Handedness and Memory for Tonal Pitch

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INTRODUCTION

There are certain well-known relationships between handedness and mode of brain organization. For instance, the large majority of right-handers have speech represented in the left cerebral hemisphere; however, of the left-handed population, about two-thirds have speech represented in the left hemisphere and about one-third in the right. Furthermore, whereas right-handers tend to show a clear-cut dominance of the left hemisphere for speech, a significant proportion of left-handers have some speech represented in both cerebral hemispheres. Therefore, left-handers as a group differ from right-handers, and are also more heterogeneous than right-handers, both in terms of direction of cerebral dominance and also in terms of degree of dominance (Goodglass & Quadfasel, 1954; Hécaen & de Ajureaguerra, 1964; Hécaen & Piercy, 1956; Hécaen & Sauget, 1971; Milner, Branch, & Rasmussen, 1966; Subirana, 1969; Zangwill, 1960).

Recently, interest has developed in the possibility that such neurological differences might be reflected in ability differences of various types. Thus, some investigators have argued for a relationship between left- or mixed- handedness and reading disability (Ginsburg & Hartwick, 1971; Satz & Sparrow, 1970; Shearer, 1968; Wold, 1968; Wussler & Barclay, 1970; Zurif & Carson, 1970; but see also Applebee, 1971; Hartlag & Green, 1971). Others have presented evidence that left-handers or mixed-handers perform more poorly than right-handers on visuospatial tasks (Levy, 1969; Miller, 1971; Silverman, Adevai, & McGough, 1966; but also see Newcombe & Ratliff, 1973). In both cases, explanations have been advanced in terms of a more bilateral representation of speech and related functions in the mixed or left-handed groups. The present study demonstrates that left-handers with mixed hand preference show enhanced performance on certain auditory tasks, and it is hypothesized that this superiority also reflects a bilateral representation of function. It is further suggested that some of the discrepancies in the literature may be due to the heterogeneity of the left-handed and mixed-handed groups; and that a four-way classification of handedness based on hand used in writing and on consistency of hand preference would produce more homogeneous results.

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EXPERIMENT 1

The first experiment was prompted by the observation that a group of subjects who had been selected for high performance on a pitch memory task contained an unexpectedly large proportion of left-handed writers. The experiment was therefore undertaken to determine whether left-handers and right-handers differ statistically in terms of their ability to make such pitch memory judgments.

The following task was employed. A test tone was presented followed by a sequence of six interpolated tones, and then by a second test tone. The test tones were either identical in pitch or they differed by a semitone, and subjects were instructed to judge whether they were the same or different. The tones were produced at equal amplitude by a Wavetek oscillator controlled by PDP-8 computer, and were recorded on tape. They were played to subjects through speakers on a high quality tape recorder. All tones were 200 msec in duration, and separated by 300-msec pauses, except that a 2-sec pause occurred between the last interpolated tone and the second test tone. The tones were sine waves, and their frequencies were taken from an equal-tempered scale (International Pitch; A = 435 Hz) ranging over an octave from Middle C (259 Hz) to the B above (488 Hz). The interpolated tones were chosen at random from this range, with the exception that no interpolated sequence contained repeated tones, or tones that were identical in pitch to either of the test tones. Twenty-four sequences were presented, and these were in two groups of 12, with 10-sec pauses between sequences within a group and 2-min pauses between the groups. Before the experiment began, the procedure was explained to the subjects and they were given four practice sequences.

The subjects were 76 right-handed and 53 left-handed university undergraduates. Handedness was assessed by the short form of the Edinburgh Handedness Inventory (Oldfield, 1971). *Right-handers* were defined as those with positive laterality quotients and *left-handers* as those with negative laterality quotients. In both handedness groups the ratio of male to female subjects was 1 to 1.3. The right-handers had had an average of 3.64 years of musical training (this included self-training and school choir) and the left-handers an average of 3.77 years.

