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Handedness and Heterogeneity in Cognitive Science

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Handedness and Heterogeneity in Cognitive Science

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Abstract

Outside of cognitive neuropsychology, it is often assumed that differences among individuals in cognitive activity may be adequately represented theoretically in terms only of quantitative variation across a population. A possible exception to the presumption of homogeneity within cognitive processing is explored here. It is shown that left-handed and right-handed populations exhibit consistent, qualitative differences in their remembering of orientational information. It is concluded that the subject matter of cognitive science may be more heterogeneous than is commonly assumed.

Assumption of Homogeneity

A widespread implicit assumption in cognitive science is that its subject matter is homogeneous, in the sense that differences in cognitive processing among individuals may generally be expressed in terms of merely quantitative variation. A major exception to this assumption is commonly recognised in the field of cognitive neuropsychology, where the cognitive processes of individuals have been shown to exhibit a range of idiosyncrasies associated with different forms of physical damage to the brain (e.g., Jones & MacAndrew, 1990). For this field, the occurrence of a double dissociation of function is generally held to indicate heterogeneity of population (e.g., Jones, 1983), although the validity even of this inference has been challenged within cognitive science (e.g., Juola & Plunkett, 1998) But for those without brain damage, differences among individuals are often viewed within cognitive science as essentially random, with variation in cognitive activity among individuals represented theoretically in terms of dispersion around a central tendency. If this is a correct characterisation of much of cognitive science, then it raises the question of whether the assumption, outside cognitive neuropsychology, of homogeneity among individuals is justified in particular circumstances.

Where may qualitative differences in cognitive processes among individuals be manifested? A classical area of investigation is that of personality (e.g., Martin, 1985). However, the domain of handedness is also an appropriate area to consider. Can the models and descriptions of cognitive science be applied indifferently, as is generally assumed, to the right-handed majority and to the left-handed minority? Or do fields of heterogeneity exist in which people's handedness influences their cognitive performance? Empirical evidence that allows these questions to be addressed is considered here. First, however, it is appropriate to consider briefly the distinctive characteristics of handedness itself.

Handedness Populations

Most human beings exhibit a preference for the use of one or other hand. This preference is not evenly distributed between left and right, as it is for most animals. Instead, the predominant pattern of limb preference is for use of the right hand.

Although hand preference can be influenced by social pressures (e.g., Harris, 1990), it has a number of features which suggest that it is also under genetic influence (e.g., Corballis, 1997; Laval, Dann, Butler, Loftus, Rue, Leask, Bass, Comazzi, Vita, Nanko, Shaw, Peterson, Shields, Smith, Stewart, DeLisi, & Crow, 1998). For example, Klar (1996) has reported that the likelihood of a person being left-handed is increased if one of the parents of the person, although right-handed, in turn had two left-handed parents. We have shown (Jones & Martin, 2000) that a genetic model for

