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Hemispheric Asymmetries in a Letter Classification Task with Different Typefaces

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Two experiments used M. I. Posner's (1969, in G. Bower & K. Spence, Eds., *Psychology of Learning and Motivation*, New York: Academic Press, Vol. 3) paradigm to investigate hemispheric asymmetries in coding. In Experiment I the stimuli were print-like letters and produced name matches faster in the left than in the right hemisphere, while for physical matches there was no lateral asymmetry. In Experiment II the stimuli were script-like letters and showed the expected opposite lateral asymmetries for name matches (faster in the left hemisphere) and physical matches (faster in the right hemisphere), although in the latter case the effect was less clear. In both experiments, different responses showed no hemispheric asymmetries. These two experiments cast some doubts on the widely accepted role of linguistic and visuospatial processing in determining hemispheric asymmetries for name and physical matches.

Posner and his colleagues (see for a review Posner, 1969) have shown that in "same–different" reaction time (RT) tasks, pairs of letters which are physically identical (e.g., AA) can be classified as "same" about 70 msec faster than when they have the same name but are printed in different cases (e.g., Aa). This finding suggests that the task of matching single letters can be performed either on the basis of physical cues (i.e., a visuospatial type of processing) or on the basis of the letter name (i.e., a linguistic type of processing). During recent years a considerable amount of evidence has been accumulated on the difference in function of the two cerebral hemispheres in right-handed subjects. A general right-hemisphere superiority for visuospatial processing has been shown, while the left hemisphere prevails when stimuli lend themselves to a linguistic type of processing (see, e.g., reviews in Milner, 1971, 1974). Accordingly, opposite laterality differences have been repeatedly demonstrated in the

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visual perception of verbal and nonverbal stimuli. Experiments using visually presented stimuli have shown that the perception of sensory material that can be encoded in words is superior in the right visual field, which has direct neural connections with the left hemisphere; on the other hand, the perception of sensory material with complex spatial attributes is superior in the left visual field, which has direct neural connections with the right hemisphere (see, e.g., Milner, 1971; Kimura, 1973; Berlucchi, 1974).

Thus, the method of unilateral presentation of letter pairs to study the relative speed of the two hemispheres in performing a "same–different" task yields the two following predictions. Mean RTs for name identity (NI) matches (e.g., Aa) should be faster in the right than in the left visual field, while mean RTs for physical identity (PI) matches (e.g., AA) should be faster in the left than in the right visual field. The difference between NI and PI matches, shown by Posner, should be smaller in the right visual field than in the left, owing to relatively reduced RTs for NI matches and relatively increased RTs for PI matches.

The results of previous studies (Cohen, 1972; Geffen, Bradshaw, & Nettleton, 1972; Davis & Schmidt, 1973) which have used Posner's paradigm to investigate hemispheric differences in coding are substantially consistent with these predictions. However, in the paper by Cohen (1972) only three of six subjects showed faster NI matches in the right visual field than in the left, while five of six subjects showed the predicted advantage of the left visual field over the right in the case of PI matches. The study by Davis and Schmidt (1973) failed to find a significant overall advantage of PI matches over NI matches, that is, they could not show the effect whose differences in the two hemispheres they intended to study. In these three studies, the results of "different" responses are very difficult to interpret. Clearly, the "different" letter pairs must be named before they can be correctly classified, and thus a superiority of the left hemisphere, as in the case of NI matches, would be predicted. However, Cohen (1972), Geffen et al. (1972) in their mixed condition, and Davis and Schmidt (1973) found a more or less clear effect in the opposite direction.

Shankweiler and Studdert-Kennedy (1967) and Darwin (1971) using a dichotic listening technique have shown that the left hemisphere is better at processing the phonemic information carried by stop consonants, whereas vowels do not show clear-cut hemispheric asymmetries and other types of consonants yield intermediate results. Thus, if the NI matches and "different" responses are performed on the acoustic transforms of the stimuli, the advantage of the left hemisphere for these letter pairs should be augmented by the use of letters which are differentiated, when pronounced, only by stop consonant sounds. The stimuli employed in the three above-mentioned studies were mixed from this point of view: A, B, D, E, G, H, R, T, N, and Q for Cohen (1972), A, E, M, and R for Geffen et al. (1972); A and B for Davis and Schmidt (1973).

