria of +75, further investigation may show that a lower cut-off criteria is better associated with performance measures than the higher criteria.

The above findings certainly suggest researchers should air some caution when attempting to make predictions about the performance of individuals based on hand preference group, particularly when such groups have been derived according to an arbitrary divide, but also when samples have been divided at zero since associations were still weak.

The Relationship between Preference and Performance Measures.

One of the biggest questions in handedness research is the way in which the two types of measure – preference and performance – are related. Some suggest that the two represent separable dimensions of handedness (Porac & Coren, 1981), however a vast body of research (e.g. Annett, 1985; Bishop, 1989; Brown *et al,* 2004; Corey *et al*, 2001; Triggs *et al*, 2000) point to this being a rather imprudent opinion, after all both are undoubtedly related to hand use.

Rather than the question being *are* preference and performance measures related, what should be asked is *how* the two are related. The central aim of the current investigation was to discover whether any particular type of manual performance was better captured by the Edinburgh Handedness Inventory (Oldfield, 1971). The three tasks, though apparently similar in nature arguably capture different aspects of hand skill. Though both the dots and lines tasks utilised the same apparatus, required the use of a pen and score was dependent on accuracy of aim, the two differed in that dots required a hitting-type movement or the direct expression of an intention whereas lines involved a continuous movement with direct feedback. Where the dots and lines tasks used a pen held in the usual manner for writing, the pegboard task required participants to pick up and release the pegs from between the thumb and first two fingers, a far less practiced movement from that of holding a pen.

As predicted, dots produced a similar bimodal distribution to that of the EHI, whilst both the lines and pegboard tasks produced a roughly normal unimodal distribution with a slight shift to the right of zero (see Figure 1a-d), this was also in line with previous findings (Annett, 1992; Oldfield, 1971). The dots task was also most strongly associated to hand preference group when the sample was divided at zero and as has been shown, this dichotomy produces a much stronger association with performance measures than an arbitrary divide. Further to this, analysis of variance and follow-up t-tests revealed dots to be the only task to produce a significant between groups difference for *both* the right and left hand when the sample was divided at zero, making dots the only manual task studied that could be predicted to some extent by EHI classification. When the sample was divided arbitrarily at +75 a significant between groups difference was found only when the right hand was used for the dots task, suggesting that such a classification has little predictive power in terms of dots task performance. The same pattern of results was revealed for both the lines and pegboard tasks regardless of the way in which the sample was divided; a significant between groups difference was found only when the right hand was used, participants produced similar responses when the left hand was used regardless of hand preference group. The lines and pegboard tasks also produced weaker associations with EHI classification than did the dots task.

So what is special about the dots task? Annett (1985; 1992; 2002) has previously suggested that tasks requiring a hitting-type movement, such as hammering, are strongly related to an individuals preferred hand and that the preferred hand has a better aim than the nonpreferred hand, resulting in the nonpreferred hand being used with reluctance. This sits well with the current findings since performing well on the dots task is dependent on the accurate aim of many hitting-like movements in succession. This is in contrast to lines where the task involves one continuous movement with direct feedback throughout the task and the pegboard task where immediate feedback is given as to time taken. Arguably, in contrast to the dots task, the latter two tasks as a consequence of direct feedback motivate the participant to use the nonpreferred hand to full advantage (Annett, 1985; 1992; 2002).

It should be noted that dots is certainly not being suggested as a definitive objective measure of hand preference. The association between hand preference group when divided at zero and the dots task is far from perfect – only 55% of variance in the dots task can be explained by categorisation on the EHI and when categorisation is derived arbitrarily the association becomes far weaker. Indeed, it has been found that to best predict hand preference, one performance measure is not enough instead a combination of performance measures is necessary (Brown *et al*, 2004).

It may be that hand preference inventories are assessing a particular aspect of hand skill. Could it be that preference measures are more strongly related to the more fundamental aspects of handedness? Tasks that have a long evolutionary history for man such as hammering have also been found to be more strongly related to preference measures than those with a far shorter evolutionary history, such as writing (Annett, 1992; 2002). Arguably the current findings lend further support to this argument; the dots task involved a hitting-like movement resembling hammering and produced the strongest association, whereas the task involving a continuous movement more closely resembling writing (lines) produced a weaker association.

More simply of course, it could be that preference measures reflect those manual skills that are more practiced; for most, writing with a pen is an everyday activity and as such could account for the finding that the dots and lines tasks are better associated with the EHI than the pegboard task, a task that involves a far less practiced movement. Of course, where individuals are more practiced at a task, they will arguably have learned to have greater confidence in one hand over the other. This is reflected nicely in the observation that during the dots and lines tasks when participants went to use the opposite hand to the one that they had professed to being dominant, there were far more negative murmurs and comments both prior to and following the tasks. This was not observed when participants were asked to complete the pegboard task. Interestingly, the above observation was far less frequent in those participants who had professed to being left-handed. However, this is not surprising if one considers Annett's (1985) Right-Shift theory of handedness that predicts greater variability in left-handed individuals; since left-handedness is determined by chance, far more left-handers will use their right hand for various tasks than right-handers will use their left.

