Towards a conceptualization of hand preference

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In the present study, we have investigated the structure of hand preference by means of a questionnaire of 51 items, using the data from 977 persons. On the basis of the scores over a larger part of the items, the respondents were divided into three groups, right-handers (523), left-handers (412) and those impossible to classify (42). The items were subjected to a cluster analysis for the left-handers and right-handers separately.

The results show a clear grouping of items for left-handers, and a vaguely similar grouping for right-handers. The clusters can be characterized by the muscle groups and joints which are involved in performing the tasks. Some attention is given to the question of whether hand preference can be better viewed as a natural dichotomy or a single continuum.

Introduction

The principal aim of the present study is to provide some insight into the nature of hand preference. We wanted to know if it were possible to classify certain everyday tasks on the basis of the hand used to perform them.

Three approaches to, or opinions about, the nature of hand preference may be distinguished (Annett, 1970). Supporters of the first and most commonly held view consider handedness a genuine dichotomous concept, and believe cultural pressure to be the cause of 'deviations' from natural handedness. All persons showing tendencies towards left usage are regarded as sinistrals who have been shifted towards right-handedness by the environment.

The second approach distinguished by Annett is characterized by the assignment of scores to questionnaire responses, and the derivation of laterality quotients ranging from extreme right to extreme left, thereby implying that handedness has a single underlying continuum. Annett cites some difficulties with this approach, and shows ways to overcome them.

Supporters of the third approach distinguish three types of handedness (e.g. left, right and mixed), and they seem to perceive a qualitative difference between sinistrals and dextrals as consistent handers on the one side, and ambidextrals or mixed handers on the other.

After a large survey of the literature on left-handedness, Hardyck & Petrinovich (1977) concluded: 'Handedness is most appropriately regarded as a continuum ranging from strong right-handedness across mixed handedness to strong left-handedness' (p. 305). Virtually all authors agree with Hardyck & Petrinovich that some people do more tasks with their left hand than others, and that people can be ordered on the basis of the number of tasks they perform with their left hand. Although such an ordering might be called a continuum, a fundamental question is whether this ordering is along a single continuum, along two or possibly three continua (one starting from the left, the other from the right and possibly a third one in the middle), or along no continuum whatsoever. At present, we see no clear-cut way to settle this question. Clearly, more is involved than simply performing a 'crucial experiment', if such experiments exist at all.

In the present paper, we side with the first approach in assuming people have a natural hand preference. We reject, however, the notion that deviations from the natural hand preference can be entirely explained by cultural pressure. The results from our

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investigations will show why such an explanation is not correct, or at least not complete. Our position in favour of a natural dichotomy was taken on *a priori* grounds, and is not based on the present data. The results will show our position to be at least a fruitful one. Although Annett (1970), for instance, claims that her types of hand preference are defined on empirical rather than *a priori* grounds, she prejudices the continuity view (the second approach) of hand preference by analysing all subjects together. In a similar way, we favour the natural dichotomy view (the first approach) by analysing left-handers and right-handers separately. Nevertheless, some of our results are difficult to explain by a single continuum theory.

Our *a priori* position bears directly on the sampling and the analysis in our study. If hand preference is a natural dichotomy with deviations superimposed on it, then a representative sample of the population will yield too few sinistrals for a proper analysis. Therefore, a special effort was made to collect data from left-handers. The dichotomy, of course, demands that left- and right-handers are not analysed together, but as separate groups.

In our study, we have explicitly attempted to investigate *hand preference*, i.e. the natural inclination of persons to perform a certain task with one hand rather than the other, instead of *proficiency*, i.e. the dexterity people exhibit in performing a task with either hand. In other words, we were not interested in whether a person was able to perform a task with either hand, but we wanted to know with which hand a person chose to perform the task.

Method

Material

In constructing our list of 51 items, we limited ourselves to a selection from already existing questionnaires (Ahrens, 1959; Annett, 1970; Bingley, 1958; Bloedé, 1946; Clark, 1957; Crovitz & Zener, 1962; Dengler, 1959; Hécaen & Ajuriaguerra, 1963; Heyster, 1942; Humphrey, 1951; Kramer, 1970; Leiser-Eggert, 1954; Nutzhorn, 1953; Oldfield, 1971; Provins & Cunliffe, 1972; Raczkowski *et al.*, 1974; Stier, 1911; Wegener, 1949; Zazzo, 1960)*.

The following criteria for inclusion were used:

(*a*) items should not require an observer for scoring;
(*b*) items should involve only tasks or equipment which were likely to be familiar to the subjects;
(*c*) tasks should not favour either hand outright.

In the instruction, the subjects were requested first to perform the task, either in reality or only mentally, as quickly and accurately as possible, and only then fill in the answer. Twelve items (those marked with an asterisk in the Appendix) required reverse scoring.

