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HEMISPHERIC DIFFERENCES FOR CONSONANT AND VOWEL PROCESSING IN THE VISUAL MODALITY

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In this paper we will discuss sóme data about the specific role of the two cerebral hemispheres in the processing of alphabetical material.

The basic experimental paradigm employed is a <u>same-different</u> letter classification task. As shown by Posner (1969), a pair of visually presented letters as "B B" may be classified as "same" faster than a pair of letters like "B b". In the first case the letters are physically identical (and, of course, have the same name), while the second ones share only the same name. The longer RT of the latter pair can be attributed to the linguistic processing of the two letters, that is of their names, while same responses to two identical letters can be based on their physical characteristics. Thus, this paradigm seems to be useful to study the specialized mechanisms of the two hemispheres involved in processing alphabetical material.

It is known that left and right hemispheres hold anatomical and functional differences. Since the Broca's (1861, 1865) observations of quite different effects of the damage of the left hemisphere as compared with that of the right, many studies have shown that the left hemisphere is better to analyse verbal stimuli and the right to analyse nonverbal and spatial configurations.

However, it is quite clear today that the verbal-nonverbal dichotomy is purely descriptive and does not capture the basic mechanisms that underlie functional hemispheric asymmetries (Moscovitch, 1979).

The studies with split-brain patients have shown that, although relatively incapable of producing either written or spoken language, the rigth hemisphere (RH) can understand single and complex syntactical construction (Searlman, 1977; Zaidel, 1978).

Other dichotomies have been proposed to explain hemispheric differences: the left hemisphere has been characterized as an analytic or serial processor and the right as an holistic or parallel processor (Cohen, 1973; Patterson and Bradshaw, 1975).

Alternatively Semmes (1968) proposed that the two hemispheres differ in their neural organization, with a diffuse representation of elementary functions in the RH and a more focal localizations of functions in the left hemisphere (LH) which would favour its specialization for language, where a temporally ordered process seems to be involved.

Generally, there is the need to define the process common to all behavioural phenomena that are associated with hemispheric differences and to specify the role each cerebral hemisphere has in information processing. In fact, the results with normals and patients leave a great deal of uncertainty about the exact nature of the underlying functional asymmetries and the range of cognitive processes over which they apply.

Here we want to discuss only of the first and oldest dichotomy, that is the verbal-nonverbal one. The general idea which is generally accepted in recent researches is that it is not the type of stimulus to determine which hemisphere is dominant, but rather the type of information processing required to perform the experimental task. In other words, if only visual recognition is called for, even when the stimulus material is verbal, the right hemisphere prevails. On the contrary, if a verbal transformation is demanded, even when the material is nonverbal, the task is performed by the left hemisphere.

In the case of Posner's paradigm (see above), the match of two letters, in a <u>same-different</u> reaction time task can be performed either on the basis of the physical characteristics (i.e. a visuo-spatial type of processing) or on the basis of the letter names (i.e. a linguistic type of processing). According to Posner the involvement of two different types of information processing is shown by the fact that physical identity matches (e.g., BB or bb) are about 70 msec faster than name identity matches (e.g., Bb or bB).

In accordance with the notion of hemispheric asymmetries, we can anticipate that the RH is faster in evaluating a physical identity, while the LH is faster in evaluating a name identity.

Previous studies that have used Posner's paradigm to investigate hemispheric differences in coding, are generally considered to be consistent with these predictions. However, in a paper by Cohen (1972) only 3 subjects out of 6 showed faster name identity (NI) matches in the left hemisphere than in the right, while 5 subjects out of 6 showed the advantage of the RH in the case of physical identity (PI) matches.

Another study by Davis and Schmidt (1973) failed to find a significative difference between PI and NI matches, and then the observed difference between the two hemispheres is difficult to interpret.

Gazzaniga (1970) and Moscovitch (1976) did not find a difference between the two hemispheres with physical identity.

