Hand Preference Observed in Large Healthy Samples: Classification, Norms and Interpretations of Increased Non-right-handedness by the Right Shift Theory

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Abstract

Healthy children and undergraduates were observed for hand preference and measured for hand skill in representative samples collected over some years. Writing and throwing were observed for 2844 participants drawn from primary, secondary and higher levels of education. The 12 actions of a standard questionnaire were observed for 2388 secondary school children and undergraduates. These findings provide normative data for comparison with selected samples that may be classified in a variety of ways, including subgroups previously defined and ordered for relative hand skill. Differences between the sexes were found only for certain subgroups of right-mixed-handers. Undergraduates were less variable for hand skill asymmetry than schoolchildren. Interpretations in the light of the RS theory show why statistical effects for comparisons with selected groups are likely to be small. Increased non-right-handedness may be caused by several influences on cerebral dominance, natural and pathological.

This paper describes hand preference in healthy samples that may be used for comparison with clinical or other selected groups. The data depend on *observed* actions in participants also individually measured for peg moving time by each hand. Observations were for the 12 items of the Annett Hand Preference Questionnaire (AHPQ, Appendix I) or fewer items for younger participants. Annett (1970) described findings for the written form of the questionnaire for over 2,000 participants. Items were examined for inter-correlation, for patterns of response by association analysis, for frequency of 'left' (L) and 'either' (E) hand responses, and also for associated peg moving asymmetry. Classes or subgroups of hand preference were defined, ordered for asymmetry of hand skill (reviews in Annett, 1985, 2002; see also for other references to my work below). The AHPQ has been used for studies of selected groups (Claridge, Clark, Davis & Mason, 1998; Giotakos, 2001; Lishman & McMeekan, 1976; Orr Cannon, Gilvarry, Jones & Murray, 1999). Because it is difficult for any one study to assemble a large sample of healthy controls, the present findings are offered as norms for hand preference.

Assessments of handedness vary with the measure used and with criteria of classification. Because there is no agreed standard, the terms 'left-hander' and 'non-right-hander' mean different things in different studies. Normative data were described by Coren (1993) for a 16 item questionnaire assessing hand, foot, eye and ear preferences. Normative studies of the Edinburgh Handedness Inventory (EHI, Oldfield, 1971) were reported from Brazil (Brito & Santos-Moreles, 1999) and England (Ellis, Ellis & Marshall, 1988). Lansky, Feinstein and Peterson (1988) surveyed hand use for five actions by telephoning adults in the USA. No previous studies are known to me of observed handedness for several standard actions, in participants from the primary school years to mature adults.

My first classifications distinguished consistent handers, left and right, from mixed handers, when 'mixed' meant firm preferences for different hands for different actions. In all of my samples, at least one third was non-right-handed by these criteria. True ambidexterity for writing is rare but E responses are more frequent for other actions. They tend to have poor reliability on follow-up (McMeekan & Lishman, 1975). The term 'ambiguous' handedness was suggested for changes of hand between trials of the same task (Soper & Satz, 1984). In questionnaire surveys of several actions I found that if Es were recognised as criteria of non-right preference, over 50% of healthy participants would be classified as non-right-handed. Findings for classifications with and without E as a criterion of non-right-handedness will be described below.

A subgroup classification was developed to distinguish degrees of right and left hand preference among mixed-handers, as defined above. There were many patterns of response, suggesting that hand preferences vary continuously between strong right and strong left. Could the continuum of preference be mapped onto the continuum of relative hand skill? Eight classes were defined (see Figure 1), ordered for L-R time for peg moving. Classes 1 and 8 were consistent right and left-handers respectively, classes 2-5 were right writers with some left preferences, and classes 6-7 were left writers with some right preferences. Six AHPQ items were found to be particularly highly correlated and these were called 'primary' actions (writing, throwing, racket, match, hammer and toothbrush) while the remaining six items were called 'non-primary' (scissors, needle, broom, shovel, dealing playing cards, unscrewing a jar). Classes 5 and 6 were right and left writers, respectively, who preferred the other hand for at least one primary action.