A number of people (subset II, see below) were asked if they considered themselves to be left-handed or right-handed. At the end of the questionnaire, people were requested to make any additional comments they might have on hand preference. About 20 per cent of the people did so. These comments have been used in the reformulation of some questions for the second subsample. The respondents were given a choice only between left and right for each question, but hardly anyone indicated difficulties with this forced choice. Some respondents commented that they could perform the task with both hands, but that the hand indicated could perform the task better or more easily. As we were primarily interested in hand preference, it seemed more appropriate to formulate the instruction as we did, rather than asking subjects to indicate the hand(s) actually *used* (e.g. Crovitz & Zener, 1962; Annett, 1970; Oldfield, 1971). In addition, the latter practice often resulted in a response 'either' instead of 'left' or 'right'.

For various reasons, the reliability of the complete questionnaire could not be assessed, but a test–retest reliability of the summed score over nine items after a period of 4 months, based on the responses of 486 persons, was 0·92. Previous studies (e.g. Koch, 1933, cited by Hardyck & Petrinovich, 1977; Raczkowki *et al.*, 1974; Sherman *et al.*, 1976) showed that the test–retest

* Our original report, available from the first author upon request, has a detailed list of the origins of each item.

reliability for similar questionnaires is generally high. With respect to the validity (i.e. the agreement between actual performance and self-report) the same studies show some, but not complete, agreement (e.g. Sherman *et al.* report an overall correlational agreement of 0·98, while Raczkowski *et al.* report high percentages of agreement for most, but not all, tasks).

These conclusions about the reliability and validity seem, however, to be at variance with the statement of Hardyck & Petronivich (1977) that '...the conclusion is that handedness is not reliably determined by questionnaire measures alone and that behavioral measures are necessary to ensure accurate classification (into various types of handedness)' (p. 393). The papers on which this conclusion is based (Benton *et al.*, 1962; Satz *et al.*, 1967; see also the study by Barnsley & Rabinovitch, 1970) define handedness solely in terms of *proficiency*, which is measured by means of a variety of manual dexterity tasks. The conclusion of Hardyck & Petrinovich should, therefore, be taken as a statement about the imperfect relation of proficiency and preference, and not as a statement about the reliability (or rather, validity) of the measurement of *hand preference*.

Subjects

The total sample ($n = 977$) consisted of two large subsets. Subset I consisted of 591 persons, 550 of whom came from a representative sample of the Dutch population of 1500 total size. The other 41 persons were so-called self-professed left-handers, collected through friends and relatives. Subset I was given the first version of the questionnaire, which did not include the question about the respondents' hand preferences, but we expect the number of self-professed left-handers in this subset to be small.

Subset II consists of a total of 486 persons, mainly volunteers, who responded to an appeal in two newspapers and a talk on the radio. Subset II filled out version 2 of the questionnaire (including the question on hand preference). The rephrased questions of this version are numbered 3*a*, 6*a*, etc., in the Appendix.

The age of the subjects ranged from 6 to 81 and the modal class from 20 to 24. The sample contained slightly more women than men (55 per cent and 45 per cent respectively). The distribution of hand preference among volunteers is usually different from that of a representative sample (cf. Annett, 1970, p. 306). As we searched explicity for self-professed left-handers, the distribution of hand preference in our sample (see Table 2) is clearly a product of the selection procedures.

Item reduction

Our primary concern with respect to the questionnaire was to avoid ambiguous items. To this end, all items had to meet the following two criteria. First, all people should interpret the item in the same way, or perform the task in the same way. Seven items failed to meet this criterion: *pencil-sharpener* (item 6), *dealing cards* (27), *threading needle* (29), *stringing beads* (35), *picking up* (36), *blowing nose*

Table 1. Pearson correlation coefficients between items and the sum of all items (*sumscore*)

Stem	Leaf	Description
9*	222222333344445555	—
8	001233478888899	—
7	002222448	—
6	49	*Stringing beads, drawing*
5	234	*Coal-bucket; pencil sharpener; writing*
4	4	*Safety-pin*
3	—	—
2	4	*Axe*
1	0	*Clasping hands*
0*	7	*Folded arms*

Notes. All values ×100; a correlation of 0·64 has a stem of 6 and a leaf of 4. For a detailed explanation and extensions of stem-and-leaf displays, see Tukey (1977). Italics indicate the correlations of the items which are performed in different ways.

(38), and *winding thread* (42). Already, in the first subsample, their inadequacy was noted and, whenever possible, the items were rephrased for the second sample. These items were not further included in the analysis.

