Patterns of hand preference for pairs of actions and the classification of handedness

Marian Annett

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Address:

Dr. Marian Annett, School of Psychology, University of Leicester, Henry Wellcome
Building, Lancaster Road, Leicester UK LE1 9HN

Email: doc@le.ac.uk

Abstract

Pairs of actions such as write x throw and throw x racquet were examined for items of the Annett Hand Preference Questionnaire (AHPQ). Right (R) and left (L) responses were described for frequencies of RR, RL, LR and LL pairings (write x throw etc.) in a large representative combined sample with the aim of discovering the distribution over the population as a whole. The frequencies of RL pairings varied significantly over the different item pairs but the frequencies of LR pairings were fairly constant. An important difference was found between primary actions (originally write, throw, racquet, match, toothbrush, hammer with the later addition of scissors for right-handers) and non-primary actions (needle and thread, broom, spade, dealing playing cards and unscrewing the lid of a jar). For primary actions, there were similar numbers of right and left writers using the 'other' hand. For non-primary actions more right-handers used the left hand than for primary actions but more left-handers did not use the right hand. That is, different frequencies of response to primary versus non-primary actions were found for right-handers but not for left-handers. The pattern of findings was repeated for a corresponding analysis of left-handed throwing x AHPQ actions. The findings have implications for the classification of hand preferences and for analyses of the nature of hand skill.

Introduction

Hand preferences are features of human biology that are influenced by socio-cultural factors. The present aim is to describe patterns of response in a large sample representative of the population studied in order to show the distribution of responses over the population as a whole. In order to be representative the sample must not be distorted by left-handed volunteers, or by additional left- or mixed-handers recruited to increase the frequency of the less numerous subsets of the population. The present analyses are based on data collected from schoolchildren and students in whole class or project groups, who were assessed by observation of hand use for specified actions, not by questionnaire. Pairs of actions such as write x throw and throw x racquet were compared for frequency between left- and right-handers (classified on 'write' or 'throw') to examine the distribution of item associations.

Gilbert and Wysocki (1992) surveyed preferences for writing and throwing in over one million respondents, age 10 – 86 years, in a questionnaire distributed by the National Geographic magazine. The primary focus of the questionnaire was smell, so frequencies of responses to questions on handedness should not have been distorted by biases associated with hand preference. The main findings were a decline in the frequency of left preference for both actions (LL), and also for left writing and right throwing (LR) after about age 50 years. Right writing and left throwing (RL), although less frequent than LR in younger groups increased with age until it became more frequent than LL and LR in older groups. The increased relative frequency of RL responses with age might be associated with greater pressure against left-handed writing experienced by older participants in their youth. However, RL preferences were found in

younger participants, and these were unlikely to be due to social pressures because such pressures have eased since World War II. Social pressures cannot account for the LR pattern because it is unlikely that pressure would be exerted against left throwing (Peters, 1995, p.192). The existence of discordant preferences, such as RL and LR for writing and throwing suggests that mixed hand preferences occur naturally as part of a continuum of lateral preference (Annett, 1970; Gillies, MacSweeney and Zangwill, 1960). The present analyses examine the 12 actions of the Annett Hand Preference Questionnaire (AHPQ, Annett, 1970) for writing paired with other actions, and also for throwing and other actions, independently of writing.

Handedness assessments vary in the questions asked, methods of presentation and treatment of results. There is no universally agreed procedure to serve as a standard across studies. A common approach is to assign numbers to left and right responses, scored according to professed strength of preference (Corey, Hurley and Foundas, 2001; Crovitz and Zener, 1962; Oldfield, 1971). Having constructed such a scale, classifications are then based on arbitrary cut-points to divide left- from right-handers, or perhaps also mixed-handers. Annett (1985, 2002) has argued that these are pseudo-scientific procedures because questionnaire items are of unknown and probably different value, and because judgements of strength of preference are arbitrary. The present aim is to determine the relative values of items in terms of frequency of response in a representative population, observed for behaviour, and not relying on self-report.