Figure 1 about here

When the subgroups were plotted for L-R time, two marred the intended linear order (Annett, 1976). Class 5 was more dextral than class 4 and class 2 more dextral than class 1. The finding that class 2 mixed-handers tend to be more *dextral* than consistent right-handers is strange, but it appears in several samples (Annett, 2002; Doyen & Carlier, 2002). In class 5, those performing only one primary action left-handed resembled the original class 3 (unscrewing the lid of a jar left-handed) and those performing two or more primary actions left-handed resembled the original class 4 (dealing playing cards left-handed). Members of class 5 were re-assigned accordingly (Annett, 1985, Table 11.4). Class 5 has not featured in my recent reports but it must be given further attention as psychiatric patients and their first degree relatives were more often mixed-handed for primary actions than controls (Orr et al., 1999). The present findings are described for both the 8 and 7 subgroup classifications.

A further modification of the original scheme was needed for right-handed writers who use normal scissors in the left hand. This was not expected because normal scissors are designed for use in the right hand. It was decided that for right-handed writers, scissors should be treated as a primary action. It is important to be clear that 'scissors' does not count as a primary action for left-handers because they often use the right hand for scissors. In the present revision of the 8 subgroup scheme, right-handers who use scissors in the left hand are in class 5. In the 7 subgroup scheme they are in class 3 if no other primary action is left, and class 4 if any other primary is left.

The subgroup approach to handedness contrasts with that of laterality quotients (Briggs & Nebes, 1975; Crovitz & Zener, 1962; Oldfield, 1971; Steenhuis, Bryden, Schwartz & Lawson, 1990). Annett (1985, 2002) criticised the scoring of questionnaire responses on several grounds. Briefly, such scales apply the same number values to items that differ in frequency and relative skill, and they require personal judgements about strength of preference that are of unknown validity. The same quotient can be obtained in different ways. Subgroups, by contrast, focus on actual preferences for groups of items.

The samples reported here have not been previously described fully for hand preference. They were combined in order to examine questions about the stability of handedness with age, sex and secular trend toward increasing left-handedness (Annett, 1998). There was no evidence of secular trend between the 1960s and early 1990s. On the contrary, the earliest samples (the ‘birthday’ samples of Kilshaw & Annett, 1983) included an unexpectedly high proportion of left-handers. A secular change over the first half of the 20th century cannot be doubted. Among the present participants of 50 + years of age, mainly Open University (OU) students attending summer schools in the early 1970s, there were only 2.9% left writers. This is consistent with evidence that the incidence of left writing was about 3% in people who started school in the 1920s (Burt, 1937; Fleminger, Dalton & Standage, 1977; Porac & Searleman, 2002). Older OU students were as likely as younger ones to be left superior for peg moving, and to prefer the left hand for actions other than writing. Porac and Searleman (2002) found 12.7% of older participants either left-handed or with a history of attempts to switch hand preference from left to right. These observations support the argument that smaller frequencies of left-handedness in older than younger participants are due to changes in secular pressure against left-handed writing (Annett, 1993; Salive, Guralnik & Glynn, 1993) rather than reduced longevity in left-handers (Coren & Halpern, 1991). In the present analyses, older participants who preferred the left hand for primary actions other than writing were classified in the subgroup scheme on the assumption that their writing hand was forcibly changed from left to right. Writing hand is described directly without modification (in Table 1) to provide norms for writing hand as the criterion. Other classifications depend on subgroup membership.

Throwing was also observed for all participants. Writing and throwing were described for over one million respondents to a questionnaire distributed with the National Geographic magazine (Gilbert & Wysocki, 1992). Annett (2000) compared the Gilbert and Wysocki data with findings for combined samples (not identical to those described here but with some overlap) and found remarkable consistency. Peters (1990) suggested that imbalance in the relative frequencies of left writers who throw with the right hand, versus right writers who throw with the left hand, might pose problems for theories that ascribe atypical handedness to chance, because such theories predict a balanced 50/50 division of atypical cases.

Annett (2002, Figure 3.5) described the distribution of R-L hand skill in the present samples, taking the difference for peg moving time as a proportion of total time for both hands (R-L% = (((L-R)/(R+L)) x 100). (Note that the subtraction is L-R because the left hand takes more time in most participants). Although L-R differences tend to be larger in younger and slower participants, R-L% is constant over age. The distribution is a continuous unimodal normal curve with small but significant negative skew, like that for hand strength (Woo & Pearson, 1927). There were 16.1% faster with the left hand. Frequencies of L and E responses for each item of the APHQ (Annett, 2002a, p. 29) confirmed the reliability of previous findings. Doyen and Carlier (2002) described peg moving asymmetry in the subgroups (of Figure 1) for a sample mainly of French academics. Annett (2003) showed that the French findings resembled those of the present undergraduates for most subgroups. Variability for hand skill asymmetry was smaller in university than school samples, as shown in a new analysis below.