The right-handed group produced an average error rate of 38.1%, and the left-handed group an error rate of 32.5%. Applying a median test, the difference between the two groups was found to be highly significant ($\chi^2 = 8.03$, $df = 1$, $p < .01$). No significant difference based on sex was obtained. Further, the variance in error rate for the left-handers was found to be significantly larger than for the right-handers ($p < .05$). Given this larger variance, it was hypothesized that a difference might emerge between people who were strongly left-handed and those with mixed hand preference, as individuals in this latter group would be expected to have more bilateral representation of function (Gillies, MacSweeney, & Zangwill, 1960; Hécaen & Sauget, 1971; Zangwill, 1960). So each handedness population was divided into two on the basis of strength of manual preference. Pure right-handers were defined as those with laterality quotients between + 60 and + 100, and mixed right-handers those with quotients between + 1 and + 59. Pure left-handers were defined as those with laterality quotients between –60 and –100, and mixed lefthanders with quotients between – 1 and – 59. Table 1 shows the average error rates in each of the four handedness categories. Applying a median test, an overall significant

Table 1
Error Rates for the Four Handedness Populations in Experiment 1.

Handedness category	*Percentage average error*
Pure right-handers ($N = 52$)	36.9
Mixed right-handers ($N = 24$)	41.0
Pure left-handers ($N = 30$)	35.3
Mixed left-handers ($N = 23$)	29.0

difference between these groups was obtained ($\chi^2 = 12.33$, $df = 3$, $p < .01$). Furthermore, the performance level of the mixed left-handers was significantly higher than that of any of the other three groups (mixed left-handers versus pure right-handers, ($\chi^2 = 10.02$, $df = 1$, $p < .01$; mixed left-handers versus mixed right-handers, $\chi^2 = 9.65$, $df = 1$, $p < .01$; mixed left-handers versus pure left-handers, $\chi^2 = 4.45$, $df = 1$, $p < .05$). The other groups did not differ significantly from each other. It was concluded that the type of brain organization characteristic of mixed left-handers is associated with enhanced levels of performance on this task.

EXPERIMENT 2

This experiment was undertaken to test the generality of the findings obtained in Experiment 1. A different pitch recognition task was used. Subjects were presented with a standard five-tone sequence, and then, after a pause, with a probe tone. They were required to judge whether or not a tone of the same pitch as the probe had been included in the sequence. On half of the sequences such a tone was included, and on the other half it was not. The included tones occurred an equal number of times at each of the first four serial positions of the sequence, and the pitches of these tones were strictly counterbalanced across serial position. As before, all tones were 200 msec in duration, and separated by 300-msec pauses, except that a 2-sec pause intervened before presentation of the probe tone. Forty-eight of these sequences were presented, in 4 groups of 12; and the experimental session was preceded by 8 practice sequences.

This experiment employed 74 right-handers and 30 left-handers. As it could be argued that equating for years of musical training is a rather arbitrary procedure, this time only subjects with three years or less of musical training were selected. The right-handers had had an average of 1.0 year of training, and the left-handers an average of 1.1 years. In both handedness groups the ratio of male to female subjects was 1 to 1.1.

The right-handers produced an average error rate of 41.5% and the left-handers a rate of 36.5%. This difference in performance was found to be statistically significant ($\chi^2 = 4.08$, $df = 1$, $p < .05$). As in the previous experiment, there was no significant effect of sex.

Table 2 shows the error rates in the four handedness populations, categorized as before. It was again found that the mixed left-handers significantly outperformed all other three groups (mixed left-handers versus pure right-handers, $p = .01$; mixed left-handers versus mixed right-handers, $p < .01$; mixed left-handers versus strong left-handers, $p < .05$, on Fisher Exact Probability tests).

Table 2
Error Rates for the Four Handedness Populations in Experiment 2.