Factor analyses of handedness questionnaire responses typically find that some items are strongly loaded on a common 'handedness' factor and other items more weakly loaded (Bryden, 1977; Healey, Liederman and Geschwind, 1986). An association

analysis of the twelve items of the AHPQ (Annett 1970) began like a factor analysis by inter-correlating all items, but proceeded to make distinctions between patterns of response. Six items were particularly highly inter-correlated (writing, throwing, racquet, match, hammer and toothbrush) and these were called ‘primary’ actions. In terms of factor analysis, the primary actions can be regarded as those most highly loaded on the first factor. The ‘non-primary’ actions (scissors, threading a needle, spade, broom, dealing playing cards and unscrewing the lid of a jar) were also significantly inter-correlated, but not as strongly as the primary actions. The analysis led to a classification of respondents in 8 subgroups, ordered for relative hand skill on a peg-moving task.

The subgroup scheme was examined in several subsequent studies (review in Annett, 2002). Summarising the main points, the 8 subgroups were reduced to 7 by deleting class 5, in order to improve the linear relationship between hand preference class and relative hand skill for peg moving (Annett, 1985, Table 11.4). The problem was that right handed writers who performed any other primary action(s) with the left hand (class 5) were *more dextral* for right minus left (R-L) hand skill than class 4 (dealing playing cards left-handed) when class 5 was expected to be less dextral than class 4. (For the 7 subgroup scheme they were re-assigned to class 3 (unscrewing the lid of a jar and/or one primary action with the left hand) or class 4 (dealing playing cards left handed and/or 2 or more primary actions with the left hand)). However, the present findings and clinical research (in discussion) suggest the original classification for inconsistent preferences for the primary actions (class 5 for right-handed writers and class 6 for left-handed writers) should be retained.

The samples described here have been reported in three previous papers. Annett (1998) examined, among other things, the stability of hand preference and hand skill over age, from preschool children to 63 year olds. Relative hand skill was remarkably stable over age, but hand preference for writing was stable only up to the 45-49 year group (at around 10%). After age 50 years there were only 2.9% left-handed writers. The majority of these participants were Open University (OU) students, assessed in 1974. They had started school before 1930 when pressures against left hand writing were strong. Hence, for the present analyses, the 50+ year group must be omitted.

Annett (2000), analysed a subset of the present samples together with an additional sample, and showed that it was possible to predict combinations of asymmetries such as write x eye preference or throw x eye preference according to expectations of the right shift (RS) theory of handedness (Annett, 1972) if each of these asymmetries followed the genetic expectations of the theory (Annett, 1978) but then combined at random. This was true also for combinations of handedness and certain cerebral asymmetries. It was shown further that the total frequencies for RR, RL, LR and LL for write x throw were virtually identical with those of Gilbert and Wysocki (1992). However, writing and throwing were associated more strongly than predicted by the rules for the pairs of variables described above. It was suggested that there is a 'pull to concordance' which increases the consistency of writing and throwing, for both right- and left-handers.

Annett (2004) described various possible classifications of hand preference using the AHPQ. The effect of counting or not counting either (E) responses as evidence of mixed-handedness was analysed. Classifications were also examined for primary actions

separately from the full questionnaire. It was shown that 8.2% of the sample was mixed-handed for combinations of R and L preference for the primary actions (when E responses were coded with R). When E responses for primary actions were counted with L responses there were 17.3% mixed-handers. This demonstrated the importance of clarity about the status of E responses in counts of mixed-handedness.

An important feature of the Annett (2004) analysis was a re-examination of the status of scissors. The treatment of scissors needs special attention because this tool is designed for use in the right hand (except for specially made left-handed scissors). Many left-handers use scissors in the right hand but a majority do not, preferring the left hand even for right-handed scissors. More surprisingly, a small number of right-handers use right-handed scissors in the left hand. It was necessary to reconsider the status of this actions, originally call non-primary. It was decided to reclassify scissors as a primary action in right-handers. It was not so re-classified in left-handers (cutting with the right hand) in view of the design factor.