METHOD

Samples

The samples include the 'combined main samples' of Kilshaw and Annett (1983), those of Annett and Manning (1989) and (Annett, 1992), together with further unpublished primary school data. The 'birthday samples' were not included because of doubts about their representativeness, as mentioned above. All samples were drawn without selection for handedness. The sources include 10 primary and middle schools, 3 large comprehensive schools, 3 grammar schools, and 4 universities. About half the undergraduates were mature OU students. Primary school children (N 417) were aged 5years 1 month to 10 years 11 months, mean 7 years 11 months, SD 20 months. Secondary school children (N 824) were aged 11 years 0 months to 17 years 11 months, mean 14 years 7 months, SD 19 months. The undergraduates (N 1603, 1567 of known age), were aged 18 to 63 years, mean 28 years 5 months, SD 10.5 years. The sexes were equally represented in the school years, but females were about 60% of the university samples.

Procedures

Hand use was observed using toys and tools provided for demonstration. Fewer actions were observed for younger than older participants but writing and throwing were observed for all. Observations were by the author or assistants except for some teenagers and most students who observed and recorded each other. Student observations were made in psychology practical classes. After initial demonstrations, students followed written instructions and recorded data on prepared forms. OU students, at several different summer schools, made copies of their data to be sent to the author. There were several purposes for laboratory classes over the years, but the overall aims were to collect data on preference and skill in normal samples, and to examine relationships with other variables.

RESULTS

Right versus left

The proportions of left writers did not differ significantly between the three age groups, at primary (8.9%), secondary (9.7%) and higher (9.4%) levels of education. Percentages were also similar for males (9.6%) and females (9.2%). There were no age or sex differences for writing or throwing.

Table 1 about here

The joint distribution of R, E, and L for writing and throwing is given in Table 1. The overall incidence of left writing was 9.4% and left throwing 8.8%. The number of left writers who throw right (LR 53) was almost identical to that of right writers who throw left (RL 54). Only 4 wrote with either hand, but 119 threw with either hand. When E responses were counted with R, then LR was 2.5% and RL 1.9%. When E responses were counted with L, LR was 1.9% and RL 5.4%.

Several different right versus left groupings could be derived from Table 1. For other actions the possibilities are multiplied. The frequencies of L responses ranged from 6% for scissors to 22% for unscrewing the lid of a jar. For E responses, the range was about 0.1% for writing to 10% for jar. Thus, many different estimates of right versus left-handedness could be based on the various actions and criteria.

How were the four E writers classified in further analyses? Other responses showed that two used the left hand for many actions, and clearly belonged in subgroups of left-handers. The others did not, and belonged in subgroups of right-handers. A further addition to the left-handers of Table 1 was made for 12 OU students who wrote with the right hand, but were left-handed for other primary actions, as described above. When handedness was classified by subgroup there were 281/2844 (9.9%) left-handers. These included 10.3% of males and 9.6% of females, a non-significant difference.

Right, Mixed and Left for the full AHPQ

Observed hand use for the full AHPQ was available for 785 secondary school and 1603 university participants (total 2388), but not for the primary school children who are therefore omitted from the following analyses. Consistent right-handers and consistent left-handers were distinguished from those with mixed preferences. Table 2 shows the effect of defining mixed-handedness with and without recognizing E responses. When any combination of R, E and L responses was counted mixed, there were 49.4% mixed-handers and only 47.6% consistent right-handers. When mixed was restricted to definite preferences for R and L (as in my previous analyses) there were 35.9% mixed. There were no differences for age or sex for either classification.

Table 2 about here

Right, mixed and left for 6 primary actions

The samples were examined for consistent versus mixed-handedness, when the latter was defined as inconsistent preference for the primary actions of the AHPQ (scissors counted as a primary action for right-handed writers but not for left-handed writers, as explained above). Table 3 sets out the definitions and the findings, with and without counting E responses as evidence of mixed-handedness. With E responses, there were 17.3% mixed-handers but without Es there were 8.2%. There were no differences for age or sex.