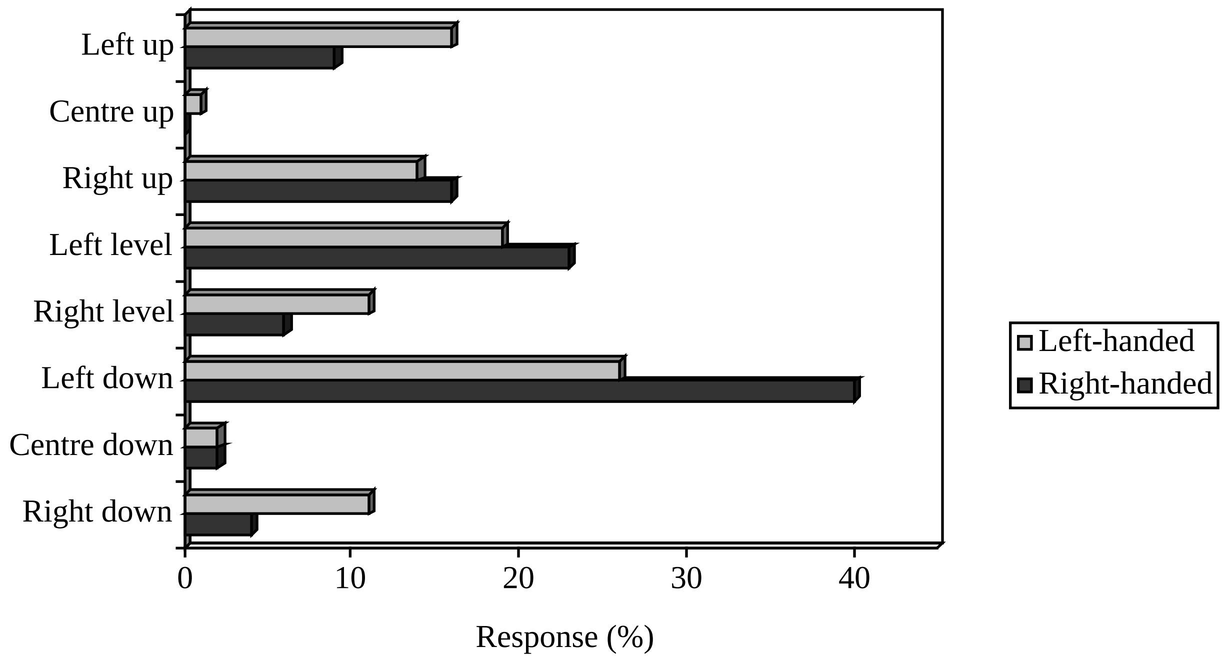

Figure 1. Orientation responses

handedness may be formulated which accounts satisfactorily for this and a number of other similar effects.

It has frequently been suggested (e.g., Day & MacNeilage, 1996) that asymmetry in limb use, via an accompanying specialisation of function in the cerebral hemispheres, played a decisive role in the evolution of language. Similarly, the degree of lateralization of language function between the hemispheres is known to differ between left-handed and right-handed populations (e.g., McManus, 1999). However, it is less clear that cognitively based performance itself differs between the left-handed and right-handed populations. Thus, despite considerable research, it has proven difficult to establish reliable associations between handedness and either developmental reading disorder (e.g., Bishop, 1990) or a variety of symptoms linked to immune disorders (cf. Geschwind & Galaburda, 1987; Bryden, McManus, & Bulman-Fleming, 1994). Indeed, until recently there has been suggestive evidence of a heterogeneity in cognitive function between left-handed and right-handed populations in only one field, that of chimeric perception.

Heterogeneity for Cognitive Function

Chimeric faces may be constructed by artificially pairing their left and right halves. If people are asked to match a control face to either a chimeric face composed only of the left half (and its mirror image) or a chimeric face composed only of the right half (and its mirror image), it has been reliably demonstrated (e.g., Levy, Heller, Banich, & Burton, 1983; Luh, Redl, & Levy, 1994) that right-handed people, but not left-handed people, have a significant tendency to select the left half (plus its mirror image) face as the better match.

The chimeric finding appears to represent a genuinely cognitive, not hemispheric, effect since it occurs with unrestricted fixation and therefore is not related to visual field (and hence hemisphericality). However, it may also be noted that the effect is a relatively narrow one. If the assumption of homogeneity of cognitive processing broke down only in this limited field, then the case for a wider consideration of heterogeneity in cognitive science would be relatively weak. It is now becoming apparent, however, that heterogeneity is demonstrable in the wider area of memory for orientation (e.g., McKelvie & Aikins, 1993; Martin & Jones, 1998). Two further studies of memory for orientation, which are described next, confirm this finding. The first also investigates whether the heterogeneity extends