A description of the subgroups in the set of combined samples to be analysed further in the present report was given by Annett (2004). The findings of particular interest here were that 4.6% of the sample ($N = 2388$) were right-handed writers who performed at least one other primary action with the left hand while 3.6% were left-handed writers who performed at least one other primary action with the right hand. This gave a total of 8.2%, as mentioned above, who were mixed-handed for the primary actions. A similar analysis of an Italian sample of healthy participants found 8.8% mixed-handed for the primary actions, suggesting that this is a stable feature of representative Western samples (Preti, Sardu & Piga, 2007).

The present focus was on the distribution of responses for all items of the AHPQ when paired with writing hand (write x throw, write x racquet etc.). The aim was to establish the frequency of the various combinations. A further analysis was made for throw x AHPQ actions, in order to show that the pattern of findings was not only a function of the writing hand. It will be shown that the relative frequencies for actions differ between primary and non-primary actions in right-handers, but not in left-handers.

Method

The sample

The sample is a subset of the combined samples, age range 3 – 63 years, described by Annett (1998, 2004). The nursery and primary school samples were not fully tested for the AHPQ and are therefore omitted here. Adults of 50 + years were omitted because they included only 2.9% left writers, as described above. As the present purpose was to examine combinations of preferences with writing, the inclusion of the 50+ age group would risk distortion of the findings.

There were 2279 participants with full information, including 887 males and 1392 females, mean age 22 years 11 months, *SD* 8 years 6 months, range 11 years 7 months – 49 years 11 months. They were drawn from 3 large comprehensive schools, 3 smaller grammar schools and 4 universities. About half of the undergraduates were OU students. The distribution for sex was about equal in the school samples but there were more females than males among undergraduates.

Procedures

The handedness information was collected as a preliminary to research on a variety of projects. It was collected from whole class groups, or from project samples where

handedness was not mentioned in the recruitment of volunteers. Participants were offered tools such as a match box with spent matches, small racquet, toy broom and spade, hammer and a small block of wood with a half driven nail. They were asked to demonstrate how to perform the actions of the AHPQ to an observer who recorded the hand used on a prepared form. If the participant was clearly uncertain which hand was preferred for a particular action, an either (E) response was recorded. Observers were fellow students, research assistants or the author. Statistical analyses were by SPSS 14.

Results

In counting combinations of hand preferences for pairs of actions it was necessary to decide to count E responses with either R or L. All E responses were counted with R so that L classifications are unambiguous.

The main analysis asked if findings for pairs differed between actions, and whether these findings differed between the sexes. The numbers of males and females responding RR, RL, LR and LL for write x throw, write x racquet etc. were entered into a hierarchical loglinear analysis. The variables were actions (11), response pairs (4) and sex (2). The final model found a significant main effect for sex, but this was trivial in the sense that it was known that there were more females than males. The interest was in the interactions. There were no interactions involving sex. The important finding was a significant interaction for actions x pairs (chi square = 1115.52, df 30, $p < .001$).

Table 1 about here

The above analysis found that the sexes did not differ for pattern of response. The inequality of Ns between the sexes was removed by finding the percentages of RR, RL, LR and LL pairs per action for each sex separately, and then averaging over sex. The

findings are shown as Ns per thousand in Table 1 *a*. The actions are ordered by frequency of RL responses. The striking finding is that the frequency of response pairs for RL varied widely over the actions, from 7 for hammer and scissors to 152 for unscrewing the lid of a jar. By contrast, the frequencies for LR pairs varied little, from 21 for match and toothbrush to 30 for jar and 38 for scissors. This is the basis of the significant interaction for action x pair found in the hierarchical log linear analysis.

The interaction was explored further by nonparametric chi square analyses. RL pairs differed significantly over actions (chi square = 448.86, *df* 10, $p < .001$), as did RR pairs (chi square = 27.30, *df* 10, $p = .002$). For LR and LL pairs there were no significant effects. LL pairs varied between 60 (scissors) and 77 (match and toothbrush).