Secondly, the items were chosen to measure hand preference, i.e. they should be able to separate left-handers from right-handers. To judge this, the correlations of the items with the sum of all item scores (from now on called '*sumscore*') were determined (see Table 1). We eliminated all items with an item–total correlation lower than 0·60, except *writing* because of its special position: practically all major studies have included this item in one way or another and, often, people are – inappropriately (see, for example, Hardyck & Petrinovich, 1977, p. 392) – divided into left-handers and right-handers on the basis of this item.

Separation of left-handers and right-handers

We would have preferred to separate the left-handers and the right-handers on the basis of their stated preference (see Barnsley & Rabinovitch, 1970, p. 361, for an outright rejection of this criterion in relation to proficiency). Unfortunately, we asked only the second subsample to indicate hand preference. On the basis of this information, we divided our total group of respondents into left-handers, right-handers and persons who could not be classified. However, we only included a person in the group left-handers if his or her *sumscore* was over 19, the highest *sumscore* obtained by a self-professed right-hander of the second subsample. Similarly, the group of right-handers consisted of only those people with a *sumscore* below 9 (see Table 2). This sort of procedure has often been used previously to separate subjects into disjunct classes, such as strong right-handers, weak left-handers, etc. (e.g. Annett, 1970; McMeekan & Lishman, 1975). Forty-two people (including some from the second subsample) were thus excluded from further analysis, because we were not able to

Table 2. Distribution of *sumscore* (based on 39 items) for all 977 respondents

ss	F_{ss}	P_R	P_L	
0–1	337	46	—	Right-handers
2–3	125	17	—	
4–5	41	9	—	
6–7	15	3	—	
8–9	8	—	1	Unclassified persons
10–11	11	2	—	
12–13	9	—	3	
14–15	5	—	4	
16–17	6	1	2	
18–19	8	1	2	
20–21	4	—	2	Left-handers
22–23	6	—	2	
24–25	8	—	1	
26–27	9	—	6	
28–29	17	—	12	
30–31	20	—	11	
32–33	47	—	32	
34–35	78	—	59	
36–37	126	—	94	
38–39	97	—	73	

Note.
ss = *sumscore*.
F_{ss} = number of persons having a *sumscore* equal to ss.
P_R = number of self-professed right-handers in second subsample.
P_L = number of self-professed left-handers in second subsample.

Table 3. Response frequencies

Item	Nr.	Frequencies LR	Frequencies RL	Percentages %LR	Percentages %RL	Percentages %AL	Percentages %AR
1. Writing	17	229	3	55·6	0·6[a]	19·9	80·1
2. Drawing	26	154	4	37·4	0·8[a]	28·0	72·0
3. Cutting meat	22	116	9	28·2	1·7[a]	32·6	67·4
4. Scissors	8	87	7	21·1	1·3[a]	35·5	64·5
5. Light-switch	7	81	29	19·7	5·5	38·5	61·5
6. Rake	25	73	69	17·7	13·2	43·6	56·4
7. Broom	44	69	71	16·7	13·6	44·3	55·7
8. Eating soup	4	62	5	15·0	1·0[a]	38·0	62·0
9. Spade	32	61	70	14·8	13·4	45·0	55·0
10. Suitcase	24	59	66	14·3	12·6	44·8	55·2
11. Rumpling paper	2	50	49	12·1	9·4	44·0	56·0
12. Sewing	30	48	5	11·7	1·0[a]	39·5	60·5
13. Shuffling cards	41	47	41	11·4	7·8	43·4	56·6
14. Bottle-top	46	45	85	10·9	16·3	48·3	51·7
15. Opening lid	49	40	42	9·7	8·0	44·3	55·7
16. Catching ball	28	39	20	9·5	3·8	42·0	58·0
17. Drawing-pin	31	38	13	9·2	2·5	41·4	58·6
18. Bicycle pump	39	38	39	9·2	7·5	44·2	55·8
19. Dust-pan	15	35	11	8·5	2·1	41·5	58·5
20. Javelin	11	33	4	8·0	0·8	41·0	59·0
21. Shot-put	13	32	4	7·8	0·8	41·1	58·9
22. Corkscrew	48	31	22	7·5	4·2	43·1	56·9
23. Hitting someone	43	30	5	7·3	1·0	41·4	58·6
24. Slicing bread	5	29	13	7·0	2·5	42·4	57·6
25. Throwing ball	50	29	6	7·0	1·1	41·6	58·4
26. Striking match	20	28	3	6·8	0·6	41·4	58·6
27. Whip	34	25	1	6·1	0·2	41·5	58·5
28. Pouring water	33	22	6	5·3	1·1	42·4	57·6
29. Pulling out nail	14	19	8	4·6	1·5	42·9	57·1
30. Lipstick	19	19	1	4·6	0·2	42·1	57·9
31. Eraser	34	18	4	4·4	0·8	42·6	57·4
32. Knife-pencil	37	16	9	3·9	1·7	43·3	56·7
33. Comb	47	15	2	3·6	0·4	42·7	57·3
34. Table-tennis	23	13	9	3·2	1·7	43·6	56·4
35. Duster	21	10	3	2·4	0·6	43·3	56·7
36. Shaving	45	10	2	2·4	0·4	43·2	56·8
37. Polishing shoes	16	8	5	1·9	1·0	43·7	56·3
38. Tooth-brush	40	7	0	1·7	0·0	43·3	56·7
39. Hammer	3	7	2	1·7	0·4	43·5	56·5

Notes.