Handedness category	*Percentage average error*
Pure right-handers ($N = 54$)	41.2
Mixed right-handers ($N = 20$)	42.2
Pure left-handers ($N = 22$)	39.5
Mixed left-handers ($N = 8$)	28.4

When we look at serial position functions, a further difference between the handedness populations emerges. Figure 1 A shows the percentage correct recognitions of the probe tone as a function of its serial position. This function is plotted separately for the mixed left-handers and for the two right-handed groups combined. (Pure left-handers were excluded from this analysis as there was no good rationale for combining them with either group.) It can be seen that the mixed left-handers produced the expected bow-shaped serial position curve, with lowest error rates at the earliest and latest positions, and highest error rates at the middle positions. Yet, the right-handers did not produce this function. It might be argued that the error rates for the right-handers were so high that this difference between the two groups could have been due simply to a ceiling effect. To examine this possibility, serial position functions were again plotted for these two groups, but taking only those subjects whose overall error rates did not exceed 33%. These comprised 6 mixed left-handers and 10 right-handers. As shown on Figure 1 B, both subgroups now produced the expected bow shaped curve; however the curve for the mixed left-handers was considerably steeper than that for the right-handers. They made fewer errors at the end positions, but more errors at the middle positions.

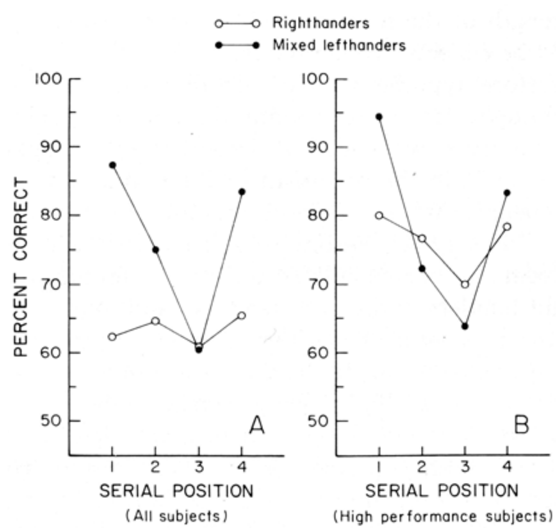

Figure 1. Percentage correct recognitions of the probe tone as a function of its serial position (Experiment 2). This function is plotted separately for the mixed left-handers and for the two right-handed groups combined.

A. Plot for all subjects.

B. Plot for those subjects whose overall error rates did not exceed 33%.

Although the overall difference between the slopes of the curves for these two subgroups did not reach statistical significance, these results strongly suggest that the substantial difference found overall was not due simply to a ceiling effect. However, a larger study on such selected subjects would have to be performed before we can establish this difference with confidence.

DISCUSSION

In this study, mixed left-handers have been found to outperform other handedness groups in making pitch recognition judgments, and this occurred for two different types of task. These findings suggest an explanation in terms of a duplication of storage of pitch information in the case of mixed left-handers. Assuming that the efficiency of storage and retrieval at one locus is identical for all handedness populations, then the retrieval of this information from two separate loci should significantly increase the overall probability of correct judgment. Such a duplication of storage could also produce an exaggeration in the slope of the serial position curve; for there should be a greater increase in the probability of correct judgment where the strength of the trace at each locus is greater, since such probabilities would be expected to cumulate.

We can therefore hypothesize that such duplication of storage occurs in parallel to the duplication of representation of speech functions in the two hemispheres. However, we cannot at present specify whether the pitch information is retained in the dominant or the nondominant hemisphere in the case of people where a more completely unilateral storage is hypothesized (Critchley & Henson, 1977; Deutsch, 1978; Milner, 1962).