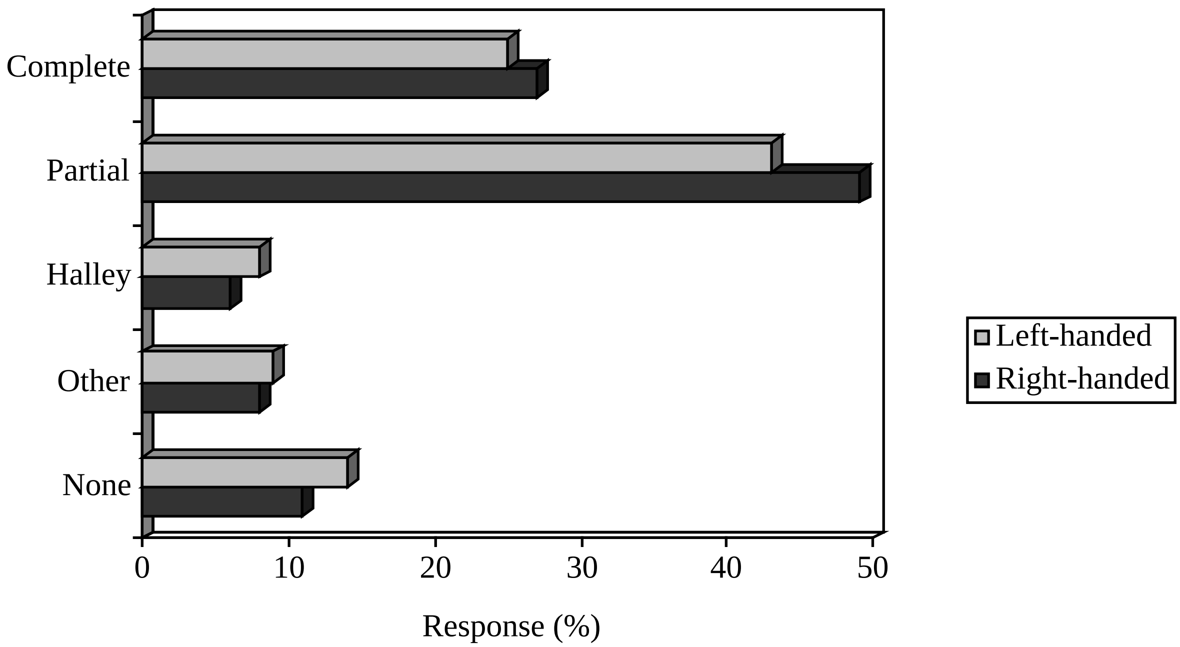

Figure 2. Name responses

to memory for other types of information, and the second also investigates whether it resides genuinely in memory or alternatively in strategic behavior.

Extent of Heterogeneity

Are differences between left-handed and right-handed populations in cognitive functioning confined to memory for orientation, or do they extend to memory for abstract information? This question was investigated by examining people's memory for Comet Hale-Bopp, selected as subject because of the long history of popular interest in cometary appearances (see Schechner Genuth, 1997).

Approximately equal numbers of left-handed and right-handed participants were tested ($N = 401$). Testing occurred approximately six months after the comet's visit. Participants were tested on a series of items "about the comet which was visible to the naked eye over the Easter period." Questions probed both abstract and concrete knowledge. Binary handedness classifications were made on the basis of the hand which the participant used for drawing.

Figure 1 shows memory for orientation for left-handed and for right-handed participants. Recall of the direction of the head of the comet was classified into eight different sectors, defined by the combination of it pointing leftwards, centrally, or rightwards; and downwards, level, or upwards. There was a significant difference between the frequency distributions of responses for left-handed and right-handed participants, $\chi^2(7) = 20.29$, $p < .01$. In particular, right-handed participants produced a significantly greater number than left-handed participants of responses with the comet facing down to the left (the orientation most frequently encountered), $\chi^2(1) = 7.86$, $p < .01$. Similarly, considering downward and level responses overall, it can be seen from Figure 1 that there was a contralateral tendency which associated right-handed participants with left-facing responses, and vice versa; this tendency also was significant, $\chi^2(1) = 12.97$, $p < .001$. Similar results were found with recognition rather than recall responses.

Figure 2 shows the distributions of written name responses which were made by left-handed and by right-handed participants. Recall was classified as either (a) completely accurate (both Hale and Bopp), (b) partially accurate (incomplete or misspelled), (c) Halley (either a semantic error or an approximation to Hale), (d) unrelated name, or (e) no response. There was no significant difference between the two frequency distributions, $\chi^2(4) = 3.08$. Similar results were found for the recall of other

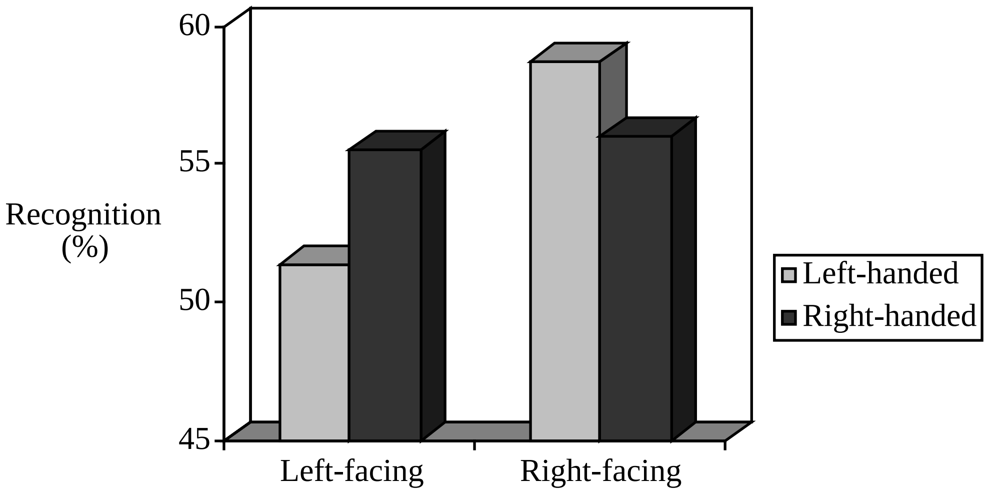

Figure 3. Contralateral handedness effect in recognition

abstract information, such as the length of time since the comet's last visit to Earth (about four thousand years).