Table 3 about here

Subgroup hand preference

Distributions of hand preference were examined for the 8 and 7 subgroup classifications. There were no differences for age but there were significant effects for sex in both analyses (chi square (7, 2388) = 16.79, p = .019 for the 8 group and chi square (6, 2388) = 15.77, p = .015 for the 7 group classification). Table 4 gives the distribution by sex for 8 subgroups. An indication of the significance of differences between observed and expected findings within each cell is offered by adjusted standardised residuals (SPSS Crosstabs procedure). The latter show that the sex difference depended mainly on class 2, where there were more females (11.1%) than males (7.3%). There tended to be more males and than females in classes 3 and 4. Frequencies in classes 1 and 5-8 were similar.

Table 4 about here

In the 7 subgroup classification, classes 3-5 were reduced to the revised classes 3 (10.8%) and 4 (9.6%). The difference between the sexes depended on class 2 as above. In the revised class 4 there were more males (11.3%) than females (8.5%). The sex difference depended on a relative excess of females in class 2 and a relative excess of males in class 4.

Subgroup hand skill

As explained above, the subgroups were defined with the aim of mapping levels of hand preference to levels of asymmetry for hand skill. Table 5 lists mean R-L% for the secondary school and university samples for the original 8 subgroups. Consistent left-handers were about as biased to the left hand (R-L% - 4.8) as consistent right-handers to the right (R-L% 5.0). Class 2 tended to be more dextral than class 1 and class 5 more dextral than class 4 in both sets of samples.

Table 5 about here

Peg moving asymmetry (R-L%, as defined above) was examined by analysis of variance for subgroup (8), sex (2) and age (2). There was a major effect of subgroup as expected ($p < .001$), but there were no main effects for sex or age. There was a highly significant interaction between subgroup and age ($F (7, 2346) = 3.601$, $p = .001$). Inspection shows that for all right-handed writers (subgroups 1-5) the means for undergraduates were smaller (closer to zero) than for schoolchildren. For left-handed writers (subgroups 6-8) the means were in favour of the left hand, but those for undergraduates were again closer to zero. The total means did not differ but the variability of the school sample was larger than the university sample (SD 5.0 & 4.4 respectively; Levene test of homogeneity of variance (1, 2376) = 11.405, $p < .001$). Post hoc contrasts with Bonferroni correction showed that all groups differed except for 1 and 2, 3 and 5, 6 and 7, and 7 and 8. Subgroup 4 was closest to zero, differing from other right-handers as well as from left-handers.

DISCUSSION

Classification and frequencies

The data should be representative of the samples from which it was drawn, because it was based on whole class groups, unselected for handedness. The school samples should be representative of the population for their age range. The university samples included many mature students who began their studies at different stages of life. However, it cannot be assumed to be representative of the general population of adults and this is a possible weakness of the present normative data. Allowing for forced change of writing hand, as judged by preference for other actions, the frequency of left preference for writing was estimated at 9.9%. Except for the older OU students, the incidence of left writing was remarkably consistent across the age groups. Evidence from actions other than writing and from peg moving asymmetry suggested that the older students did not differ from the younger ones for hand preference or skill, but only for the expression of preference in writing. This is consistent with other evidence for secular trend in the last century (Gilbert & Wysocki, 1992; Porac & Searleman, 2002), with the main difference between the years before and after World War 2. The consistency between children and undergraduates for the frequency of left writing suggests that the secular trend has not persisted in the latter years of the 20th century. Therefore, normative data collected in these years is likely to remain valid. The frequency of left writing was a little higher for males than females, as generally found, but the difference was small and not statistically significant. The trend is consistent but the effect very small.

Frequencies for throwing were 8.8% for L but 13% for L plus E responses. The frequencies of left writers who throw right (LR) versus the opposite pattern (RL), were virtually identical when R and L were counted for definite preferences. They were consistent with a balanced 50/50 division, as expected if determined by chance. Imbalances depended on the classification of E responses. When E was counted with R (R+ E versus L), the percentages were LR 2.5% and RL 1.9%. Gilbert and Wysocki's (1992) combined data for over a million questionnaire respondents (as analysed by Annett, 2000) found LR 2.7% and RL 1.9%. The frequencies of these two patterns of atypical preference are, therefore, stable in the population. When E responses were counted with L, the direction of imbalance reversed. If the size and direction of imbalance varies with decisions about the classification of E responses, imbalance seems unlikely to have great theoretical significance (McManus, Porac, Bryden and Boucher, 1999; Peters, 1990).

