HEMISPHERIC DIFFERENCES IN LETTER PROCESSING: A SEMINAR

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Tratti distintivi - sonorità

In this paper, I want to discuss some data about the specific role each hemisphere has in a letter information processing. The problem is to understand how each hemispere works and when a superiority of one on the other appears.

To this end a simple paradigm has been used. As shown by Posner (1969), a pair of letters as "B B" may be classified as "same" faster than a pair of letters like "B b". In the first case the letters hold a physical identity (and, of course, a name identity), while the second ones have only a name identity. The longer RT of the latter seems due to a verbal processing of the two letters, that shows their same name and perhaps their same sound so, the paradigm seems to be useful to see which mechanisms of the brain are involved in an apparently simple process of letter matching.

Left and right hemispheres hold anatomical and functional differences.

From Broca's observations (1861, 1865) of a quite different effect in the damage of the left hemisphere as compared with that of the right one, 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 descriptive only and does not say much about the basic mechanisms that underlie functional hemispheric asymmetries.

Why must the left hemisphere be better to process verbal material? Or what are the particular processes involved in verbal behaviour?

The studies with split-brain patients have shown that, although relatively incapable of producing either written or spoken language, the right hemisphere (RH) can understand single and complex syntactical constructions.

Other dichotomies have been proposed to explain hemispheric differences and how the two hemispheres work: the left hemisphere has been seen as an analytic and serial processor while the right as an holistic and parallel processor.

Again it has been proposed that the two hemispheres differ in their neural organization with a diffuse representation of elementary functions in the RH and a higher localization of functions in the LH, which would favour the latter's specialization for language (where a temporally ordered process seems to be involved).

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

Here I want to discuss only the first and oldest dichotomy, that is the verbal-nonverbal one. Nowadays, it is evident that it is not the type of stimulus to determine which hemisphere is dominant, but rather the type of information processing required to solve the given problem.

If only visual recognition is called for, even if the material is verbal, the right hemisphere acts. However, if a verbal transformation is demanded, even if the material is nonverbal, it is handled by the left hemisphere.

Some data are now available that show a RH superiority even with a seemingly linguistic task like a verbal report, or a match between an acoustically presented letter and a visually presented one.

Two possible hypoteses may be proposed. One is that the RH might determine the name of the letter or the word and also generate a corresponding visual image from a linguistic information.

Another hypotesis is that linguistic analysis occurs only in the LH, the results of which are transferred to the right.

As shown by Posner (1969), the single match of two letters, in a same-different reaction time task, can be performed either on the basis of physical clues (i.e. a visuo-spatial type of processing) or on the basis of the letter name (i.e. a linguistic type of processing). Posner showed that a physical identity (e.g. BB or bb) can be classified as "same" about 70 msec faster than a name identity (e.g. Bb or bB).

According to the data on hemispheric asymmetries we can suppose that the RH is faster in evaluating a physical identity, while the LH can be faster in the evaluation of a name identity.

Previous studies that have used Posner's paradigm to investigate hemispheric differences in coding, are 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 (Davis and Schmidt, 1973) failed to find a significative difference between PI and NI matches and thus could not show a difference between the two hemispheres.

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

An interesting point to discuss with the same-different paradigm is the result given by "different" responses. Clearly the "different" letters must be named in order to correctly classify their name, and thus a superiority of the left hemisphere would be predicted, as for NI matches.

Previous studies have not shown a clear effect and often no differences have been found between the two hemispheres. We have to note that, generally, different responses are longer than PI and NI matches, suggesting that the different responses are analyzed in a different way.

Dichotic listening experiments have shown that the left hemisphere 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 NI and different matches are performed on an acoustic basis, the advantage of the left hemisphere for stops could increase.

I don't know of works that have studied the problem of similar differences with visual perception.

Recent works on the acoustic modality have shown that even vowel perception may yield a significant difference between the two hemispheres when listening conditions are difficult as compared to normal conditions(stimuli presented with noise; greater similarity among stimuli; lenght of vowels).

Whether vowels are in effect processed differently from consonants is not clear today. In particular, it is not clear if vowels are also analyzed by phonetic categorization or rather by an acoustic processing of the signal.

I mentioned before that hemispheric studies with visual presentation have not analyzed this problem and letters of several types have been used. Despite this, it seems to me that it is very important to know if consonants and vowels behave in the same way for different modalities. In fact,this could mean that the same processes are involved regardless of the modality of presentation.

Another problem to discuss is that advanced 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 left superiority, others e.g. script-like material, show a right superiority. Bryden and Allard (1976) proposed that the identification of script-like letters requires more visuo-spatial pre-processing than print -like letters, and so the right hemisphere 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 more clear advantage of the right hemisphere for PI matches might be expected.

Another hypothesis is that, with script-like material, the importance of the preliminary stages of visuo-spatial pre-processing might show an overall advantage for the RH both for PI and NI matches (and also for "different" responses).

To study these problems we have done some experiments. For all of these, the paradigm is the same: the subject has to classify a pair of letters as "same" if the letters have the same name or the same shape, that is, if they have a PI or a NI, or as "different" if the letters have different shapes and different names. The pairs were presented to the right and to the left hemisphere of right-handed subjects for 100 msec and RTs and errors were recorded.

In a first study we used the five Italian vowels and five stop-consonants together. The most interesting result of that experiment was a strong difference in RTs between vowels and consonants (734 msec vs 768). It was not possible to attribute this difference to particular complexities of the consonant letters and so we suggested that different processes were involved.