Bryden and Allard (1976) have demonstrated that the left-hemisphere superiority normally obtained for the identification of tachistoscopically presented single letters (e.g., Bryden, 1965; Zurif & Bryden, 1969, Rizzolatti, Umiltà, & Berlucchi, 1971) depends on the physical structure of the stimuli. In fact, while the majority of typefaces, including those most commonly used in experiments, yield the expected right-visual-field superiority, other typefaces, mainly script-like material, show left-field superiorities. According to Bryden and Allard (1976) the identification of script-like letters requires more visuospatial preprocessing than that of print-like letters, hence the right-hemisphere superiority.

In the case of Posner's paradigm with lateralized visual stimuli, the use of script-like typefaces might not modify the advantage of the left hemisphere for NI matches and "different" responses, since in any case the task should be performed on the name of the letters. On the other hand, when the task makes high demands on visuospatial analyzing mechanisms, as should be the case for script-like letters, one might expect a more clear-cut advantage of the right hemisphere for PI matches. A more extreme point of view could maintain that, in the case of script-like material, the preponderance of the initial stage of visuospatial preprocessing over the successive stage of naming should yield an overall advantage for the right hemisphere in the case of both PI matches and NI matches (and also in the case of "different" responses).

EXPERIMENT I

In this experiment the subjects performed a "same–different" letter classification task with pairs of print-like letters which either were physically identical or shared the same name but were printed in different cases.

Materials and Methods

The stimulus set comprised the six stop consonants of the Italian alphabet.

Stimulus material. The stimuli were pairs of letters which were printed on plain white cards. The style chosen was Gill extra bold (RP Series of R41) which according to Bryden and Allard (1976) yields a right-field advantage (see Fig. 1). Photographic negatives (35 mm) of each pattern were mounted in slide holders for tachistoscopic projection on a back-projection screen. The letters were placed one above the other to eliminate horizontal scanning effects (Bryden, 1966). One-third of the pairs consisted of different letters and two-thirds consisted of the same letter. Half of the same pairs were PI pairs (like BB or bb) and half were NI pairs (like Bb or bB). The different pairs could be both upper case (BT), both lower case (bt), or mixed (bT, Bt), so that case could not be used as a classification cue. The letters chosen as stimuli were B, C, D, G, P, and T. All these letters are stop consonants, either voiced (B, D, and G) or unvoiced (C, P, and T), and appeared equally often in all types of pairs. Two of them (i.e., C and G) in Italian are not always spoken with a stop. However, in Italian elementary schools children are usually taught to pronounce C and G as stop sounds. Furthermore, in this experiment the instructions stressed the importance for the subjects to pronounce every consonant as a stop with the same "ee" vowel sound. It must be also noted that C, P, and T might form what Posner (1969) has called analog pairs, in which the upper- and lower-case representations are physically very similar.

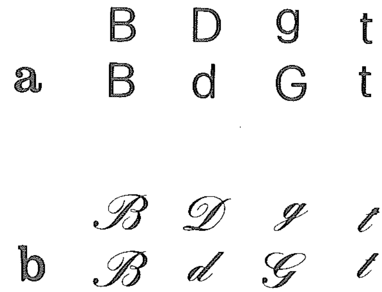

FIG. 1. Examples of letter pairs (same) for print-like (a) and script-like (b) material.

Subjects. Twelve students of the University of Padua (six males and six females) took part in the experiment. All subjects completed the Edinburgh Handedness Inventory (Oldfield, 1971) that showed that they were fully right-handed, with right eye preference.