An interesting point to discuss in the framework of a <u>same-different</u> paradigm is the result given by "different" responses. Clearly different letter pairs must be named in order to be correctly classified as different, and thus a superiority of the left hemisphere, similar to that found for NI matches, would be predicted. However, previous studies have usually shown no clear effect and often no difference has been found between the two hemispheres in the case of different responses.

In this contest another source of interesting empirical evidence arises from the dichotic listening experiments which have shown that the LH is better at processing the phonetic information carried by stop-consonants, while vowels don't show clear-cut hemispheric asymmetries and other types of consonants yield intermediate results.

If, as supported by Liberman (1974) and Posner (1978), NI matches are performed on the phonetic basis, the advantage of the left hemisphere should be maximized by the use of stops even in the visual modality.

Recent work on the acoustic modality has shown that also vowel perception may yield a significant difference between the two hemispheres when listening conditions are difficult as compared to normal conditions (e.g. stimuli presented with noise; greater similarity among stimuli; length of vowels).

It seems very important to know if consonants and vowels behave in the same way for different modalities. In fact, this could indicate that the same processes are involved regardless of the modality of presentation.

Another interesting possibility arises from a study by Bryden and Allard (1976). They have found that the LH superiority for single letters depends on the physical structure of the stimuli. In fact, while the normal typefaces, like those generally used in experiments of visual perception, yield a LH superiority, others, as script like material show a RH superiority. Bryden and Allard (1976) proposed that the identification of script-like letters requires more visuo-spatial preprocessing than print-like letters, and so the RH processing prevails.

In the Posner' paradigm the use of script-like typefaces might not modify the advantage of the left hemisphere for NI matches, since in any case the task should be performed on the name of the letters. On the other hand a clearer advantage of the RH for PI matches might be expected, owing to the specialized capability of this hemisphere in visuo-spatial processing.

Another hypothesis is that, with script-like material, the importance of the preliminary stages of visuo-spatial preprocessing might show an overall advantage for the RH for both PI and NI matches.

The following researches were conducted to test the above-mentioned hypotheses.

The procedure was always the same: the subject had to classify a pair of letters as "same" if the letters had the same name or the same shape, that is, when they allowed PI or NI matches, or as "different" if the letters had different shape and name. The letter pairs were presented to the right visual field (i.e. to the LH) and to the left visual field (i.e. to the RH) for 100 msec and RTs and errors were recorded. All the subjects were right-handed. For further details about the experimental procedure see Umilta', Sava and Salmaso (1980) and Salmaso and Umilta' (in preparation).

In the first study we have used only the six Italian stop-consonants, in both a print-like form (the first row of Figure 1) and a script-like form (the second row of the same figure).

Same and different responses were analyzed separately.

In the condition with print like material, "same" responses for PI and NI matches yielded different latencies: PI matches were faster than NI matches of 119 msec. But this difference depended on the field of presentation. In fact, PI matches were faster in the left visual field (LVF) and NI matches in the right visual field (RVF), as shown in Table 1. The difference between PI and NI matches was greater in the LVF than in the RVF (146 vs 93 msec).

Different responses were longer than same responses, but no difference between the two visual field emerged.

In the condition with script-like material, again "same" responses showed shorter latencies for PI than for NI matches (715 vs 913) and again this effect was different in the two visual fields. LVF was faster for PI matches and RVF for NI matches. The difference between PI and NI was larger in the LVF than in the RVF (264 vs 131).

"Different" responses were longer than "same" responses, but again there was no difference between the two fields of presentation.

These results obtained with stop-consonants, complement previous observations and can be explained quite easily, since the specialization of the left hemisphere for linguistic processing is known. The fact that the advantage of the left hemisphere for NI matches was unusually consistent (19 subjects out of 20 showed this effect) might be attributed to the use of stop consonants, the processing of which, according to dichotic listening studies, is strongly lateralized to the LH.