The present findings suggest therefore that the assumption of homogeneity, which breaks down in the case of memory for orientation, continues to hold in the case of memory for more abstract information.

Heterogeneity for Memory or for Strategy?

Although overt responses concerning memory for information have been shown to differ for left-handed and right-handed populations, it is possible in principle that the underlying difference between these populations relates not to their memory processing but instead to their strategic behavior. That is, it is possible that left-handed and right-handed populations differ not in their likelihoods of retrieving information about orientation, but instead in their strategies of producing responses when memory fails. To investigate this possibility, the confidence with which responses are produced can be examined. If heterogeneity is confined to strategic behavior, then differences between populations should arise only for responses that are made with relatively low confidence. But if heterogeneity applies to memory itself, then differences should be observed in those responses which are made with high confidence.

Approximately equal numbers of left-handed and right-handed participants were tested ($N = 230$). Each participant was shown a sequence of 40 different black-and-white photographs for 3 sec each. In half of the photographs a person faced to the left of the viewer and in half a person faced to the right. Subsequently, each photograph was shown alongside its mirror image (reflected in a vertical plane) in a two-alternative forced-choice recognition task. In addition, for each recognition response the participant assigned a confidence level on a scale between 1 (guess) and 5 (certain).

Figure 3 shows the overall levels of recognition. There was a significant interaction between the effects of the direction in which the stimulus faced and the handedness of the participant, $F(1, 228) = 9.18$, $p < .01$. It can be seen that the effect was a contralateral one, in that left-facing stimuli were recognised better by right-handed than by left-handed participants, whereas right-facing stimuli were recognised better by left-handed than by right-handed participants.

To examine the possible influence of confidence, further analyses were carried out on the recognition responses that were made with the lowest level of confidence (1) and those made with the highest confidence (4 or 5). Confidence level was found to modify the two-way interaction, yielding a significant three-way interaction, $F(1, 174) = 4.19$, $p < .05$. Decomposing the three-way interaction, it was found that for those responses made with high confidence there was again a significant interaction between the effects of stimulus direction and of handedness, $F(1, 201) = 5.06$, $p < .05$. In contrast, for those responses made with low confidence, there was no significant interaction.

Thus it is in memory processing itself, rather than in strategic behavior, that the assumption of homogeneity appears to break down. Left-handed and right-handed populations differ in how they remember orientation, not in how they guess.

Origin of Population Effect for Memory

It is important to note that the results do not suggest that either left-handed or right-handed populations enjoy a general advantage in memory. Rather, the finding is one of contralaterality, in that left-handed people were more accurate than right-handed people when recalling right-facing stimuli, but less accurate when recalling left-facing stimuli. This zero-sum finding of contralaterality presents a problem for any theorists (e.g., Luh, Redl, & Levy, 1994; McKelvie & Aikins, 1993) who attempt to explain the influence of handedness upon cognition in terms of possible correlated differences in hemispheric specialization of function, because such a theory would predict that either left-handed or right-handed people should show a consistent advantage in performance.

In contrast, we have recently proposed (Martin & Jones, 1999) that the consistent differences among people in patterns of overt motor activity which categorise them as either left-handed or right-handed are accompanied by correlated differences in motor imagery. It is well established that extensive motor activation occurs in the cortex in the absence of physical movement (e.g., Decety, Grezes, Costes, Perani, Jeannerod, Procyk, Grassi, & Fazio, 1997; Jeannerod, 1994; Logie, 1995). Characteristic patterns of motor activation for left-handed people differ from those for right-handed people, partly in response to the asymmetric nature of the everyday environment (e.g., left-to-right writing). The present results suggest that, depending upon the precise details of a cognitive task, either left-handed or right-handed motor imagery may prove to be the more effective in assisting memory for orientation.

Conclusions

Outside of cognitive neuropsychology, it is often assumed that differences in cognitive activity between individuals may be adequately represented theoretically in terms of random variation around a central tendency. One exception to the implicit assumption of homogeneity within cognitive science has been characterised here. Subtle differences can be detected in the remembering of orientation by left-handed and right-handed populations. It remains to be investigated, however, how widespread is the occurrence of such heterogeneity.

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