Procedure. The subjects maintained a constant head position by leaning their foreheads against a headrest and placing their chins on a chin rest. They faced a translucent screen located at a distance of 50 cm. An acoustic signal (400 Hz for 1 sec) prompted the subjects to fixate a clearly marked central point of the screen and one of the experimenters monitored subjects' fixation by looking at the subjects' eyes in a mirror. With this technique a deflection of less than 1° of visual angle was reliably detected. One second after the warning signal a slide was back-projected for 100 msec on the screen, on a level with, and either to the right or left of, the central fixation point. The interval between presentations was 5 sec. The stimuli extended from approximately 8.50 to 9.74° of visual angle from fixation and the angular separation between the fixation point and the center point between the two letters was approximately 9.12°. The task was to judge whether the letters in a pair were the same or different by pressing one of two keys on the response panel using the index and middle fingers. Half of the subjects used their right hand, the other half their left hand. Pressing the key stopped an electronic millisecond counter that was started at the beginning of the 100-msec exposure period. The subjects were instructed to respond "same" if the letters had the same name or the same shape and to respond "different" if the letters did not share the same name. They were also instructed to press the appropriate key as fast as possible while trying to avoid errors, but were not given any feedback about speed or accuracy. The stimuli were white drawings on a dark background. The stimulus intensity was 2.5 foot-lamberts while the luminances of ambient light and fixation field were 0.16 and 0.32 foot-lamberts, respectively. The fixation point was a red spot with a diameter of approximately 0.23° of visual angle drawn with a felt pen on the geometric center of the screen. Each letter was not higher than 1.53° and not larger than 1.25°; the spacing between the two letters of a pair subtended 1.14° of visual angle. Half of the subjects (three males and three females) used the index finger for "same" responses and the middle finger for "different" responses, and half used the reverse arrangement.

Formal testing began after informal practice trials during which the subjects became acquainted with the experimental situation, while learning to fixate the central point of the screen and to press the correct key in response to "same" and "different" pairs. Each subject was tested during one session which lasted about 50 min. Each session consisted of 288 trials, divided into four blocks of 72 trials separated by a 5-min rest period. One-third of the trials required "different" responses and two-thirds "same" responses. Of the "same" responses, half were to PI matches and half to NI matches. The four blocks of trials were presented to the right visual field and to the left according to ABBA and BAAB sequences counterbalanced across subjects. If a subject made an error, or the response latency exceeded an arbitrary limit of 2 sec, or if a lateral eye movement was observed during a trial, then these trials were discarded but not replaced. The occurrence of eye movements and RTs longer than 2 sec was very rare (about 0.6% of the trials in the whole experiment) and evenly distributed between the two visual fields.

Results

A summary of mean RTs for each subject and of all subjects together is given in Table 1. A three-way within-subjects analysis of variance was carried out on mean correct RTs for "same" responses only. The three factors were visual field (either right or left), type of matching (either PI matches or NI matches), and type of letter (i.e., B, C, D, G, P and T). The type of matching and type of letter main effects were significant: $F\ (1,11) = 75.59, p < .001$ and $F\ (5.55) = 11.28, p < .001$. RTs for PI matches were 119.3 msec faster than for NI matches (614.9 vs. 734.2 msec). Mean correct RTs for "same" responses varied according to what letter was presented: 709.7 msec for B, 627.5 msec for C, 702.1 msec for D, 752.8 msec for G, 679.1 msec for P, and 575.6 msec for T. The visual field × type of matching interaction was significant: $F\ (1,11) = 5.55, p < .05$. The advantage of PI matches over NI matches depends on the field of stimulation. In the right visual field PI matches are 92.9 msec faster than NI matches (621.6 vs. 714.5 msec), while in the left visual field this difference is much larger, that is, 145.8 msec (608.2 vs. 754.0 msec). This result can also be stated in the following way: PI matches are 13.4 msec faster in the left field than in the

TABLE 1
REACTION TIMES (msec) ACROSS THE TWO VISUAL FIELDS AND UNDER THE THREE RESPONSE CONDITIONS, WHERE LETTERS IN A PAIR WERE PHYSICALLY IDENTICAL, HAD ONLY THE SAME NAME, OR WERE DIFFERENT (PRINT-LIKE MATERIAL)

	PI matches[a]		NI matches		NI–PI difference		Different	
	RVF	LVF	RVF	LVF	RVF	LVF	RVF	LVF
S1	651	647	754	794	103	147	826	920
S2	534	586	656	679	122	93	638	691
S3	498	513	603	629	105	116	690	665
S4	793	660	1007	932	214	272	947	984
S5	546	559	668	678	122	119	770	571
S6	805	912	899	908	94	−4	940	956
S7	558	515	584	616	26	101	631	641
S8	440	443	564	597	124	154	597	610
S9	820	788	864	993	44	205	913	891
S10	567	560	619	730	52	170	734	786
S11	664	602	693	796	29	194	734	822
S12	583	514	663	696	80	182	804	744
$\bar{X}$	621.6	608.2	714.5	754.0	92.9	145.8	768.7	788.4