My previous estimates of the relative proportions of consistent right, mixed and consistent left preferences were about 66%, 30%, 4% (Annett, 1972). Table 2 shows 60%, 36%, 4% respectively here. The slightly lower frequency of mixed-handedness in some earlier samples might be due to the use of fewer items than the full of AHPQ. Giatokas (2001) found 35.7% of healthy Greek conscripts mixed-handed for the AHPQ, consistent with the present findings (35.9%) but an increased frequency of mixed-handers in schizophrenics (54.4%). However, another sample of schizophrenics was 30% mixed-handed on this criterion (Malesu, Cannon, Jones, McKenzie, Gilvarry, Rifkin, Toone & Murray, 1996). Table 2 shows that when E was used as a criterion, there were 49% mixed-handers and 52% non-right-handers on this very broad definition.

Table 3 reveals that 8.2% showed mixed preferences for primary actions. Three psychiatric samples have found some 14-16% patients mixed on this criterion (Giatokas, 2001; Lishman & McMeekan, 1976; Orr *et al*, 1999), about twice as many as in the present healthy samples. Further, Orr et al. found increased mixed preference in the first degree relatives of their patients. Table 3 shows that when E responses were counted for the primary actions, there were 17.3% mixed-handers and 22.5% non-right-handers.

There were more left-mixed-handers (6%) than consistent left-handers (4%) while consistent right-handers (60%) were twice as frequent as right-mixed-handers (30%) (see Table 4). Right-mixed-handers have received little attention in the literature but it should be noted that they are the majority of non-right-handers. Differences between the sexes occurred only among right-mixed-handers. Females were more frequent than males in class 2, while males tended to be more frequent in classes 4 and 5. The tendency for class 2 to be more dextral than class 1 (Table 5) has been observed also for eye preference, foot preference and frequency of non-right-handed relatives (Annett, 1985, 1994, 2001). The finding is curious, but too frequent to be dismissed as accidental. Differences between the sexes for associations between handedness and cerebral anatomy (Amunts, Jaencke, Mohlberg. Steimetz, & Zilles, 2000; Witelson, 1989) may be due to greater dextrality in some mixed-handed females.

R-L% means (Table 5) were positive for right-handed writers and negative for left-handed writers, as expected, but there were significant differences between subgroups of the same writing hand. Class 4 (dealing playing cards left-handed) was closest to zero (1.9%) and differed significantly from all other groups, right and left. Dealing cards has been rejected as a questionnaire item by some researchers because of doubts about its validity (see for example Oldfield, 1971, p. 104) but for hand skill, this item is associated with the weakest bias to the right in right-handers. Classes 2 and 5 tended to be out of line for R-L% in both samples, as mentioned above. Explanations of these curious phenomena cannot be offered at present, but they are reliable observations that merit further study. The final point about Table 5 is that the mean asymmetries of the school and university samples did not differ but the university sample was significantly less variable. The difference for variability is consistent with the hypothesis of heterozygote advantage for the RS locus, as explained below.

Theoretical interpretations by the RS theory

Handedness is associated with cerebral dominance, but the mechanism is unknown. The RS theory distinguishes between an accidental, nongenetic, Gaussian distribution of asymmetry for hand skill and a factor for left hemisphere advantage (possibly a single RS + gene) that displaces the handedness distribution in the dextral direction. Genetic effects have to be detected against the substantial 'noise' of accidental normal variation. Large influences on cerebral dominance, may have only small influences on the location of the handedness distribution.

Increased non-right-handedness has been associated with many conditions including learning disability (Gordon, 1921), literacy problems (Orton, 1937), epilepsy (Bingley, 1958), homosexuality (Lalumiere, Blanchard & Zucker, 2000; Lindesay, 1987), criminality and psychopathy (Bogaert, 2001), gender identity disorder (Zucker, Beaulieu, Bradley, Grimshaw & Wilcox 2001) and schizophrenia (Sommer, Aleman, Ramsey, Bouma & Kahn, 2001). It is also associated with special talents as in baseball pitchers, bowlers in cricket, tennis players, artists, mathematicians, musicians and surgeons (Annett, 2002 for review). The diversity of weaknesses and talents is sufficient to show that handedness cannot be *the cause* of any of these conditions. Bogaert (2001), for example, specifically cautioned against using non-right-handedness as a marker for criminality. Neither can it be a marker for dyslexia, mathematical ability, or schizophrenia. Changes to the handedness distribution are a by-product of many influences on cerebral dominance.