As the performance of mixed left-handers was found to differ from that of mixed right-handers, pure left-handers, and pure right-handers, we should consider the way in which these handedness groups were defined. Subjects were asked to complete the short form of the Edinburgh Handedness Inventory (Oldfield, 1971). They were classified as right-handers if they obtained a positive laterality quotient, and as left-handers if they obtained a negative laterality quotient. Such a classification correlates highly with hand used in writing. Indeed, when the data were reanalyzed using this criterion alone, the same pattern of results was obtained, though slightly attenuated. The second basis for classification was consistency of hand preference.

Such a classification accords well with Annett's (1970) conclusions. She performed an association analysis of responses to a handedness questionnaire by university undergraduates. Although preferring to regard variations in hand usage as continuous rather than discrete, Annett concluded that the best criterion for differentiating handedness groups is that of hand used in writing (with the possible exception of hammering). She also concluded that the best criterion for distinguishing subgroups within the right-handed and left-handed populations is consistency of hand usage.

It is interesting that in both the present experiment and that of Annett the subjects had been taught to write within the last 25 years. This means that they would have been permitted to write in accordance with their spontaneous hand preference. However, subjects in earlier studies would have had pressure applied by their teachers to write with their right hand. This would also be true of older patient groups in more recent studies. The hand of writing reported in such studies, therefore, would not reflect basic hand preference in the same way as in experiments using recently educated subjects.

It remains to be determined to what extent the superiority of mixed left-handers found here generalizes to other musical memory tasks. However, the author has found that other left-handers, selected for experiments on the basis of high performance on pitch memory tasks, also did very well on further tasks involving musical memory, including transposition of melodic sequences. Such subjects might also be expected to perform unusually well on tests of memory for speech sounds.

In this context, an experiment by Byrne (1974) should be cited. He compared the performance of a group of pure right-handers with a group of mixed handers on a variant of the Seashore tone memory test, and found no difference between the groups. Using the short form of the Edinburgh Handedness Inventory, he defined right-handers as those with laterality quotients of over + 50, and mixed handers as those with laterality quotients between ± 50, inclusive. Pure left-handers were excluded from this study. However, this classification combines mixed right-handers and mixed left-handers into a single group, so the lack of effect found by Byrne is not surprising. Had these two groups been combined in the present study, no significant differences would have emerged either. Furthermore, if Byrne's mixed-handers had been sampled at random, we would expect the mixed right-handers to form the majority of this group (Oldfield, 1971).

The present findings also raise the issue of a possible overrepresentation of mixed left-handers among musicians as compared to other occupational groups. Oldfield (1969) used the long form of the Edinburgh Handedness Inventory to compare the handedness distribution of members of a school of music with that of a group of psychology undergraduates, and found no differences. He considered this interesting, as most musical instruments are designed for right-handed use, and so are relatively cumbersome for left-handers to manipulate. Thus, left-handed violinists and guitarists sometimes "remake" their instruments so that they can be played in reverse. One famous example here is Charlie Chaplin, who shifted the bar and soundpost and restrung his violin for that purpose (Chaplin, 1964). With other instruments such as the piano, such remaking is not practicable. (The case of the violin is rather interesting, because when played in the normal "right-handed" manner, the left hand actually does the more intricate work; however, the right hand produces the sound by bowing. So what seems to be important is which hand is the "executor.") At all events, the design of most musical instruments is such as to place left-handers at a disadvantage.

In the more recent study by Byrne (1974) cited above, the short form of the Edinburgh Handedness Inventory was administered to a group of students in a music conservatory, and also to a group of unselected university students. Byrne then computed the proportions of pure right-handers and of mixed handers in these two groups, and found that the mixed handers were significantly overrepresented among the musicians. Unfortunately, we cannot tell from this study how much this overrepresentation was due to mixed right-handers and how much to mixed left-handers. A study is currently underway to examine this issue further.

The present finding of handedness differences in the retention of pitch information follows on several earlier studies demonstrating differences at the perceptual level in the processing of tonal sequences (Deutsch, 1974; 1975a, 1975b). It would appear that there are substantial variations between handedness populations in the way music is processed.

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