Hemispheric differences in a letter classification task*

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The experiment examined hemispheric differences in same-different judgments for unilaterally presented letter pairs which could be classified as "same" on the basis of name identity (NI, e.g., Aa) or physical identity (PI, e.g., AA). Two groups of Ss were tested, a right-handed group and a predominantly left-handed group. The experiment employed a reaction time measure, and fixed the duration of brief exposures to yield an overall performance level of 90% correct. Analysis of the results focused on the difference between RTs for the NI matches and for the PI matches in each hemisphere. The method allowed differences in cognitive processing to be assessed while sensory and response factors were minimized. The right-handed group all showed a smaller mean NI-PI difference in the left hemisphere (84 msec) than in the right hemisphere (181 msec). The left-handed group showed smaller and less consistent differences, but the group as a whole had a reversed asymmetry, with a mean NI-PI difference of 128 msec in the left hemisphere and 90 msec in the right hemisphere.

Laterality differences have repeatedly been demonstrated in the visual perception of verbal, as opposed to nonverbal, stimuli. In many studies, attentional set and directional scanning tendencies derived from reading habits have contributed to the effect, but it is generally agreed that the differences are at least partly attributable to the functional specialization of the hemispheres for linguistic and visuo-spatial processing (White, 1969). Even so, the methods used lack precision since stimuli characterized by the E as "verbal" or as "nonverbal" may not be processed as such. Ss are notoriously ingenious at labeling the most abstract patterns, and conversely, linguistic stimuli such as words and letters may sometimes be treated as physical configurations.

The present experiment utilizes a method introduced by Posner and Mitchell (1967) in a letter classification task. They demonstrated that letter pairs like AA could be classified as "same" about 70 msec faster than pairs like Aa, that is, matching based on comparison of physical shapes was faster than matching based on comparison of names. Their finding, which has proved extremely stable and repeatable, provides a tool for separating and comparing physical analysis (a visuospatial type of processing) and nominal analysis (a simple type of linguistic processing) within an experimental framework employing only a single kind of stimulus, letters.

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This method can therefore be combined with unilateral presentation of the letter pairs to study the relative speed and accuracy of each hemisphere for the name identity (NI) matches and for the physical identity (PI) matches. Previous research, extensively reviewed by White (1969) gives rise to the following predictions for right-handed Ss.

The dominant hemisphere should yield superior performance for NI matches, since when these are presented to the minor hemisphere they are either transferred across the corpus callosum for analysis in the major hemisphere, with subsequent loss of time and possibly of information, or handled by a more primitive and unpracticed linguistic system.

There is some evidence to suggest minor hemispheric superiority for visuo-spatial processing (Buffery, in press; Kimura, 1963). Lateralization of this function would produce superior performance for PI matches presented directly to the minor hemisphere. The combined effect of such a crossed asymmetry of function would be a smaller NI-PI difference in the major hemisphere (NI scores being relatively reduced and PI scores elevated), and conversely, a larger NI-PI difference in the minor hemisphere.

Comparison of the performance of groups of left-handed and right-handed Ss in this task was also expected to provide some information about the extent to which asymmetry of either the verbal or visuo-spatial functions is present, absent, or reversed in sinistrals. Miller (1971) and Levy (1969) have suggested that left-handers may possess bilateral language representation at the expense

of a specialized visuospatial function in the minor hemisphere. They found left-handers equalled right-handers at verbal IQ tests, but were significantly poorer at visuo-spatial tests. If their view is correct, the sinistral group should show little or no difference in NI scores between the hemispheres, but be relatively poorer at PI matches. If, on the other hand, left-handers have unilateral language representation which may be either ipsilateral or contralateral to the preferred hand (Zangwill, 1960), then NI scores for individual Ss should show hemispheric differences, although the direction of asymmetry may vary within the group.

METHOD

Stimulus Materials

The stimuli were pairs of letters which were printed on 6 x 4 in. plain white cards with Letraset, 24-pt Folio Light, Bauer. The letters were placed one above the other to eliminate horizontal scanning effects. The total set of 240 letter pairs was divided equally: on one-third of the stimulus cards, the pair was central; on one-third, it appeared 3 deg of visual angle to the left of the fixation point; and on one-third of the cards, it appeared 3 deg right of fixation. A distance of 3 deg was selected as being far enough off center to be nonfoveal, without being so far as to fall in an area of insufficient visual acuity. The three positions were randomly interspersed throughout the series in order to prevent the formation of expectancies which could bias attention, or give rise to anticipatory eye movements. Half of all the letter pairs were different, and half were same. The same pairs were subdivided into PI pairs (like AA or aa) and NI pairs (like Aa or aA). The different pairs could be either both uppercase (AB), both lowercase (ab), or mixed (Ab, aB), so that case could not be used as a classification cue. Nine types of letter pairs resulted: in the center, CNI, CPI, and CD; in the left visual field, LNI, LPI, and LD; and in the right visual field, RNI, RPI, and RD. All these were mixed randomly throughout the whole series.