The RS theory suggests four ways in which atypical asymmetry might be enhanced by differences associated with the RS genetic locus. These are absence of the RS + gene, reduced gene expression, heterozygote advantage, and mutation. Absence of the RS factor was suggested from the first formulation of the RS theory (Annett, 1972) to be a possible cause of dyslexia, because the factor was expected to be associated with left hemisphere advantage for speech as well as right shift for handedness. Increased mixed- and left-handedness are expected in children with specific disorders of speech and literacy, when the latter are associated with absence of typical cerebral dominance (Orton, 1937). These arguments have been supported by subsequent studies (Annett, 2002, chapter 13).

Reduced gene expressivity is likely to depend on a sensitive period during foetal development. Enhanced frequencies of right-handedness are associated with greater maturity at birth, more often present in females than males, in single than multiple births, and in normal than low birth-weight infants. Any factor that disturbs the normal developmental path is likely to reduce RS + gene expression, and thus increase non-right-handedness. This is the probable explanation of the raised atypical handedness associated with twin birth, learning disability and many other conditions (review by Geschwind & Galaburda, 1985). There may be no intrinsic connection between the condition and handedness, but both are influenced by some third variable affecting foetal growth.

The third RS hypothesis relevant to the handedness distribution is a genetic balanced polymorphism with heterozygote advantage. This suggests that the RS + gene is associated with advantages (for speech) but also disadvantages (perhaps for the right hemisphere). RS + - genotypes are expected to enjoy advantages for speech acquisition, while avoiding risks associated with the RS + + genotype (Annett, 1995, 2002). In the present comparisons between school and university samples, there were no differences for hand preference or for mean R-L%, but there was a smaller standard deviation for undergraduates. The latter is consistent with a smaller range for an intermediate genotype in an educationally advantaged group. The variability of adults from the general population is needed to check this interpretation. The enhanced frequency of non-right-handers among those with certain sports skills, spatial and mathematical abilities, and manipulative skills in music and surgery, might be due absence or reduction (in RS - - and RS + - genotypes) of right hemisphere deficits.

The fourth suggestion of the RS theory is that a mutation might impair the directional coding of the RS + gene so that it becomes 'agnosic' for left and right. Annett (1997, 1999) argued that such a mutation offers a mechanism for the theory that schizophrenia is a disorder of cerebral dominance (Crow, 1997). The RS + gene is hypothesised to normally handicap speech areas of the right hemisphere, but an agnosic gene (RS + a) would handicap either hemisphere at random. A handicap to *one* hemisphere, right or left, might not be associated with psychosis, but when an agnosic gene is paired with a normal RS + gene (RS + a RS + genotype) there would be impairment to speech areas of *both the right and the left* hemisphere in 50% of cases. This could give a risk for schizophrenia. When the agnosic gene affected the right hemisphere the left hemisphere would be normal, thus accounting for discordance for schizophrenia in monozygotic twins. All of the mechanisms that reduce RS and raise the frequency of non-right-handedness reviewed above might increase 'hemispheric indecision' in some people (Crow, Crow, Done, & Leask, 1998). However, most individuals in at risk groups should develop definite asymmetries by chance and some hemispheric indecision might be associated with advantages (in RS - - and RS + - genotypes) rather than disadvantages.

The present observations of preference and skill open up areas for further research. The reliable mappings between preference subgroups and relative hand skill imply that the subgroups offer a more objective classification of hand preference than available hitherto. The substantial number of participants, individually observed, gives unrivalled normative data.

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Table 1. The joint distributions of hand preference for write and throw: count (percent)

		THROW			
		right	*either*	*left*	*Total for write*
WRITE	*right count*	2420 (85.1)	99 (3.5)	54 (1.9)	2573 (90.5)
	either	2 (0.1)	1 (0.0)	1 (0.0)	4 (0.1)
	left	53 (1.9)	19 (0.7)	195 (6.9)	267 (9.4)
	Total for throw	2475 (87.0)	119 (4.2)	250 (8.8)	2844 (100.0)

Table 2. Consistent versus mixed hand preference for 12 actions, with and without counting 'either' as evidence of mixed-handedness: N = 2388.

	'Either' counted	*Percent*	*'Either' not counted*	*Percent*
Handedness				
Right consistent	R only	47.6	R only or R & E	60.0
Mixed	R & E or L	49.4	R & L	35.9
Left consistent	L only	3.0	L only or L & E	4.1

Table 3. Consistent versus mixed hand preferences for 6 primary actions*, with and without counting 'either' as evidence of mixed-handedness: N = 2388.

