

A GROUP TEST FOR THE ASSESSMENT OF PERFORMANCE BETWEEN THE HANDS

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Abstract—A group performance test of handedness was administered to 1556 undergraduates. This test required subjects to place dots in circles as rapidly as possible. The test was found to be reliable, and to correlate with hand preference. Both hand performance and hand preference measures are skewed in the population as a whole, but the distributions can be adequately fitted by two normal curves, one with a right bias and one with a left bias. These findings suggest that left-handers are a distinct subgroup of the population.

INTRODUCTION

CURRENT interest in hemispheric specialization, coupled with the observation that patterns of cerebral organization differ in left- and right-handers, has led to considerable interest in the neuropsychology of left-handedness [cf. 13, 18, 23]. As a result, many investigators concerned with hemispheric asymmetries now routinely screen their subjects for handedness. Most group tests of handedness assess lateral preference; that is, they determine the preferred hand for performing diverse activities, such as writing and throwing [10, 16, 18]. Such inventories normally lead to a J-shaped distribution, with about 90% of the population showing a right-hand preference [3]. These inventories are often criticized for not reflecting the underlying continuous distribution of handedness scores [5].

ANNETT [2, 5] has argued for the use of proficiency measures of handedness, comparing the relative skill of the two hands on some task. She has made use of a peg-moving task to compare the relative proficiency of the two hands, and has argued that this leads to a more refined measure of handedness. Unfortunately, the peg-moving task requires equipment and is not readily administered to groups of subjects. Furthermore, PROVINS and CUNLIFFE [19] found very low test-retest reliability for a dexterity task similar to Annett's: of seven measures of manual proficiency, they found that handwriting and tapping had the greatest reliability.

The present paper reports data on a group-administered test of manual proficiency, using tapping speed as a dependent measure. This test was developed as one which could easily be given to large groups of subjects, and which provided a reliable continuous measure of hand proficiency.

METHODS

Subjects

The subjects for this study were 1556 undergraduate students registered in introductory psychology courses (704 males, 843 females, and nine who failed to specify their gender). They were tested in eight separate classes over a period of two terms. Participation in the study was voluntary.

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Handedness measures

Two separate handedness measures were used, a preference inventory and a performance test. In the preference questionnaire, subjects were asked to rate their hand preference on a 5-point scale for each of the following activities: writing, drawing, throwing, using scissors, using a toothbrush, using a knife without a fork, using a spoon, and holding up a match when striking [8, 16]. A rating of 2 indicated that the subject stated he/she would not use the left hand unless forced to, and a rating of -2 indicated a similar strong preference for the left hand, while a rating of 0 indicated that the subject declared no preference for either hand. Thus, a total score of -16 indicated a strong left-hand preference, and a total score of +16 indicated a strong right-hand preference.

Hand performance was assessed with a group version of a test employed by STOTT *et al.* [24] (see Fig 1). Subjects were told to "make a dot in each circle following the pattern as quickly as you can". It was emphasized that the dot