The letters selected as stimuli were A B D E G H R T N Q. All these letters appeared equally often in all types of pairs. None of these letters form what Posner (1969) has called analog pairs, in which the uppercase and lowercase versions are physically similar, so that NI pairs could never be matched by physical cues.

Procedure

The stimuli were presented in a three-field tachistoscope by Electronic Developments, Ltd. A plain white preexposure field (duration, 500 msec;

illumination level, 1.1 log fL) with a small central fixation point was followed by the stimulus field (illumination level, .8 log fL). A plain white postexposure field, also .8 log fL, was present for 1 sec, and there was a dark interval between trials.

The stimuli were viewed monocularly with the preferred eye, since there is some evidence that with binocular viewing laterality effects can be accounted for by a combination of eye dominance and the superiority of the crossed optic pathway (Hayashi & Bryden, 1967). The nonpreferred eye was occluded with a commercial eyepatch.

Pilot work for this experiment had been carried out using a verbal response and an accuracy measure. The exposure durations were adjusted to yield a 75% correct level of performance, and the percentage of correct responses was scored for each type of letter pair within each hemisphere. This method showed some trend toward a smaller NI-PI difference in the major hemisphere, but was discarded as being insufficiently sensitive. It seemed possible that the extent of the NI-PI difference in the minor hemisphere was being obscured by requiring a verbal response. If name matches are handicapped because the stimuli must be transmitted across the corpus callosum before nominal analysis can take place, this disadvantage could be partially cancelled out because the verbal response can be emitted directly by the hemisphere in which the analysis is performed. Physical matches can be carried out in the minor hemisphere, but the result must then be transferred to the other hemisphere before it can be signaled. Thus hemisphere-of-output and hemisphere-of-analysis effects are confounded. And, although the output effects would be primarily on speed of response, some reduction in accuracy might also result. Accordingly, the design finally adopted employed a keypress response and a latency measure.

The E initiated the trial after a verbal warning signal. The S sat with his hands resting lightly on the response keys, which were labeled "same" and "different." Right-handed Ss had the "same" key allocated to the right hand, and the "different" key to the left hand. Left-handed Ss had the opposite arrangement. The keypress required a gross whole-hand movement, and there is evidence that such movements can be mediated by either hemisphere. [Filbey and Gazzaniga (1969) found that RT differences between hemispheres disappeared when a manual response

was substituted for a verbal one.]

The exposure duration of the stimulus was fixed individually for each S at the first session. The aim was to find the duration which would yield a performance of about 90% correct over all types of trial. A rough and ready titration technique was employed. Exposure duration was initially set at 10 msec and reduced as performance improved with practice. Duration was then adjusted in ascending and descending steps until the required proportion of two errors in 20 trials was obtained in two consecutive 20-trial series. The exposure durations thus selected ranged from 3.75 msec to 6 msec. Durations of this order are clearly far too short to allow eye movements.

The Ss were instructed to classify the letter pairs as "same" if the letters had the same name, and "different" if they did not, and to press the appropriate key as fast as possible while trying to avoid errors. The onset of the stimulus field triggered an Advance timer which was stopped by the keypress response. Error incidence and reaction times were noted, and the S was informed of both after each trial. Error trials were replaced later in the series, the number of trials intervening being sufficient to ensure that the S was not aware of the replacement. Ss were instructed to fixate the central dot, and were reminded at intervals throughout the experiment to maintain fixation.

Subjects

The Ss were university and preuniversity students of both sexes, without previous experience of this kind of experiment. All Ss completed a handedness questionnaire, the Edinburgh Handedness Inventory. This queried hand preference for 10 common tasks, such as writing, striking a match, etc., and also foot and eye preference. Six Ss were fully right-handed for all tasks, with right eye preference. Six Ss were predominantly left-handed (the only inconsistencies were in use of eating implements), and left-eyed. None of these Ss had a uniformly left-handed family history; they represent individuals with a strong left-hand preference rather than the infrequently encountered "pure" left-handers.

They were paid for their services. Each attended for four sessions. The first session was devoted to practice and to titrating the exposure duration. Several Ss were discarded from each group during this preliminary testing because they were unable to reach the 90% correct level of performance, even with exposure durations two or three times as long as those fixed for the

other Ss. The subsequent sessions tested at the rate of 80 trials per session. The task was found to be fatiguing, and longer sessions were impracticable.