Handedness	*'Either' counted*	*percent*	*'Either' not counted*	*percent*
Right consistent	R only	77.6	R only or R & E	85.5
Mixed	R & E or L	17.3	R & L	8.2
Left consistent	L only	5.2	L only or L & E	6.4

* Primary actions were write, throw, racket, match, hammer, toothbrush; for right-handers scissors used in the left hand also counts as primary, but for left-handers scissors used in the right hand does not count.

Table 4. Males and females in eight handedness subgroups: percent (adjusted standardised residuals > 1.5z).

Handedness subgroup				*Male*	*Female*	*Total*
			N	949	1439	2388
1	R consistent	R or R & E, no L		60.0	60.0	60.0
2	R weak L *	L for needle, broom or spade		7.3 (-3.1)	11.1 (3.1)	9.6
3	R mild L	L for jar		9.2 (1.9)	7.0 (-1.9)	7.9
4	R mod L	L for cards		9.2 (1.7)	7.2 (-1.7)	8.0
5	R strong L	L any primary action		4.4	4.7	4.6
6	L strong R	R any primary action		3.6	3.6	3.6
7	L weak R	R any non-primary action		2.7	2.0	2.3
8	L consistent	L or L & E, no R		3.7	4.3	4.1

*Note that classes to the left (in Figure 1) take precedence. For example, L preferences for needle, broom, spade and jar would be classified as subgroup 3.

Table 5. Peg moving asymmetry in school and university samples for eight handedness subgroups: mean R-L% (SD)

			School		*University*		*Total*	
Handedness subgroup			N		N		N	
1	R consistent	R or R & E, no L	448	5.3	981	4.9	1429	5.0
2	R weak L*	L for needle, broom or spade	87	5.8	140	5.0	227	5.3
3	R mild L	L for jar	69	4.1	119	3.5	188	3.7
4	R mod L	L for cards	62	2.2	129	1.8	191	1.9
5	R strong L	L any primary action	38	4.1	69	3.1	107	3.5
6	L strong R	R any primary action	28	-3.8	58	-1.3	86	-2.1
7	L weak R	R any non-primary action	21	-4.2	34	-3.3	55	-3.6
8	L consistent	L or L & E, no R	27	-6.6	68	-4.2	95	-4.8
	Total		780	3.9 (5.0)	1598	3.7 (4.4)	2378	3.8 (4.6)

*Note that classes to the left (in Figure 1) take precedence. For example, L preferences for needle, broom, spade and jar would be classified as subgroup 3.

APPENDIX I

ANNETT HAND PREFERENCE QUESTIONNAIRE *

Name………………………………………….. Age…….…….. Sex……………..

Were you one of twins, triplets at birth or were you single born?……………………….

Please indicate which hand you habitually use for each of the following activities by writing R (for right), L (for left), E (for either).

Which hand do you use:
1. To write a letter legibly?……………………………………………………………..

2. To throw a ball to hit a target?……………………………………………………….

3. To hold a racket in tennis, squash or badminton?……………………………………

4. To hold a match whilst striking it?…………………………………………………...

5. To cut with scissors?………………………………………………………………….

6. To guide a thread through the eye of a needle (or guide needle on to thread)?………

7. At the top of a broom while sweeping?………………………………………………

8. At the top of a shovel when moving sand?……………………………………………

9. To deal playing cards?………………………………………………………………...

10. To hammer a nail into wood?…………………………………………………………

11. To hold a toothbrush while cleaning your teeth?……………………………………...

12. To unscrew the lid of a jar?……………………………………………………………

If you use the *right hand for all of these actions,* are there any one-handed actions for which you use the *left hand?* Please record them here

....