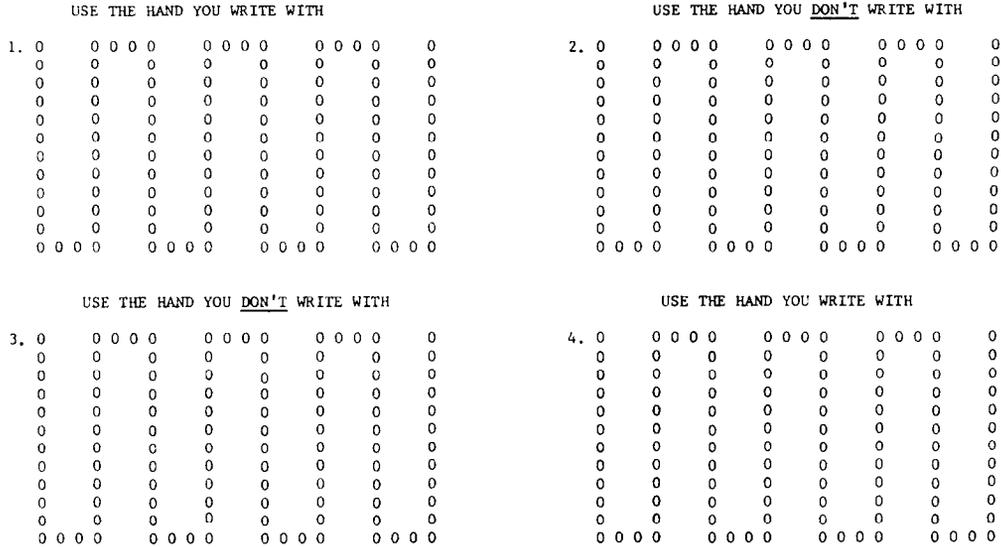


FIG. 1. The performance test.

must be *in* the circle, not on the edge or outside of it, in order to be scored. Twenty seconds were allotted for each of four trials. Subjects used their preferred hands on the first and fourth trials, and their nonpreferred hands on the second and third trials. To score this test, the number of circles properly filled was counted for each trial. Hand differences were then expressed as the difference between right- and left-hand scores divided by the total $(R - L)/(R + L)$. This measure represents the difference in rate expressed as a proportion of the overall rate. It was chosen, in part, because of a feeling that the difference between 100 and 98 circles filled represented performance similar to that seen in a performance of 200 and 196, rather than 200 and 198. Although one of us has criticized this same index when applied to data which can be interpreted as proportions [9], these criticisms do not apply in the present case, where there is no upper bound on the numbers obtained. As an alternative, we might have selected a measure of the difference in speed, such as $R - L/R \times L$. Within relatively broad limits, the term $(R - L)$ is the major determinant of variability in all these measures, and therefore our conclusions hold across different possible indices. Thus, we defined right-handers as those who obtained positive scores and left-handers as those who obtained negative scores.

Finally, each subject filled out a brief questionnaire concerning the handedness of their parents, siblings, and second-order relatives.

RESULTS

The reliability of the performance measure was assessed by determining the hand proficiency score separately for the first two trials and for the last two trials. The correlation between these two scores was highly significant ($r = 0.81$, $P < 0.001$). Therefore, an overall

score based on the sum of the number of circles filled on the two trials for each hand was used in subsequent analyses.

The performance test also shows a high correlation with the preference inventory ($r=0.75$, $P<0.001$). At the same time, only eight of the 1556 subjects indicated that they did not prefer to use the hand which showed the superior test performance. Thus, the measures of hand performance and hand preference seem to be measuring some common property of handedness.

Scores on the hand performance test are summarized in Table 1, along with the standard deviations and measures of skewness (the asymmetry of the distribution) and kurtosis

Table 1. Descriptive data for the performance test scores

Group	<i>N</i>	Mean	S.D.	Skewness	Kurtosis
Males	704	0.194	0.162	-1.322*	1.723
Females	843	0.216	0.160	-1.694*	3.030
Right-handers	1395	0.252	0.088	-0.092	1.826
Left-handers	161	-0.191	0.082	0.075	0.501
Male RH	625	0.242	0.092	-0.009	1.065
Female RH	759	0.261	0.084	-0.108	2.830
Male LH	79	-0.181	0.078	-0.214	-0.741
Female LH	81	-0.201	0.086	0.375	1.667

* $P<0.001$ deviation from normality.

(whether the distribution is flatter or more peaked than normal). This table indicates that women tended to be more strongly "handed" than men. The sex difference reached statistical significance for right-handers [$t(1384)=3.96$, $P<0.001$], but not for left-handers [$t(160)=1.56$, $0.10<P<0.20$]. The observation that women are more extreme in hand performance than men corroborates an earlier report of a similar effect with a preference questionnaire [8]; but see KILSHAW and ANNETT, [14]. It also indicates that sex differences cannot be wholly accounted for in terms of the tendency for males to show a response bias by exaggerating their ambidexterity, as suggested by BRYDEN [8].

In addition, dextrals were more right-handed (mean = 0.252) than the sinistrals were left-handed (mean = -0.191), $t(1554)=8.24$, $P<0.001$. Again, this finding is a common one.

Overall, left-handers comprised 10.34% of the total sample, with 11.22% of the men and 9.64% of the women being left-handed. This is consistent with most recent large-scale surveys of handedness in undergraduate populations [8, 18].