RESULTS

The results are set out by pair types in Table 1. The most relevant aspect of these results is the NI-PI difference; that is, the magnitude of the difference in RTs for name matching and for physical matching within each hemisphere. Hemispheric asymmetry of *cognitive* function is more likely to be revealed by comparison of the magnitude of the NI-PI difference in the left and in the right hemispheres. A direct comparison of, for example, name match scores between hemispheres might reveal differences arising from unequal visual acuity in the two half fields. By focusing on the relationship between NI and PI scores within each hemisphere, sensory and response asymmetries are minimized and the asymmetry of cognitive function is pinpointed.

All of the right-handed Ss show a larger NI-PI difference in the right hemisphere. Four out of six left-handers show the reverse effect, a larger NI-PI difference in the left hemisphere. SS M.W. and G.S. have small differences in the other direction.

Wilcoxon matched-pairs signed-ranks tests were carried out to compare the NI-PI difference in each hemisphere. For the right-handed group, the NI-PI difference is greater in the right hemisphere, and this difference is significant at $p < .025$. For the left-handed group the NI-PI difference does not vary significantly between the hemispheres.

Two three-way analyses of variance were performed, one for each group of Ss. The factors were Ss by Type of Processing (name match/physical match) by Visual Field (RVF/LVF). In the right-handed group, the interaction of Type of Processing by Visual Field was significant, $F(1,5) = 11.17$, $p < .025$. Subsequent Newman-Keuls tests showed that mean reaction time for RNI was significantly faster than LNI, and that LPI was faster than RPI; i.e., name matches are faster in the left hemisphere, while physical matches are faster in the right. The analysis of variance for the left-handed group did not produce a significant interaction of Type of Processing by Visual Field, so that a posteriori tests were not performed.

Although a smaller number of errors occurred for the centrally projected letter pairs, the numbers of errors occurring in the left and in the right visual fields was almost exactly equal (RNI = 52, LNI = 53; RPI = 25,

Table 1
Mean RTs in Milliseconds for Group 1 and Group 2

S	ED	RVF			LVF			CVF			NI-PI Difference		
		RNI	RPI	RD	LNI	LPI	LD	CNI	CPI	CD	RVF*	LVF†	C
Group 1: Right-Handed Ss													
TE	3.75	1013	982	1057	1161	930	996	1039	895	960	31	231	144
SH	3.75	879	818	931	879	712	884	677	553	684	61	167	124
VC	4.0	895	756	891	888	640	1142	782	562	957	139	248	220
AD	4.0	665	583	727	644	572	739	573	547	696	72	82	26
PH	5.50	1213	1073	1247	1227	1005	1211	950	930	1247	140	222	20
RL	6.0	816	750	1029	935	799	978	836	781	943	66	136	55
$\bar{X}$		913	827	980	955	776	991	809	711	875	84	181	102
Group 2: Left-Handed Ss													
DP	5.50	959	830	951	869	851	996	952	759	957	129	18	193
RR	4.0	1053	883	1141	1143	998	1048	1130	940	1131	170	145	190
MW	4.0	626	567	573	558	492	555	555	505	538	59	66	50
GS	6.0	808	761	778	874	798	844	738	687	798	47	76	51
AB	5.0	633	580	688	705	665	654	619	521	660	53	40	98
SH	4.0	1015	705	717	949	749	841	771	660	788	310	200	111
$\bar{X}$		849	721	808	849	758	823	794	678	812	128	90	115

*Left hemisphere; †right hemisphere

LPI = 23), so that differences in RTs between the visual fields cannot be attributed to a difference in the speed-error tradeoffs.

DISCUSSION

The results confirm the predicted hemispheric asymmetry in the right-handed group. The task which requires verbal labeling of the stimuli is better performed when the letters are projected directly to the major hemisphere. The minor hemisphere is superior for physical analysis. This crossed asymmetry produces the smaller NI-PI difference in the left hemisphere. There are two possible explanations for these findings.

Unilateral Representation

If the linguistic and the visuo-spatial functions are completely lateralized, the difference in reaction time is attributable to the extra time required to transmit the stimulus across the corpus callosum for processing in the appropriate hemisphere. Estimates of transcallosal transmission time are usually of the order of .5 to 10 msec (Moscovitch & Catlin, 1970), but larger differences in reaction time would result if the signal required a train of impulses rather than a single one, or if information was lost in transit so that the analysis was rendered more difficult. The use of brief exposures with consequent reduction of information probably has the effect of sharpening the differences in decision time. The increase in reaction time caused by transcallosal transmission would be enhanced if further information loss occurs along the pathway making the decision more difficult.