The most interesting feature of Table 1 *a* is evident from inspection of the distribution of frequencies over actions. For 6 actions, hammer, scissors, toothbrush, racquet, throw, match, the frequencies of right-handed writers who performed these actions with the left hand were no greater than the frequencies of left-handed writers who performed them with the right hand. These actions, with writing but with the exception of scissors, were the originally defined primary actions (Annett, 1970). Scissors was redefined as a primary action for right-handers (Annett, 2004) but not for left-handers, as explained above. The non-primary actions were performed by right-handers with the left hand very much more frequently (from 68 to 152 of the total sample). However, as seen above, the primary and non-primary actions did not differ for left-handers.

The analysis for actions, pairs and sex was repeated for actions paired with throwing (10 actions excepting writing). The pattern of findings was as just described for writing. There was an effect of sex due to the larger number of females but no interaction

involving sex. The important finding was the interaction of actions and pairs (chi square = 891.21, df 27, $p < .001$). The findings, for sexes combined, are given in Table 1 *b*. LR participants preferred the right hand for other actions in 17 – 36 (per thousand) of the sample. RL participants preferred the left hand at similar rates for the primary actions (12 - 25) but non-primary actions very much more often (74-159). Nonparametric analyses found that actions did not differ for frequency for LR pairs but did significantly for RL pairs (chi square = 349.32, df 9, $p < .001$).

Discussion

These findings have implications for handedness questionnaires and for the classification of handedness. First, they demonstrate that questionnaire items are not equal in value, in the sense of frequency of response in the population. Second, they reinforce the distinction between primary and non-primary actions (Annett, 1970). These analyses show that primary actions are performed about as often by right-handers with the left hand as by left-handers with the right hand (as proportions of the total population). It should be noted, however, that although the non-primary actions were performed more often than primary actions by right-handers with the left hand, they were still relatively infrequent. Three quarters of the sample were RR for writing and unscrewing the lid of a jar. Right-handers unscrewing the lid of a jar with the left hand were shown to be more sinistral than consistent right-handers for R-L hand skill (Annett, 2002). This shows that non-primary actions have value as indicators of handedness, even if less value (in some sense) than primary actions. The differences in frequency of response between the questionnaire items reinforce the argument that to give items equivalent weight in marking schemes does not do justice to the pattern of responses. The practice of scoring

the AHPQ, as by Oldfield (1971) for the Edinburgh Inventory, suggested by Briggs and Nebes (1975), is not one I support.

An alternative way of looking at the findings might be to examine the percentages of response pairs within right-handers and left-handers separately. This would show that a higher percentage of left-handers than right-handers is inconsistent (LR as a proportion of LR + LL, versus RL as a proportion of RL + RR). This is a well known observation at least since Humphrey (1951). By contrast, what is being shown here is that as a proportion of the total population there are many more right-handers than left-handers with inconsistent preferences for the non-primary actions, whereas right- and left-handers are about equally consistent for the primary actions.

What classifications are likely to be useful in handedness research? One system is to distinguish consistent left-handers and consistent right-handers from all those who show inconsistent preferences between right and left responses. (In using this classification Annett (see review 2002) did not regard E responses as evidence of mixed-handedness, only definite combinations of R and L.) Mixed-handers on this criterion constituted some 25%-40% of various samples.

An alternative classification of mixed-handedness is based on combinations of R and L responses for the primary actions only. This distinguishes about 8 – 9% of the sample. This grouping was found of interest in studies of schizophrenia. Orr, Cannon, Gilvarry, Jones and Murray (1999) classified a psychiatric sample for mixed-handedness based on the primary actions of the AHPQ and found a raised incidence in schizophrenic patients and also in their relatives. A raised incidence of mixed-handedness, on this criterion, was found for early onset schizophrenia (Collinson, Phillips, James, Quested

and Crow, 2004). Annett and Moran (2006) examined schizotypy scores in undergraduates classified in the 8 subgroup scheme and found raised scores in class 5 only (right writers performing any other primary action with the left hand). This was found in two data sets. These findings suggest that it is important to distinguish people who differ between the hand used for writing and other primary actions (and thus retain classes 5 and 6 of the original subgroup scheme).