Nr. = sequence number of item in questionnaire (see Appendix).
LR = number of left-handers performing a task with their right hand.
RL = number of right-handers performing a task with their left hand.
%LR = percentage of left-handers performing a task with their right hand.
%RL = percentage of right-handers performing a task with their left hand.
%AL = percentage of all persons performing a task with their left hand.
%AR = percentage of all persons performing a task with their right hand.
[a] = items excluded from the computations of the correlation coefficient.
$n_{left} = 412$; $n_{right} = 523$; $n_{all} = 935$.

allocate them to one of the groups. This made it impossible to make any meaningful statement about the third approach mentioned by Annett (1970).

Results

Proportions

For both left-handers and right-handers, the proportion of persons performing each item with the non-preferred hand was determined (see Table 3). In Fig. 1, the proportions for the left-handers are plotted against those for the right-handers. The Spearman rank

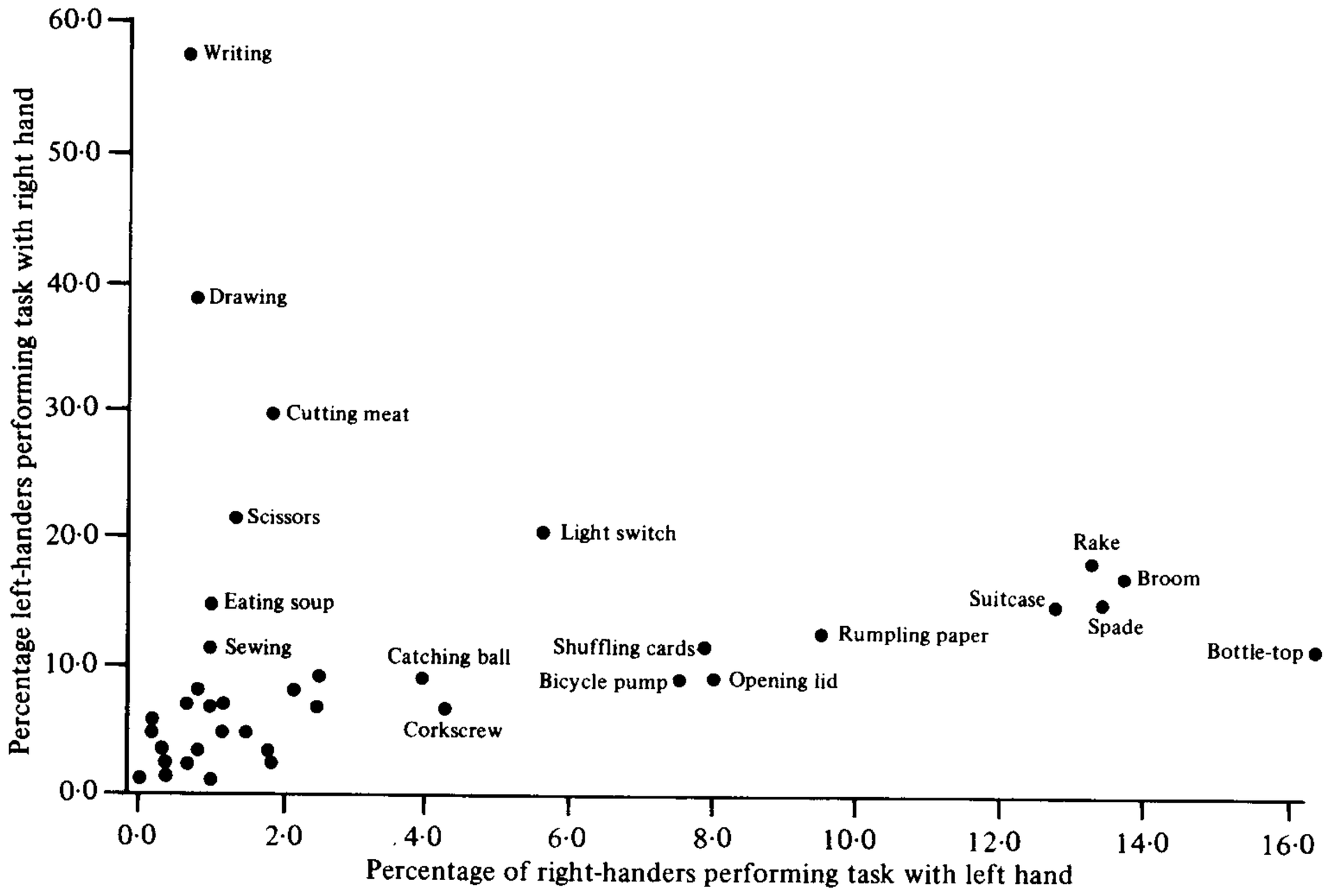

Figure 1. Relative use of non-preferred hand.