Most interestingly, Table 1 indicates that the distribution of hand performance scores was markedly skewed in both males and females. While this is a common observation [20], statistical measures of skewness are rarely reported (but see [7]). The most interesting thing about these data is that when the subjects are subdivided into left- and right-handers, the skewness disappears (Table 1). In fact, data from both left-handers and right-handers can be adequately described by normal distributions of different means but having the same variance (see Fig. 2). This would suggest that left- and right-handers represent two distinct subsamples of the general population.

Many of the same effects are observable in the preference data (Table 2): right-handers are somewhat more right-handed than left-handers are left-handed, and left-handed women tend to be more strongly left-handed than left-handed men. There is, however, virtually no

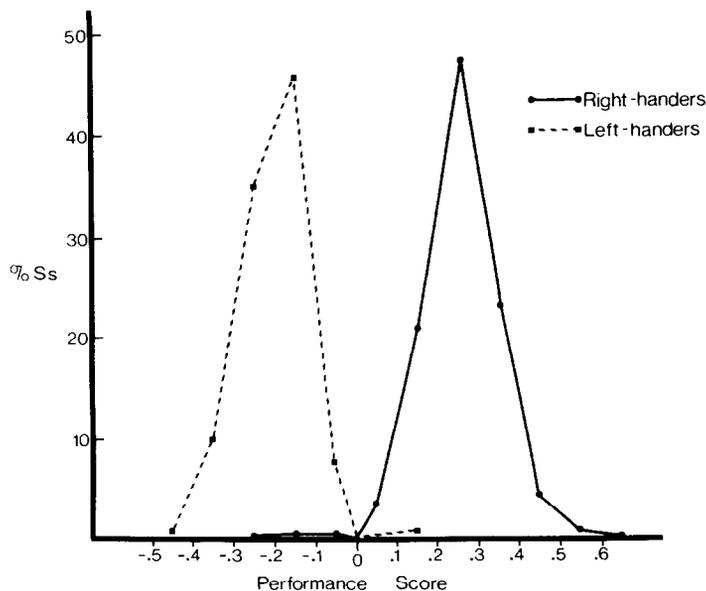


FIG. 2. Distribution of right-handed and left-handed subjects' performance scores.

Table 2. Descriptive data for the preference test scores

Group	<i>N</i>	Mean	S.D.	Skewness	Kurtosis
Males	687	8.099	6.489	-1.495*	2.271
Females	827	8.470	6.340	-1.702*	3.077
Right-handers	1363	10.128	3.476	-0.119	-0.099
Left-handers	160	-8.894	4.436	0.107	-0.082
Male RH	608	10.028	3.571	-0.130	0.046
Female RH	744	10.227	3.399	-0.092	-0.265
Male LH	79	-7.253	4.340	-0.157	-0.056
Female LH	80	-8.512	4.548	0.375	0.106

* $P < 0.001$ deviation from normality.

difference between right-handed men and women. Again, the data for the group as a whole are highly skewed, while the separate handedness groups are more normally distributed.

When self-professed left- and right-handers are considered separately, the correlation between preference and performance is sharply reduced. For right-handers ($N = 1363$), the correlation is 0.17, and for left-handers ($N = 160$) it is 0.20. While both are statistically significant ($P < 0.02$), they are far less than the 0.75 seen in the whole sample. Undoubtedly, some of this reduction is a result of the restriction of range, but the low correlations suggest that hand preference and hand performance may be controlled by different factors.

Familial sinistrality, as defined by the presence of one or more left-handed parents, siblings, or grandparents, has little effect on either preference or performance. There was a slight trend for left-handers with a positive familial history to show larger scores (-0.193) than did those without a familial history of left-handedness [-0.188 ; $t(106) = 1.62$, $P < 0.10$, two-tailed], but none of the other comparisons even approached significance.

DISCUSSION

The present data have provided convincing evidence that an easily-administered paper-and-pencil test can be used to assess manual differences in hand performance in large groups. The dot-filling test proved to be reliable and to correlate significantly with measures of hand preference.