So it seems that preference measures may be most closely related to those performance tasks that more closely resemble practiced abilities where the individual has learned to have more confidence in one hand over the other, an opinion that sits nicely with Annett's (1985) argument that hand preference follows performance. Furthermore, those practiced skills that have a longer evolutionary history in humans may be more closely related still.

Conclusions

The current findings attest to the opinion that preference and performance measures are related. Associations between the preference and performance tasks were regrettably imperfect though do suggest that performance measures tapping more practiced abilities may be better captured by preference inventories. Further investigation is needed to discover whether this is in fact the case, certainly if it is found to be so then this will aid greatly in the development of objective measures of hand preference.

The finding that EHI categorisation is only very weakly related to hand performance when the sample is divided arbitrarily is one that should be heeded in future. However, varying cut-off criteria are used to produce such arbitrary groups and as such further research is needed to discover whether a lower cut-off criterion would produce better association, a possibility that seems promising since a divide at zero produces a much stronger association.

There is undoubtedly still much to discover about the phenomenon of handedness and as a result defining it remains a problem yet one thing seems certain; defining handedness in the traditional way, referring to hand preference alone, is somewhat deficient. A true definition of handedness would unquestionably have to incorporate both preference and performance aspects.

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<u>Appendix A</u>

Brief

Debrief

Brief

As a stage three psychology undergraduate this study is being conducted as part of a course requirement. The following study is looking at patterns of handedness and eye dominance in humans.

Handedness can be measured in two ways, through questionnaire and through behavioural measures. Therefore you will be asked to complete one questionnaire that assesses handedness and three manual tasks also assessing handedness. The main aim of this study is to discover the ways in which these different measures are related.

Of further interest in the study is eye dominance and it’s relationship with handedness. In order to determine eye dominance, you will be asked to complete a quick and simple task.

The study should take no longer than 20 minutes. Your data will be kept confidential, will only be seen by the experimenter and will not be identifiable as coming from you. You have the right to withdraw from the experiment at any time.

Do you have any questions?

Debrief

I.D. Number…………

Thank you for taking part in this study.

As you have seen, handedness can be measured in a variety of ways. However, research has shown that the two types of measurement (questionnaire and manual tasks) appear to be measuring different aspects of handedness. The aim of this study is to discover what type of manual performance is best captured by the questionnaire. Of further interest is the finding that eye dominance and handedness are related and the study aims to discover any patterns of handedness within the two groups (left eye dominant and right eye dominant).

Your data will remain confidential and will not be identifiable as having come from you in the write up of this study. Should you have any questions, wish to raise any concerns or wish to withdraw your data retrospective to this study please contact the experimenter or supervisor; rosemary.stephens@students.plymouth.ac.uk, Matt.roser@plymouth.ac.uk.

Do you have any questions before you leave?

Appendix B

Edinburgh Handedness Inventory

Are you right handed …. Left handed …. Or ambidextrous ….? Please tick.
Sex…………   Date of Birth…………..

Have you ever had any tendency to left-handedness?

YES   NO

Please indicate your preferences in the use of hands in the following activities *by putting + in the appropriate column*. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, *put ++*. If in any case you are really indifferent *put + in both columns*.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand-preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

		R	L
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Comb		
6	Toothbrush		
7	Knife (without fork)		
8	Spoon		
9	Hammer		
10	Screwdriver		
11	Tennis Racket		
12	Knife (with fork)		
13	Cricket bat (lower hand)		
14	Golf Club (lower hand)		
15	Broom (upper hand)		
16	Rake (upper hand)		
17	Striking Match (match)		
18	Opening box (lid)		
19	Dealing cards (card being dealt)		
20	Threading needle (needle or thread according to which is moved)		
40	Which foot do you prefer to kick with?		
41	Which eye do you use when using only one?		

Instructions for performance tasks

Instructions for the dots and lines tasks;

The aim of this task is to place a dot in the centre of each circle as accurately and as quickly as possible. The zigzag lines are there to guide you in the correct direction.
You will be given a practice trial followed by three test trials.

The experimenter will indicate which hand they wish you to start with.

Hold the pen in the start position, the experimenter will tell you when to begin.

The principle is the same for the LINES task as it was for the DOTS task instead this time you must draw one continuous line, following the zigzag lines. The aim of this task is to accurately and as quickly as possible, entering and leaving each circle without overshoot.
Again, you will be given one practice trial followed by three test trials.

Instructions for the Pegboard task;

In this task you will be asked to move the pegs in the further row to the nearer row as quickly as you can one by one.

If you drop a peg or if any distraction occurs you will be asked to restart the trial. You will be given one practice trial and three test trials.

The experimenter will indicate which hand they wish you to start with.

Place your hands on the desk in front of you, the experimenter will tell you when to begin.

Appendix C

SPSS data file and output (disc)