correlation between these proportions is 0·54, and rises to 0·83 if we eliminate those items which are asymmetrically influenced by the envirnoment, i.e. *writing* (17), *drawing* (26), *sewing* (30), *eating soup* (4), *scissors* (8), and *cutting meat* (22). The size of the rank correlation coefficient shows that the rank order for the proportions of performing the items with the non-preferred hand is very similar for both left-handers and right-handers. This could indicate a similar process which causes the deviations. Note that the proportions for right-handers are lower than those for left-handers, i.e. the right-handers use their preferred hand more consistently than do left-handers (see also Humphrey, 1951; Annett, 1970, p. 317; Raczkowski *et al.*, 1974, p. 46; Hardyck & Petrinovich, 1977, p. 398). For the items we have in common with Raczkowski *et al.*, there seems no agreement with respect to the size of the proportions of left-handers performing the task with the right hand. It should, however, be realized that their proportions are based on a total of only 27 persons, making their estimates rather unreliable.

A number of the proportions were very small, with only very few people scoring in the non-preferred-hand category. Association measures based on items with such skew distributions are very sensitive to misclassification errors for one or two subjects. Therefore, we eliminated from the remainder of the analysis all items with fewer than 10 respondents in either category, leaving 36 items for the left-handers and only 15 items for the right-handers.

Similarities between tasks

The structure of the items in the questionnaire was investigated by computing a measure of association or similarity between the items and, subsequently, performing a cluster analysis on the similarity matrix. An appropriate measure, in our case, was the adjusted Pearson product moment correlation for 2×2-tables, called $\phi/\phi_{\max}$ by e.g. Guilford (1965), and H_{ij} by Loevinger (1947) and Mokken (1971). See, for instance, Cole (1949), for use of this measure in similar situations in ecology. A high value of H_{ij} for two items indicates that people generally perform two items with the same hand. Whether one says that people tend to perform the items with the preferred hand or with the non-preferred hand is immaterial, as in 2×2-tables there is only one degree of freedom. We will explain our results, generally, in terms of the non-preferred hand.

Our concern for 'real' similarity, and not similarity due to chance, raised the question if some or all of our obtained H_{ij}s could possibly have come from a distribution of the statistic under the assumption of statistical independence of the two tasks (given the marginal totals). Large non-significant H_{ij}s included in further analyses could, potentially, have an adverse effect on the outcomes. We have, therefore, for each 2×2-table (and, thus, for each H_{ij}) computed the exact null-distribution in a manner analogous to the Fisher–Irwin exact test and, from this, we have established an exact descriptive level of significance for each H_{ij}.

Testing large numbers of measures always raises the point of the appropriate significance level. Were all the tests independent (and Anderson & Goodman (1957) say that this might be the case here), then we could expect that five out of a hundred tests would yield a falsely significant coefficient if we were using an α of 0·05. As there were 630 distinct measures for left-handers (based on 36 variables), we could expect some 32 falsely significant ones under the null hypothesis of independence. The number of falsely significant measures is, most likely, even smaller than 32, as we found 279 measures significant beyond the five per cent level.

Cluster analysis of 'cleaned' similarity matrices

Cluster analysis has been applied to the similarity matrices of the left-handers (36 items) and the right-handers (15 items), in which all non-significant measures have been eliminated. We will refer to these matrices as 'cleaned' similarity matrices. More particularly, we used the so-called *average linkage* or *group average* procedure (see, for example, McQuitty, 1966) as implemented in CLUSTAN (version 1C, Wishart, 1978, p. 33). In the cluster analysis, items which did not yet belong to a cluster when the cut-off point (0·50) was reached were allocated to the nearest cluster, provided their similarity with that cluster was higher than 0·30. The results of the cluster analyses are here presented in the form of rearranged similarity matrices (see Tables 4 and 5). The advantage of this presentation is that it is easy to see if certain items belong to more than one cluster (here, for example, *pulling out nail* (10), *striking match* (15) and *pouring water* (26)).

The most striking aspect of the ordered similarity matrix for left-handers (Table 4) is that there exist four almost independent clusters (I, II, III), (IV), (V) and (VI, VII). Table 4 also indicates a strong association between the clusters I, II and III, with the average similarity within clusters higher than between clusters, and some association between VI and VII.