The evidence for possible clinical significance supports the argument for distinguishing patterns of mixed-hand preference. The alternative, for those who regard handedness as a dichotomous variable, recognising only R or L preferences, is either to discard those of uncertain classification, or arbitrarily place them with right- or left-handers. One argument that has been suggested for classifying mixed-handers with left-handers is that they are ‘true’ left-handers who were forced to use the right hand by socio-cultural pressures. If this were the case, right writers who throw with the left hand should be left-handed for all other questionnaire items that are not subject to social pressure. This pattern has indeed been observed in older persons with a history of forced right-handed writing (personal observation). However, it was not found in the present sample when older participants were excluded. Further, the LR pattern cannot be attributed to social pressures, as mentioned above. When throwing was taken as the first action for pairing with all other actions of the AHPQ, the same pattern of relative preferences was found as observed for writing. Therefore, the pattern of mixed hand preferences cannot be attributed to social pressures against left –handed writing.

The action of cutting with scissors is a special case because it is a tool normally designed for use in the right hand. It is an example of an instrument supporting the thesis

that ‘a right-handed world’ induces mixed-handedness in ‘true’ left-handers. It was found that more left-handed writers used the right hand for scissors than for any other action, and this was found for left-handed throwers also. However, there were nearly twice as many left-handed writers who used the left hand for scissors, showing that not all are governed by the design factor. It was surprising to find that some right-handed writers were not governed by the design constraint and used the left hand for right-handed scissors. These varied and apparently inconsistent patterns suggest that there are natural variations in hand preferences with many intermediate between strong right and strong left.

In the classification of handedness there will continue to be occasions when it is desired to have a broad classification of non-right-handedness to include all those who do not have consistent preferences for the right hand. In this case up to about 40 percent of the sample will be so identified. If E responses are included in the criterion of sinistrality, more than 50% of the sample are likely to be called non-right. This is to dilute the group of non-right-handers so far as to make any interesting findings unlikely. The distinction between primary and non-primary actions makes it possible to identify a smaller group of mixed-handers who have mixtures of preferences for those actions which are relatively rarely performed by the ‘other’ hand in right-handers, and which are fairly consistently performed at a similar rate by the ‘other’ hand for left-handers, giving a total of about 8-9% in the population. Exploration of this group may be more productive than more broadly defined groups of mixed-handers.

Aside from practical questions of classification, the findings lead to deeper theoretical questions. What is the nature of the difference in skill which distinguishes the

actions which right-handers perform rarely with the left hand (and no more often than left-handers perform them with the right hand, as proportions of the total sample) and the non-primary actions which are performed with the left hand more often by right-handers? Whatever this difference may be, why does it not affect the relative responses of left-handers? Of course, there are fewer left-handers than right-handers in the total population but if there are differences in relative skill one would have expected left-handers to unscrew the lid of a jar with the right hand more often than they use a tennis racquet in the right hand (as for right-handers with the left hand) but this was not found.

With regard to the nature of the difference in skill between primary and non-primary actions, it may be argued that they are primarily unimanual versus bimanual actions respectively. It is true that the non-primary actions require the coordinated use of both hands in manipulating a broom or spade, holding playing cards and dealing from the top of the pack, whereas the primary actions write, toothbrush, and throw are unimanual. However, it could be argued that match is a primary action which normally involves both hands. A tennis racquet can be held in both hands during play. When cutting, it is usually necessary to hold the material to be cut with one hand while holding the scissors in the other hand. Also, for hammer, it may be necessary to steady the base into which a nail is to be driven. Thus, the contrast between bimanual and unimanual actions does not fully capture the required distinctions.