[a] PI, Physical identity; NI, name identity; RVF, right visual field; LVF, left visual field.

right (608.2 vs. 621.6 msec), while NI matches are 39.5 msec faster in the right field than in the left (714.5 vs. 754.0 msec). Eleven of the twelve subjects responded more quickly to right-field stimuli in the NI condition; conversely 7 of 12 subjects have faster mean RTs for PI matches in the left visual field. The type of matching × type of letter interaction was also significant: $F(5.55) = 3.62, p < .01$. The advantage of PI matches over NI matches depends on the type of letter: 194.4 msec (612.5 vs. 806.9 msec) for B, 67.1 msec (594.0 vs. 661.1 msec) for C, 140.6 msec (631.8 vs. 772.4 msec) for D, 141.4 msec (688.1 vs. 829.5 msec) for G, 81.7 msec (638.2 vs. 719.9 msec) for P, and 90.4 msec (530.4 vs. 620.8 msec) for T.

A two-way within-subjects analysis of variance was carried out on mean correct RTs for "same" and "different" responses. The two factors were visual field (either right or left) and type of response (either "same" or "different"). Only one source of variability attained statistical significance, that is, the type of response main effect: $F(1,11) = 74.42, p < .001$. "Same" responses are 103.6 msec faster than "different" responses (674.9 vs. 778.5 msec).

Similar analyses of variance performed on the number of errors yielded no significant results. The overall error rate in the experiment was 3.8%.

"Different" responses tend to be faster in the right than in the left visual field, the difference being 19.7 msec (768.7 vs. 788.4 msec). However only 7 of 12 subjects behaved in this way and the trend did not attain statistical significance with a t test for correlated means.

EXPERIMENT II

The second experiment was similar to the previous one, but examined script-like material instead of print-like material.

Materials and Methods

Stimulus material. The stimuli were photographic negatives of pairs of letters printed on plain white cards. The style chosen was Palace script (SK series of R41) which according to Bryden and Allard (1976) yields a left-field advantage (see Fig. 1). The letter stimuli were again the six stop consonants: B, C, D, G, P, and T. Each letter was not higher than 1.48° and not wider than 1.36°, and the spacing between them subtended 0.91° of visual angle. The stimuli extended from approximately 8.44 to 9.80° from fixation and the angular separation between the fixation point and the center point between the two letters was approximately 9.12°. Also in this experiment the subjects were instructed to pronounce every consonant as a stop with the same "ee" vowel sound. It must be noted that in this case analog pairs were absent.

Subjects. This time there were eight right-handed subjects (four males and four females), selected in the same way as before.

Procedure. The experimental procedures were similar to those of the previous study. In this case, however, several subjects were discarded during preliminary trials because they were unable to reach a 85% correct level of performance. Also in this case the occurrence of eye movements and RTs longer than 2 sec was very rare (about 0.9% of the trials in the whole experiment) and evenly distributed between the two visual fields.

Results

Table 2 shows individual and overall mean RTs as a function of field of stimulation and of the three response conditions. A three-way within-subjects analysis of variance was carried out on mean correct RTs for "same" response only, with the same factors as in the first experiment. In this case only the type of matching main effect and the visual field × type of matching interaction were significant: $F(1,7) = 37.58, p < .001$ and $F(1,7) = 16.44, p < .01$, respectively. As in the previous study, RTs for PI matches were faster than NI matches (the difference is 197.7 msec: 715.1 vs. 912.8 msec), and the degree of advantage depends on the field of stimulation. In the right visual field PI matches were 131.4 msec faster than NI matches (744.2 vs. 875.6 msec), while in the left visual field this difference was much larger, that is, 263.9 msec (686.0 vs. 949.9 msec). The same result can be stated in another way: PI matches are 58.2 msec faster in the left visual field than in the right (686.0 vs. 744.2 msec), while NI matches are 74.3 msec faster in the right than in the left (875.6 vs. 949.9 msec). All the subjects responded more quickly to right-field stimuli in the NI condition; six of eight subjects had faster mean RTs for PI matches in the left visual field.