The strength of the clusters I, II and III can also be seen from the fact that all items within these clusters have, with a few exceptions, significant similarities with all other items of the three clusters. *Shaving* (45) is an exception, and it even accounts for 9 of the 18 missing similarities.

The picture for right-handers is very vague, primarily because we were unable to include

Table 4. The rearranged 'cleaned' similarity matrix for left-handers

Nr.	Item	48	49	46	14	33	45	20	2	7	31	21	11	50	13	43	9	23	28	24	17	26	30	19	34	4	25	44	32	39	8	47	5	22	15	37	41
48.	Corkscrew	10	5	3	3	2		3	2	3	3		3	3	3	3	3	3	4	2					2					2	2				2		2
49.	Opening lid	5	10	6	4	2		5	3	3	4	4	3	4	4	4	3		3	2										1				2	2	2
46.	Bottle-top	3	6	10	5	2		3	2	1	3		3	5	3	4	3		3	2														2		1
14.	Pulling out nail	3	4	5	10	2		2	3	4	5	3	3	3	3	4	4	4	2	3				2	2					3	2					2
33.	Pouring water	2	2	2	2	10			4	4	2	3	3	3	4	3	4	3	2	3										2	3	2				
45.	Shaving						10	2	4	5	4	2			3	5	5	3						4					3	4	5	3	2	2	4		
20.	Striking match	3	5	3	2		2	10	3	4	4	6	2	3	3	2	3		3			3	2	3	3						2			3		2
2.	Rumpling paper	2	3	2	3	4	4	3	10	4	4	8	4	5	5	5	5	3	4	2										2		3				1
7.	Light-switch	3	3	1	4	4	5	4	4	10	5	6	4	4	4	4	5	5	3	2	3	2		4	3						1	4	2				2
31.	Drawing-pin	3	4	3	5	2	4	4	4	5	10	8	5	5	6	7	6	4	4	3				2	2					1	2						1
21.	Duster		4		3	3	2	6	8	6	8	10	3	4	5	4	4			3				5	4									3		
11.	Javelin	3	3	3	3	3		2	4	4	5	3	10	9	8	7	6	7	6	3											2					2
50.	Throwing ball	3	4	5	3	3		3	5	4	5	4	9	10	9	7	6	6	8	4																3
13.	Shot-put	3	4	3	3	4	3	3	5	4	6	5	8	9	10	7	7	7	6	3										2	2					2
43.	Hitting someone	3	4	4	4	3	5	2	5	4	7	4	7	7	7	10	7	7	6	3				1						2	2					2
9.	Whip	3	3	3	4	4	5	3	5	5	6	4	6	6	7	7	10	8	6	3				2						2	4		2			
23.	Table-tennis	3			4	3	3		3	5	4		7	6	7	7	8	10	5	4				3						3	4					3
28.	Catching ball	4	3	3	2	2		3	4	3	4		6	8	6	6	6	5	10	2																1
24.	Suitcase	2	2	2	3	3			2	2	3	3	3	4	3	3	3	4	2	10											1					1
17.	Writing									3											10	10	8	8	6	7										
26.	Drawing							3		2											10	10	8	6	6	5					2					
30.	Sewing							2													8	8	10	2	3	2					2					
19.	Lipstick				2		4	3		4	2	5				1	2	3			8	6	2	10	2						4		2		2	1	
34.	Eraser	2			2			3		3	2	4									6	6	3	2	10								2			4
4.	Eating soup																				7	5	2			10				2		4		2			
25.	Rake																										10	7	6	4	1					
44.	Broom																										7	10	5	3						
32.	Spade						3																				6	5	10	3	2					
39.	Bicycle-pump	2	1			2	4		2		1				2	2	2	3								2	4	3	3	10	2	2	2	3	2		
8.	Scissors	2			3	3	5	2		1	2		2		2	2	4	4		1		2	2	4			1		2	2	10	6	4	2	2		
47.	Comb				2	2	3		3	4					2	2	4	4		1		2	2	4		4			2	6	10	3			2	
5.	Slicing bread						2			2							2							2	2					2	4	3	10	6	2	2
22.	Cutting meat		2	2																						2				3	2		6	10	2	3
15.	Dust-pan	2	2				2	3				3												2						2	2		2	2	10		
37.	Knife-pencil						4																	1								2	2	3		10	
41.	Shuffling cards	2	2	1	2			2	1	2	1		2	3	2	2		3	1	1					4					2						10
Cluster		I					II						III								IV					V				VI		VII				

Note. All values have been rounded to the first decimal and, subsequently, multiplied by 10. Nr. = seqeuence number of item in questionnaire (see Appendix).