Also the RH advantage for PI matches might be simple to explain, because an RH superiority for visuo-spatial processing has been demonstrated in many studies. However, in these two experiments the RH effect for PI matches was not as consistent as the effect for NI matches. For example, in the case of print-like stimuli the difference between fields for PI matches was much smaller than that for NI matches. Furthermore only 7 subjects out of 12 showed the effect, which did not reach statistical significance. Thus, there is good evidence to suggest that PI matches may be performed equally easily by both hemispheres. Only in the case of script-like stimuli a consistent and significant RH effect for PI matches emerged.

In both experiments, different responses were slower than same, and did not show any hemispheric asymmetry.
It is difficult to explain the discrepancy between same and different responses in terms of hemispheric specialization. Different letters can be correctly classified only through a process of name identification, as in the case of NI matches. However, while NI matches yielded

a very clear LH advantage, different responses did not show this effect. This finding is not without precedent. Moscovitch (1976) suggested that "different" responses may be due to both hemispheres. Beatty and Wagoner (1977) proposed that some different responses could be given on the basis of a physical comparison, whereas others require full processing before a correct classification.

According to Bryden and Allard (1976) the identification of the alphabetical material implies at least two stages of processing: 1) the pre-processing of the relevant features of the stimulus, performed by the non-linguistic hemisphere and 2) the actual identification and naming of the stimulus, performed by the linguistic hemisphere. The relative importance of these two stages in different conditions might yield different asymmetries. With print-like material the naming is more important and then the LH prevails, but with script-like material the pre-processing stage is more important and then is the RH to prevail.

Our data doesn't support this hypothesis. It seems that the linguistic hemisphere is better at performing NI matches irrespective of the complexity of typeface employed. On the contrary, the nonlinguistic hemisphere yields better performances for PI matches only when the typeface employed is more demanding from the point of view of visuospatial processing.

As said before, dichotic-listening studies have shown some differences between consonant and vowel processing. Therefore the same experiment was replicated by using vowels instead of consonants. The experimental procedure was the same as that of the previous study.

In the first condition the stimuli were presented in print-like form (see first row of Figure 2). As for dichotic experiments with normal vowels, there was no difference between the two visual field, that is the two hemispheres. Despite the fact that a significant difference was found between PI and NI matches (638 vs 723), neither PI nor NI matches, nor different responses yielded significant differences between the two hemispheres. This finding seems in accordance with previous results of dichotic listening studies, since also for vowels the subject could correctly classify NI and "different" matches only after identification of the name of the two letters.

However, some dichotic studies have shown that vowel perception may be based on the same mechanisms of consonant perception, which yield a significant right-ear advantage when listening conditions are much more difficult.

According to these results, at least with NI matches, a LH superiority might be expected with the difficult script-like material. Our data don't support this hypothesis. In fact, with script-like material (see the bottom row of Figure 2) we found a difference between PI and NI matches (662 vs 759) and a significant superiority of the RH for PI (649 vs 674) and NI matches (734 vs 784) and different responses (808 vs 847). Thus, whereas in dichotic listening studies the perceptual difficult promotes a left-hemisphere superiority, visual perceptual complexity promotes a right-hemisphere superiority.

The main findings of the studies reported can be better understood if the results for stops are compared with these for vowels.

In the case of print-like stops an LH advantage was found for NI matches, whereas no hemispheric asymmetry emerged for PI matches. It is suggested that visuospatial processing of print-like letters can be performed by both hemispheres. To the contrary, the phonetic processing required by name matches for stops can be performed only by the LH. When pairs of print-like vowels were used, neither PI nor NI matches yielded hemispheric asymmetries. In the case of PI matches this finding can be viewed as confirmatory of the ability of both hemispheres to conduct simple visuospatial processing (Moscovitch, 1979). The lack of lateral asymmetry for NI matches can be attributed to the fact that phonetic characteristics of vowel sounds are processed by the two hemispheres.