In the case of the two-way analysis of variance with field of stimulation and response type as within-subjects factors, only the response type main effect turned out to be significant: $F(1,7) = 16.27, p < .01$. "Same" responses were 161.4 msec faster than "different" responses (811.6 vs. 973.0 msec).

TABLE 2

REACTION TIMES (msec) ACROSS THE TWO VISUAL FIELDS AND UNDER THE THREE RESPONSE CONDITIONS, WHERE LETTERS IN A PAIR WERE PHYSICALLY IDENTICAL, HAD THE SAME NAME, WERE DIFFERENT (SCRIPT-LIKE MATERIAL)

	PI matches[a]		NI matches		NI–PI differences		Different	
	RVF	LVF	RVF	LVF	RVF	LVF	RVF	LVF
S1	1037	861	1109	1123	72	262	1256	1290
S2	791	826	990	1066	199	240	1074	994
S3	803	838	904	939	101	101	958	918
S4	776	638	877	961	101	323	1041	1086
S5	496	473	652	676	156	203	645	679
S6	666	568	960	1072	294	504	1189	1202
S7	658	576	663	809	5	233	780	643
S8	727	708	850	953	123	245	899	914
$\bar{X}$	744.2	686.0	875.6	949.9	131.4	263.9	980.2	965.8

[a] PI, Physical identity; NI, name identity; RVF, right visual field; LVF, left visual field.

Similar analyses of variance carried out on the number of errors yielded no significant source of variability. The overall error rate in this experiment was 8.9%.

"Different" responses appeared to be faster in the left visual field than in the right, the difference being 14.4 msec (965.8 vs. 980.2 msec). However, only three of eight subjects behaved in this way and the trend did not attain statistical significance with a *t* test for correlated means.

DISCUSSION

The findings of Experiment I complement previous observations by Cohen (1972), Geffen et al. (1972), and Davis and Schmidt (1973) that have used Posner's (1969) paradigm to investigate hemispheric asymmetries in coding. The NI–PI difference is smaller in the left hemisphere and NI matches are faster in the left than in the right hemisphere. The interpretation of these results is straightforward, since the specialization of the left hemisphere for linguistic processing is by now a classical datum in neuropsychology.

Furthermore, in the present study the advantage of the left hemisphere for NI matches (that is, for matches involving a name code) is very consistent and 11 out of 12 subjects show this asymmetry. This clear-cut result might be attributed to the use of stop consonants as stimuli, that is, the use of those sounds which seem to be best processed by the linguistic hemisphere (Shankweiler & Studdert-Kennedy, 1967).