Bilateral But Unequal Representation

It is also possible that all stimuli are

processed directly in the hemisphere to which they are projected, and that differences are attributable to a degree of lateralization rather than absolute specialization of function. Gazzaniga's (1970) results with split-brain patients suggest that the right hemisphere, though mute, can comprehend simple verbal stimuli and make nonverbal responses. Evidence from lesions suggests that visuo-spatial processing is not completely absent in the left hemisphere, but that the right hemisphere "plays a proportionately greater role [Milner, 1962]." It is quite possible, therefore, that letters can be name-matched in the right hemisphere, although more slowly and less accurately, and similarly that physical matches can be carried out in the left hemisphere although with suboptimal performance. The results do not allow the inference that transcallosal transmission is essential. And, of course, it is perfectly plausible that the verbal function and the visuo-spatial function are differently organized, so that the unilateral representation explanation applies to one and the bilateral but unequal explanation applies to the other.

Confidence in the integrity of the findings of these experiments is increased by consideration of two further points from the data. The uniformly lower scores for the foveally projected stimuli provide a check that fixation was in fact maintained, and the interaction of hemisphere with type of processing provides evidence that the results are not due to hemisphere-hand connections. Since "same" responses are always made with the dominant hand, an overall superiority of the dominant hemisphere would be expected if response effects were crucial. Similarly, the results cannot be due to hemisphere-eye connections, since the

superiority of the crossed optic pathway would produce a consistent advantage for the nasal hemiretina.

In the left-handed group, the NI-PI difference shows smaller and less consistent variation between hemispheres. The results can be interpreted as showing that some Ss have a functional lateralization similar to that of the right-handers, but in the opposite direction, while others have equal bilateral representation. There is no evidence to support the hypothesis that bilateral representation of language is achieved at the expense of visuo-spatial abilities in left-handers. The left-handers have shorter latencies for all categories of stimulus. The superiority of their physical match scores is more marked in the left hemisphere than in the right. While the mean PI latency for right-handers is shorter in the right hemisphere, for left-handers it is shorter in the left. So that while there is some indication of a reversed lateralization of the visuo-spatial function, there is no hint of an overall deficit.

The scores for the "different" responses are not easy to interpret. Since the "different" letter pairs must be named before they can be classified as different, a superiority of the dominant hemisphere, as in the NI matches, would be predicted. Table 1 shows that only 4 of the 12 Ss have shorter "different" RTs in the same hemisphere as they have shorter NI RTs. Semmes (1968) suggested that the right hemisphere might be specialized for judgments of dissimilarity and the left for judgments of similarity. A mechanism of this kind might underlie the conflicting results for the "different" responses.

The main interest of these experiments lies in the fact that they confirm a hemispheric difference of cognitive function and its connection

with handedness. Whereas previous studies related hemispheric differences to the type of stimulus presented, the differences are here related directly to the type of processing required.

REFERENCES

- BUFFERY, A. W. H. Asymmetrical lateralisation of human cerebral functions. In M. Kinsbourne (Ed.), *Hemispheric asymmetry of function*, London: Tavistock, in press.
- FILBEY, R. A., & GAZZANIGA, M. S. Splitting the normal brain with reaction time. *Psychonomic Science*, 1969, 17, 335-336.
- GAZZANIGA, M. S. *The bisected brain*. New York: Appleton-Century-Crofts, 1970.
- HAYASHI, T., & BRYDEN, M. P. Ocular dominance and perceptual asymmetry. *Perceptual & Motor Skills*, 1967, 25, 605-612.
- KIMURA, D. Right temporal lobe damage. *Archives of Neurology*, 1963, 8, 264-271.
- LEVY, J. Possible basis for the evolution of lateral specialisation of the human brain. *Nature*, 1969, 224, 614-615.
- MILLER, E. Handedness and the pattern of human ability. *British Journal of Psychology*, 1971, 62, 111-112.
- MILNER, B. Laterality effects in audition. In B. B. Mountcastle (Ed.), *Interhemispheric relations and cerebral dominance*. Baltimore: The Johns Hopkins Press, 1962.
- MOSCOVITCH, M., & CATLIN, J. Interhemispheric transmission of information in normal man. *Psychonomic Science*, 1970, 18, 211-212.
- POSNER, M. I. Abstraction and the process of recognition. In G. Bower and K. Spence (Eds.), *Psychology of learning and motivation*. Vol. 3. New York: Academic Press, 1969.
- POSNER, M. I., & MITCHELL, R. F. A chronometric analysis of classification. *Psychological Review*, 1967, 74, 392-409.
- SEMMES, J. Hemispheric specialisation: A possible cue to mechanism. *Neuropsychologia*, 1968, 6, 11-26.
- WHITE, M. J. Laterality differences in perception: A review. *Psychological Bulletin*, 1969, 72, 387-405.
- ZANGWILL, O. L. *Cerebral dominance and its relation to psychological function*. Edinburgh: Oliver & Boyd, 1960.

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