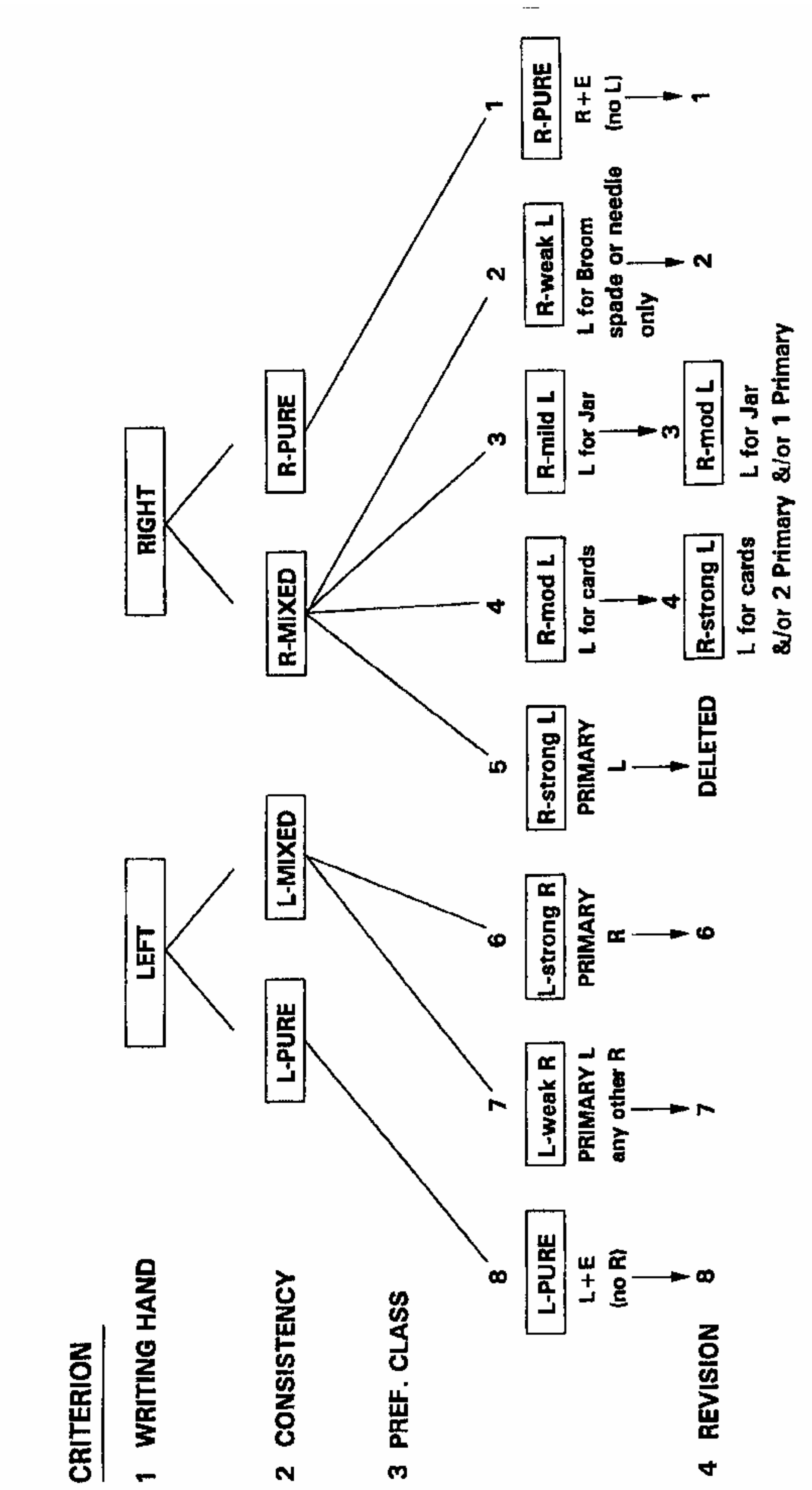
If you use the *left hand for all of these actions,* are there any one-handed actions for which you use the *right hand?* Please record them here

....

* Annett (1970)

Figure legend

Figure 1 A decision tree for hand preference subgroups of the Annett Hand Preference Questionnaire (Annett, 1970): Primary actions are writing, throwing, racket, match, hammer, toothbrush. Classes to the left take precedence over those to the right (e.g. if 'cards' and 'jar' are both left, the class is 4).


CRITERION
1 WRITING HAND
2 CONSISTENCY
3 PREF. CLASS
4 REVISION
LEFT
RIGHT
L-PURE
L-MIXED
R-MIXED
R-PURE
8
7
6
5
4
3
2
1
L-PURE
L-weak R
L-strong R
R-strong L
R-mod L
R-mild L
R-weak L
R-PURE
L+E (no R) → 8
PRIMARY L any other R → 7
PRIMARY R → 6
PRIMARY L → DELETED
L for cards → 4
L for Jar → 3
L for Broom spade or needle only → 2
R+E (no L) → 1
R-strong L
L for cards &/or 2 Primary
R-mod L
L for Jar &/or 1 Primary