The interpretation of the results indicating a right-hemisphere superiority for PI matches (that is, for matches involving a visuospatial code) also seems, at first sight, equally simple, since the dominance of the right hemisphere in analyzing visuospatial relations has been demonstrated in many studies. However, only 7 of 12 subjects have shown this asymmetry. Furthermore the finding that the NI–PI difference is smaller in the left hemisphere than in the right does not support by itself a relative increase in the speed of PI matches in the right hemisphere, since it can be simply attributed to relatively shorter RTs to NI matches in the left hemisphere. In brief, it seems safer to conclude that in Experiment I PI matches are performed equally quickly by both hemispheres. The fact that "same" responses are faster than "different" responses is a typical finding of "same–different" studies (see, e.g., Bamber, 1969; Nickerson, 1972). Furthermore, in the present experiment "same" and "different" letter pairs were not balanced: 67.66% of the trials required "same" responses, 33.33% "different." This difference in the probability of stimulus occurrence is sufficient to explain the difference in speed of response (see, e.g., Hyman, 1953; Sternberg, 1969). No suggestion, however, can be advanced to explain the lack of hemispheric asymmetry observed in the case of "different" responses. There can be no doubt that stimuli containing letters that are different in both shape and name can be correctly classified only through a process of identification and naming, just as in the case of correct NI matches. However, while the latter trials yield a very clear-cut left-hemisphere advantage, the former show no hemispheric asymmetry, even though the stimuli employed, i.e., stop consonants, seem to be the most appropriate to yield an advantage for the linguistic hemisphere. The findings of Experiment II are similar to those of Experiment I: the NI–PI difference is smaller in the left than in the right hemisphere; NI matches are faster in the left hemisphere (all 8 subjects showing this asymmetry); PI matches are seemingly faster in the right hemisphere than in the left (however, only 6 of 8 subjects behaved in this way). "Same" responses are faster than "different" responses, and the latter do not show any hemispheric asymmetry. A striking difference between Experiments I and II is the fact that in the latter experiment latencies were much longer and interfield differences became much larger. This can be a specific effect of the difficulty of the task, as suggested by previous studies (Umiltà, Frost, & Hyman, 1972; Umiltà, Rizzolatti, Marzi, Zamboni, Franzini, Camarda, & Berlucchi, 1974) which have indicated a positive correlation between mean overall RTs and the difference in RT for the two hemispheres. As previously noted, the letters employed might have created some problems since for print-like C, P, and T upper- and lower-case representations are similar enough to permit analog matches (see Posner, 1969), while C and G can be pronounced as nonstop sounds. In Experiment I, C, P, and T do in fact yield smaller NI–PI differences (see the significant first-order interaction, type of matching × type of letter) as should be expected when analog matches occur.

However, the failure of the second-order interaction, visual field × type of matching × type of letter, to approach statistical significance in both Experiments I and II indicates that neither physical similarity between upper- and lower-case representations nor optional pronunciation as stops affects interhemispheric differences. The lack of consistent right-visual-field effects for "different" responses cannot be attributed to the physical similarity of upper- and lower-case representations of some letters, since judgments based on physical or analog processing can occur only for "same" responses. Furthermore "different" responses fail to show any laterality effect even in the case of script-like material, when instances of physical similarity between upper- and lower-case representations are absent. Five subjects in Experiment I and two subjects in Experiment II do not show a left-visual-field advantage for PI matches. It might be suggested that they use a verbal mediation to obtain PI matches. However, the unexpected verbal mediation should manifest itself through comparatively slow RTs and comparatively small NI–PI differences. This is clearly not the case as can be seen from Tables 1 and 2.

The work by Bryden and Allard (1976) suggests that the identification of script-like material is more difficult than the identification of print-like material, since the former requires a longer initial stage of visuospatial preprocessing in order to extract the relevant features of the stimulus. According to these authors the task of identifying alphabetic material is performed through two distinct stages of processing. The first implies preprocessing operations on the relevant characteristics of the stimulus and occurs in the nonlinguistic hemisphere, while the second stage comprises the actual identification and naming of the stimulus and occurs in the linguistic hemisphere. The perceptual asymmetries in accuracy or in speed of response would depend on the relative importance of these two stages. With print-like material the second stage is more important and therefore the left hemisphere prevails, while with script-like material the first stage is more important and therefore the right hemisphere prevails. If this is true, then one would expect a very clear-cut asymmetry in favor of the right hemisphere for PI matches in Experiment II, or even a right-hemisphere advantage also for NI matches in accordance with previous findings (see Bryden & Allard, 1976) that showed a right-hemisphere advantage for the verbal identification of script-like letters. This prediction is clearly not supported by the data of the present study. We suggest that the initial stage of feature preprocessing does not substantially differ between the two kinds of typefaces, while the second stage of letter identification and naming becomes more complex with script-like material. Thus overall RTs are longer in Experiment II than in Experiment I while the relative importance of the two stages of stimulus processing, and thus the differential involvement of the two hemispheres, remains the same. In summary, these two experiments cast some doubts on the widely accepted role of linguistic and visuospatial processing in determining perceptual asymmetries for NI and PI matches. The left-hemisphere advantage for NI matches is very clear, but if one attributes this asymmetry to linguistic processing it becomes very difficult to explain why the same type of linguistic processing does not yield the same asymmetry in the case of "different" responses. On the other hand, the right-hemisphere advantage for PI matches, which should involve a visuospatial type of processing, is not very clear even when the most favorable stimuli, i.e., script-like letters, are employed.

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