The results indicate that both performance and preference data are skewed when the data for the entire group are considered, but that the distributions for left- and right-handers considered separately are essentially normal. While it may well be important to consider handedness as a continuous variable, as ANNETT [5, 6] has advised, these data suggest that there are two distinct subpopulations of handedness, one essentially left-handed and the other essentially right-handed. If this is true, one should view with some scepticism those studies in which a large group is defined as being of "mixed" handedness (e.g. [1]) or in which all but the most extreme right-handers are lumped into a group of "non-right handers" (e.g. [17, 21]). It is clear that whatever criterion one uses for defining handedness groups that one should use the same criterion for left-handers as for right-handers [4]. The present data suggest that defining two groups, one left-handed and one right-handed, is appropriate. Only in the case of performance scores close to zero in combination with ambiguous preference scores is there any serious question as to which distribution a particular individual belongs.

The present data are in rather striking contrast to those recently presented by ANNETT and KILSHAW [7]. They reported data on peg-moving for a very large sample, and, like us, found that the overall distribution was significantly skewed. However, Annett and Kilshaw found that the peg-moving data is best fitted by two normal distributions, one with a positive mean and one with a zero mean, rather than by separate distributions with positive and negative means. Such results are precisely what would be predicted from ANNETT's [6] right-shift model of handedness.

It is not immediately evident why the secondary distribution should have a mean of zero for the peg-moving task but a negative one for our tapping task. Since our task was designed as a group test, one can get away with a somewhat less precise movement than in peg-moving. If the peg is not correctly placed in the hole, it will fall over, while a mark in a circle can be simply a tick, overlapping the edge, or a neat dot in the centre of the circle. Perhaps more importantly, our scoring procedure differs from that used by ANNETT and KILSHAW [7]. They timed their subjects moving dowels from one set of holes to another, and used the difference in time between left and right hands as the dependent variable. This difference score is likely to show greater variability for slow subjects than for those who perform the task rapidly. In effect, Annett and Kilshaw measured the difference in time required to execute a fixed number of actions. In contrast, we gave our subjects a fixed time period and counted the number of actions performed in that interval. In addition, we expressed our dependent variable not as a simple difference between hands, but as a ratio, to correct for differences in rate of responding. It is unlikely, as indicated earlier, however, that differences in scoring can account for the differences between our results and those of Annett and Kilshaw. No matter how the data are scored, subjects remain on the positive or negative side of zero. In our data, there is a clear secondary mode on the negative side. This is less obvious in the Annett and Kilshaw data, although the main sample females and the birthday samples do show negative secondary modes. Rather than attempting to reconcile the two sets of data it seems more reasonable to conclude that different tests of hand performance measure somewhat different factors.

The fact that performance and preference scores correlate only about 0.2 within handedness groups in our samples also suggests that the two tasks may measure different aspects of handedness. In the absence of any absolute criterion for what constitutes "handedness", it is not clear how to treat this fact. If the primary concern is one of distinguishing between those who claim to be left-handed from those who claim to be right-handed, then combining preference and performance measures will clearly give better discrimination. Similarly, a combined distribution would emphasize the two separate normal distributions seen in our data. On the other hand, if the objective is to understand the relation between handedness and some other variable, such as cerebral lateralization, then it may well be important to keep the two measures separate. There is some evidence from both aphasia [12] and dichotic listening [11, 22] that the incidence of right-hemisphere language representation is related to the degree of left-handedness. Perhaps some of the ambiguities in this area could be resolved by combining preference and performance measures.

Finally, the existence of two separate subgroups, one left-handed and the other right-handed, has implications for a general model of the origins of handedness. ANNETT's [6] "right-shift" model, currently very popular, assumes that there is one group of right-handers, either homozygous or heterozygous for the right shift, and a second group, not possessing the right-shift gene, that is centred at the neutral point. The present data, indicating a subgroup of clear left-handers, provides evidence against Annett's model, and suggests that left-handers do not arise adventitiously. The present data are more consistent with models that provide a direct mechanism for generating left-handedness (e.g. [15]). The ANNETT and KILSHAW [7] data, of course, lead to quite the opposite conclusion. In light of these differences, it is perhaps best to claim only that our data provide the documentation for a quick and reliable performance test of handedness that can be administered to large groups.

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