In the experiment with script-like stops, a significant interaction was observed between visual field and type of match, with PI matches yielding an RH advantage and NI matches yielding an LH advantage. We propose that, while the phonetic encoding of stops was again performed in the linguistic hemisphere, the much more complex visuospatial processing of script-like letters was preferentially performed in the RH. In the case of script-like vowels, an overall RH advantage was found, regardless of the type of match. This result for PI matches can be easily explained as before by assuming that an RH advantage emerges when the requirement for visuospatial processing exceed the capabilities of the LH. The RH advantage for NI matches to script-like vowel pairs can be explained by considering: 1) that the phonetic characteristics of vowel sounds are amenable both to RH and LH encoding ; and 2) that the better ability of the RH to process complex visuospatial material, apparent at the stage of visuospatial processing, is transmitted to the stage of phonetic processing that "per se" should not yield any hemispheric asymmetry (for a discussion of the hypothesis of transmitted asymmetry, see Moscovitch, 1979).

TABLE 1 : Mean reaction times for print-like and script-like stop consonants (same responses only)

	PI MATCHES		NI MATCHES		NI-PI DIFF.	
	LVF	RVF	LVF	RVF	LVF	RVF
PRINT-LIKE	608.2	621.6	754.0	714.5	145.8	92.9
SCRIPT-LIKE	686.0	744.2	949.9	875.6	263.9	131.4

PI : physical identity NI : name identity

LVF : left visual field RVF : right visual field

FIGURE 1 : Examples of print-like (a) and script-like (b) stop-consonant stimuli in both the PI and NI form.

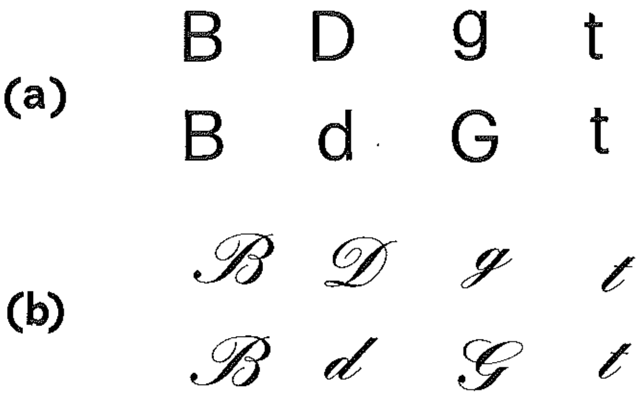
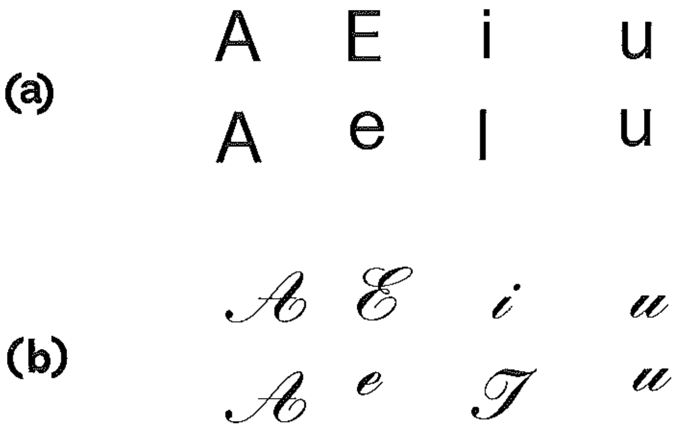


FIGURE 2 Examples of print-like (a) and script-like (b) vowel stimuli in both the PI and NI form.



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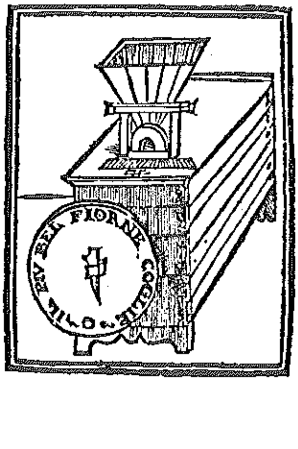

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