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Table 5. The rearranged 'cleaned' similarity matrix for *right-handers*

Nr.	Item	46	49	28	31	24	2	7	41	25	44	32	39	5	48	15
46.	Bottle-top	10	8	4	4	1	2	3	3							
49.	Opening lid	8	10	3	2	2	2	3	3							
28.	Catching ball	4	3	10				2								
31.	Drawing-pin	4	2		10	4	2									
24.	Suitcase	1	2	2	4	10	2	2	1							
2.	Rumpling paper	2	2		2	2	10	4	1				1			
7.	Light-switch	3	3	2		2	4	10								
41.	Shuffling cards	3	3			1	1		10							
25.	Rake									10	7	6	2			
44.	Broom									7	10	6	2			
32.	Spade									6	6	10				
39.	Bicycle-pump					1				2	2		10	3		
5.	Slicing bread												3	10	3	2
48.	Corkscrew													3	10	
15.	Dust-pan													2		10
Cluster		I (II, III)								V						

Note. All values have been rounded to the first decimal and, subsequently, multiplied by 10.
Nr. = sequence number of item in questionnaire (see Appendix).

Table 6. Cluster characterizations

Cluster	Task	Characterization
I	Corkscrew, opening lid, bottle-top, pulling out nail, pouring water	Tasks which involve turning of the wrist.
II	Shaving, striking match, rumpling paper, light-switch, drawing-pin	Relatively easy tasks generally performed with a stiff wrist, and in which not much specific (or detailed) activity of the individual fingers is required (except, maybe, for *drawing-pin*).
III	Javelin, throwing ball, hitting someone, whip, table-tennis, catching ball, suitcase	Tasks which are ballistic in nature (except the not-too-well-fitting *suitcase*), and which are performed with the whole arm moving from the shoulder joint.
IV	Writing, drawing, sewing, lipstick, eraser, eating soup	Tasks which require delicate movements of the fingers, and many of which are also influenced by social pressure or etiquette, e.g. *writing*, *drawing*, *sewing* and *eating soup*.
V	Rake, broom, spade, bicycle pump	Tasks which are performed with both hands, involve turning of the spine and use of the back muscles, and which require stick-like equipment.
VI–VII	Scissors, comb, slicing bread, cutting meat	Tasks which seem to be mainly performed by moving the elbow. The clusters are, however, rather ill-defined.

a large number of items, due to the extreme skewness of their distributions. It was, therefore, *a priori* impossible to retrieve some of the clusters we found for the left-handers. The only very clear result is the emergence of cluster V: the second cluster consists of the same items that form the nucleus of cluster I, and picks up some items out of clusters II and III, but fails to do so with *cork-screw* (48). It seems not unreasonable to speculate that the muscle group and/or joints involved in performing the tasks might be causing the grouping of items. In Table 6, we give a characterization of the clusters along these lines. Using the characterizations of the clusters, one could try to explain why some tasks belong to more than one cluster. Either the task is more complex, in that more joints and muscle groups move simultaneously, or the respondents had different ideas about the way to perform certain tasks.

Raczkowski *et al.* (1974) found a relatively poor agreement between questionnaire response and a performance test on the *broom* item of 0·78. Bryden, too, (1977, p. 622) cites an unusual position of the *broom* in his factor analysis. The clustering of all bimanual items (*broom*, *rake*, *spade*, *bicycle pump*) for both left-handers and right-handers indicates, at least, that all four items were scored in a similar way.

Discussion

Although the non-randomness of the sample used in this study precludes inferences about the distribution of preferences, the structure of preferences found does not support the view that hand preference is a single one-dimensional continuum from left to right, as Gillies *et al.* (1960), Annett (1970) and Oldfield (1971) imply. The high correlation between the deviations from the preferred hand for left-handers and right-handers reinforces that impression.

In addition, the results, especially the detailed structure emerging from the cluster analysis, do not agree with the view that deviations from the natural handedness are solely due to cultural pressure. On the other hand, it is interesting to note that most of the items which many authors agree are culturally influenced, i.e. *writing*, *drawing*, *sewing*, and *eating soup* (but not *cutting meat* and *scissors*), merge into one cluster. That the environment is not a negligible factor is also borne out by the item *bottle-top*. The anti-clockwise movement necessary to unscrew a bottle-top makes it the only item in our questionnaire favouring the left hand and, indeed, more right-handers prefer to use their left hand for this item than for any other one (see Table 3 and Fig. 1).

Whether one accepts the above points or not, the results could be of some help in deciding what the sampling domain of items for a questionnaire should be (this issue was, for instance, raised by Barnsley & Rabinovitch, 1970, and Oldfield, 1971), or, to use Oldfield's formulation, which 'particular selection of items can be regarded as a "fair" sample'. Depending on the purpose for which one intends to use the questionnaire, one could select a specific number of items from each cluster.