More useful distinctions may depend on the force, speed and accuracy of the movements to be made. The primary actions require discrete movements which must be made with controlled force. The non-primary actions involve movements that can be made with variable force and without strong time constraints, as in sweeping, shovelling,

threading a needle or dealing a playing card. Hammering and throwing are rapid, ballistic movements that cannot be corrected in mid-flight and have a discrete outcome in success or failure to hit the target. Efficient writing requires the rapid production of specific movements. By contrast, when unscrewing the lid of a jar, force can be applied gradually until the release of the lid gives direct feedback of success. Woodworth (1899) found that the left hand was as capable as the right hand when plenty of time was allowed but the advantage of the right hand appeared when more rapid control was required. The differences between primary and non-primary actions probably depend on the need for speed and control. (For discussion of the motor control of hand movements see Rosenbaum, 1991; Schmidt and Lee, 1999.)

If the variables of relative force and speed influence the responses of right-handers, why do they not also affect left-handers? Left-handers hammer with the right hand about as often as they thread a needle or deal playing cards right-handed. It seems that constraints on accuracy are fairly constant for left-handers while they are more variable for right-handers. It may be noted that consistent left-handers are faster than other handedness subgroups for peg moving (Annett, 2002, p.200; Kilshaw and Annett, 1983).

According to the RS theory, handedness depends on chance asymmetries in everyone (right-, mixed-, and left-handers), while most but not all individuals inherit a genetic influence for left hemisphere dominance which increases the probability of right hand preference. Chance asymmetries give rise to a normal distribution of asymmetry for hand skill which implies that some individuals are about equally skilled with both hands. In such people, which hand comes to be preferred for particular actions is likely to

depend on accidents of learning experiences, giving ample scope for mixed preferences. Chance asymmetries also imply that some individuals may be so strongly biased to the left hand that they remain below the threshold of right-handedness, even in the presence of the RS + gene. This could lead to conflicts between mechanisms governing preferences for actions with different types of skill. Such conflicts in the presence of the RS + gene would be more frequent in those with mild biases to the right, as in right-mixed-handers than in left-handers. Perhaps it is such conflicts that lead to a higher proportion of RL preferences for non-primary actions in right-handers than LR preferences for non-primary actions in left-handers. For primary actions, there appears to be greater consistency than for non-primary actions, which was earlier called a 'pull to concordance' (Annett, 2000). This consistency implies that possible conflicts between chance effects and genetic effects are over-ridden in most right-handers for primary actions. This idea then raises further questions about the reasons for the inconsistency of some 4% of right-handers who have mixed preferences for the primary actions. These ideas remain speculative until the relevant mechanisms are identified.

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References

- Annett, M. (1970). A classification of hand preference by association analysis. *British Journal of Psychology*, 61, 303-321.
- Annett, M. (1972). The distribution of manual asymmetry. *British Journal of Psychology*, 63, 343-358.
- Annett, M. (1978). *A single gene explanation of right and left handedness and brainedness*. Coventry: Lanchester Polytechnic.
- Annett, M. (1985). *Left, right, hand and brain: The right shift theory*. London: Lawrence Erlbaum Associates Ltd.
- Annett, M. (1998). The stability of handedness. In J. K. Connolly (Ed.), *The psychobiology of the hand*. (pp. 63-76). London: MacKeith Press.
- Annett, M. (2000). Predicting combinations of left and right asymmetries. *Cortex*, 36, 485-505.
- Annett, M. (2002). *Handedness and brain asymmetry: The right shift theory*. Hove, East Sussex: Psychology Press.
- Annett, M. (2004). Hand preference observed in large healthy samples: Classification, norms and interpretations of increased non-right-handedness by the right shift theory. *British Journal of Psychology*, 95, 339-353.
- Annett, M. & Moran, P. (2006). Schizotypy is increased in mixed-handers, especially right-handed writers who use the left hand for primary actions. *Schizophrenia Research*, 81, 239-246.
- Briggs, G. G. & Nebes, R. D. (1975). Patterns of hand preference in a student population. *Cortex*, 11, 230-238.