The main conclusion emerging from these data is, thus, that, if it is assumed that handedness is a natural dichotomy, the deviations from the non-preferred hand do not occur randomly. There is, at least for left-handers, a clear structure in the deviations while, for right-handers, some indication exists that a similar structure might be present. The clusters can be characterized by the muscle groups and joints which are involved in performing the tasks, although this might not be the only way to explain them. An obvious way to check the above conjecture while continuing to use inventories, is to expand the questionnaire with new tasks, which are *a priori* assigned to the clusters of the present analysis.

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Appendix

Questionnaire		Abbreviation
1.*	Which hand is closest to the opening of the coal bucket when you are emptying it?	Coal bucket
2.	With which hand do you rumple up a piece of paper (when you are doing it with one hand)?	Rumpling paper
3.	In which hand do you hold a hammer when driving in a nail?	Hammer
3*a*.	In which hand do you hold a hammer when hitting?	
4.	In which hand do you hold your spoon when eating soup?	Eating soup
5.*	With which hand do you hold the bread when slicing it?	Slicing bread
6.	In which hand do you hold a pencil when sharpening it with a pencil-sharpener?	Pencil-sharpener
6*a*.	Which hand is turning when you use a pencil-sharpener?	
7.	With which hand do you switch on the light?	Light-switch
8.*	With which hand do you hold the paper when cutting out something with a pair of scissors?	Scissors
9.	Which hand do you use when cracking a whip?	Whip
10.	With which hand do you close a safety-pin?	Safety-pin
11.	Which hand do you use throwing a javelin?	Javelin
12.*	Which hand is pointing downwards when your arms are folded?	Folded arms
13.	Which hand do you use in putting the shot?	Shot-put
14.	Which hand do you use when pulling out a nail with a pair of pliers?	Pulling out nail
15.*	In which hand do you hold the dust-pan when using dust-pan and brush?	Dust-pan
16.	With which hand do you polish your shoes?	Polishing shoes
17.	With which hand do you write?	Writing
18.*	Which little finger is the bottom one when clasping hands?	Clasping hands
19.	Which hand do you use to put on lipstick?	Lipstick
20.	Which hand do you use when striking a match?	Striking match
21.	Which hand do you use when using a duster?	Duster
22.*	In which hand do you keep the fork to hold the meat when cutting it?	Cutting meat
22*a*.	In which hand do you hold the fork when cutting meat?	
23.	In which hand do hold the bat when playing table-tennis?	Table-tennis
23*a*.	With which hand do you play table-tennis?	
24.	With which hand do you carry the heavier of two suitcases?	Suitcase
25.*	Which hand is lower when using a rake?	Rake
26.	With which hand do you draw?	Drawing
27.	With which hand do you deal cards?	Dealing cards
28.	Which hand do you use to catch a small ball if you have to do it with one hand?	Catching ball
29.*	In which hand do you hold the needle when threading it?	Threading needle
29*a*.	Which hand is moving when you thread a needle?	

Ouestionnaire		Abbreviation
30.	In which hand do you hold the needle when sewing?	Sewing
31.	With which hand do you push in a drawing-pin?	Drawing-pin
32.	Which hand is higher when using a spade?	Spade
33.	With which hand do you pour water from a jug?	Pouring water
34.	In which hand do you hold an eraser when erasing?	Eraser
35.	Which hand is the more active one when stringing beads?	Stringing beads
36.	With which hand do you usually pick up something?	Picking up
36*a*.	With which hand do you pick up a penny from a smooth floor?	
37.	In which hand do you hold the knife when sharpening a pencil with it?	Knife-pencil
38.	In which hand do you hold your handkerchief when blowing your nose?	Blowing nose
39.*	In which hand do you hold the non-moving part of a bicycle pump (if you are using a small hand-pump)?	Bicycle pump
40.	Which hand do you use when brushing your teeth?	Tooth-brush
41.	Which hand is moving more when shuffling cards?	Shuffling cards
42.	Which hand is moving more when winding a thread on a reel?	Winding thread
43.	With which hand do you hit someone?	Hitting someone
44.*	Which hand is lower when sweeping with a broom?	Broom
45.	Which hand do you use when shaving yourself with a safety razor?	Shaving
46.	With which hand do you unscrew the stuck top of a bottle of lemonade?	Bottle-top
47.	With which hand do you comb your hair?	Comb
48.*	In which hand do you hold the bottle when pulling out the cork with a corkscrew?	Corkscrew
49.	With which hand do you open a box whose lid is stuck?	Opening lid
50.	Which hand do you use to throw a small ball as far as possible?	Throwing ball
51.	Which hand is closer to the end of the handle of a large axe when felling a tree?	Axe
51*a*.	Which hand is closer to the blade of an axe when felling a tree?	

* Indicates an item for which the left/right order is reversed.
a Rephrased question for second subsample.