- Bryden, M. P. (1977). Measuring handedness with questionnaires. *Neuropsychologia*, 15, 617-624.
- Collinson, S. L., Phillips, T. J., James, A. C. D., Quested, D. J. & Crow, T. J. (2004). Is lateral bias anomalous in early onset schizophrenia? Selected comparison with normal population. *Psychiatry Research*, 125, 219-224.
- Corey, D. M., Hurley, M. M. & Foundas, A. L. (2001). Right and left handedness defined: A multivariate approach using hand preference and performance measures. *Neuropsychiatry, Neuropsychology and Behavioral Neurology*. 14, 144-152.
- Crovitz, H. F. & Zener, K. A. (1962). A group test for assessing hand and eye dominance. *American Journal of Psychology*, 75, 271-276.
- Gilbert, A. N. & Wysocki, C. J. (1992). Hand preference and age in the United States. *Neuropsychologia*, 30, 601-608.
- Gillies, S. M.M., MacSweeney, D. A. & Zangwill, O. L. (1960). A note on some unusual handedness patterns. *Quarterly Journal of Experimental Psychology*, 12, 113-116.
- Healey, J. M., Liederman, J. & Geschwind, N. (1986). Handedness is not a unidimensional trait. *Cortex*, 22, 33-53.
- Humphrey, M. E. (1951). Consistency of hand usage. *British Journal of Educational Psychology*, 21, 214-225.
- Kilshaw, D. & Annett, M. (1983). Right and left hand skill I: Effects of age, sex and hand preference showing superior skill in left-handers. *British Journal of Psychology*, 74, 253-268.

- Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9, 97-114.
- Orr, K. G. D., Cannon, M., Gilvarry, C. M., Jones, P. B. & Murray, R. M. (1999). Schizophrenic patients and their first-degree relatives show an excess of mixed-handedness. *Schizophrenia Research*, 39, 167-176.
- Peters, M. (1995). Handedness in relation to other indices of cerebral lateralization. In R. J. Davidson & K. Hugdahl (Eds.), *Brain Asymmetry* (pp. 183-214). Cambridge, Mass: MIT press.
- Preti, A., Sardu, C. & Piga, A. (2007). Mixed-handedness is associated with the reporting of psychotic-like beliefs in a non-clinical Italian sample. *Schizophrenia Research*, 92, 15-23.
- Rosenbaum, D. A. (1991). *Human Motor Control*. San Diego: Academic press.
- Schmidt, R. A. & Lee, T. D. (1999). *Motor Control and Learning: A Behavioral Emphasis*. (3rd ed.). Champaign Ill.: Human Kinetics.
- Woodworth, R. S. (1899). The accuracy of voluntary movement. *Psychological Review*, Monograph supplement, no. 2.

Table 1. Percentages of the total sample (balanced for sex) responding RR, RL, LR and LL for actions of the Annett Hand Preference Questionnaire (Annett, 1970) expressed as N per 1000.

a. Write x action

	RR	RL	LR	LL
<i>Hammer</i>	896	7	23	74
<i>Scissors</i>	895	7	38	60
<i>Toothbrush</i>	888	14	21	77
<i>Racquet</i>	886	16	29	69
<i>Throw</i>	885	17	25	73
<i>Match</i>	882	20	21	77
<i>Spade</i>	834	68	22	76
<i>Needle</i>	822	80	22	76
<i>Broom</i>	819	83	24	74
<i>Cards</i>	804	98	23	75
<i>Jar</i>	750	152	30	68

b. Throw x action

	RR	RL	LR	LL
<i>Hammer</i>	898	12	21	69
<i>Scissors</i>	896	14	36	54
<i>Toothbrush</i>	888	22	21	69
<i>Racquet</i>	894	16	22	68
<i>Match</i>	884	25	19	72
<i>Spade</i>	836	74	20	70
<i>Needle</i>	826	84	17	73
<i>Broom</i>	836	74	20	70
<i>Cards</i>	806	103	21	70
<i>Jar</i>	760	150	19	71