In that experiment the experimental situation was quite complex for the subject, because he had to discriminate between same and different matches, between vowels and consonants and between PI and NI matches. In the following experiments we preferred to separate stop-consonants from vowels. Thus for the second study we used only the six Italian stop consonants, both in a print-like form (as you can see at the top of figure 1 or in a script-like form (at the bottom of the same figure).

Same and different responses were analyzed separately.

In the first experiment with print-like material, "same" responses for PI and NI matches are different: PI matches are

La differenza NI-PI dovrebbe essere minore nell'ES perché NI è più rapido e PI più lungo

119.3 msec faster than NI matches. But this difference depends on the field of presentation. In fact, PI matches are faster in the LVF and NI matches in the RVF. As you can see in the Table 1 the difference between PI and NI matches is greater in the LVF than in the RVF (145.8 vs 92.9).

Different responses are longer than same responses, but no differences between the two hemispheres are shown.

In the second experiment, with script-like material, again the "same" responses show a difference between PI and NI matches (715.1 vs 912.8) and again this effect is different for the visual field of presentation. LVF is faster for PI matches and RVF for NI matches. The difference between PI and NI is larger in the LVF than in RVF (263.9 vs 131.4).

"Different" responses are longer than "same" responses, but again there is no difference between the field of presentation.

These data with stop-consonants complement previous observations by other authors and are quite easy to explain, since the specialization of the left hemisphere for linguistic processing is known. The advantage of the left hemisphere for NI matches is very clear and, perhaps, might be caused by the use of stop-consonants.

Also PI matches, at first sight, might be simple to discuss, because RH superiority for visuo-spatial relations has been demonstrated in many studies. However, in these two experiments PI matches are not so strong as NI matches. For example, the difference between fields for PI matches is smaller than that between NI matches. We have good reason to suggest that PI matches may be performed equally quickly by both hemispheres.

Also the second experiment shows that the LH is better with NI matches and RH with PI matches, but here too the superiority is stronger for name matches than for PI.

In both experiments, same responses are faster than different ones, and the latter don't show any hemispheric asymmetry. devono essere distinte dal nome

* How to explain this result ? Different letters can be correctly classified only through a process of identification, as with NI matches. However, while NI matches yield a very clear left-hemisphere advantage, different responses don't show this effect. Similar data have been found by other authors. Moscovitch (1976) put forward the hypothesis that "different" responses may be due to both hemispheres. Beatty and Wagoner (1977), in an article on the level of activation in a same-different task, proposed that some different responses can be given on the basis of physical comparison, whereas others require full processing before a correct classification can be made.

Our work doesn't support previous data by Bryden and

* IF < IN < Different

Allard. According to these authors in the identification of the alphabetical material there are two stages of processing: 1) a pre-processing operation on the relevant feature of the simulus, performed by the non-linguistic hemisphere and 2) an actual identification and naming of the stimulus, performed in the linguistic hemisphere. The relative importance of these two stages might yield different asymmetries. With print-like material the naming is more important and then the left hemisphere wins, but with script-like material the pre-processing stage is more important and then the RH wins.

Our data do not support this hypothesis. We suggest that the pre-processing stage might be the same, and the naming stage become more complex with script-like material and therefore left-hemisphere analysis prevails.

In summary, the two experiments cast some doubts on the important role of linguistic and visuo-spatial processing for NI and PI matches. The left hemisphere advantage for NI matches is very clear, but if one attributes this to linguistic processing it becomes very difficult to explain why the same type of processing does not yield the same asymmetry for different responses.

As I have said before, dichotic-listening studies have shown some differences between consonant and vowel processing. So, we have repeated the same experiment using only the five Italian vowels. The paradigm is the same as that of the previous study.

In the first experiment we again used print-like material (see examples at the top of figure 2. As for the dichotic experiments, with normal conditions of presentation, that is, print-like material, there are no differences between left and right hemisphere, despite that even here a significant difference is found between PI and NI matches (638 vs 723).

Since also for vowels the subject can correctly classify NI and "different" matches only after having named the letters, we could conclude that both hemispheres are capable of identifying single letters.

But another hypothesis is also possible. As suggested by acoustic studies, vowel processing might be due to different processing mechanisms. However, some dichotic studies with vowels have even shown that vowel perception may be based on mechanisms similar to those consonant perception. So a significant right-ear advantage has been found when listening conditions are more difficult than in normal perception.

According to these results, at least with NI and different matches, a left hemisphere superiority could be seen using script-like material. Our data do not support this hypothesis. In fact, with script-like material like that you can see at the bottom of figure 2, we again have a difference between PI and NI matches (662 vs 759) and a global superiority of the RH for the same (691 vs 729) and different responses (808 vs 847).

Like with dichotic listening conditions, where the perceptual difficulty promotes a superiority of the left-hemisphere whose neural mechanisms are better suited to produce the fine discriminations required by verbal behaviour, visual perceptual complexity promotes a right-hemisphere superiority. So, as suggested by Bryden and Allard the pre-processing stage, that is, the process of the basic features of the stimuli, seems to be more important than that of the name.

However a different pattern has been found with stop-consonants and we believe that the RH superiority for script-like material is caused only by the fact that vowels are processed by both hemispheres. This is consistent with the results of dichotic listening experiments. Unfortunately, I don't know of any research done with normal people and with visual presentation. In a recent work by Beatty and Wagoner (1977) vowel and consonant stimuli were used in a same-different paradigm, but the authors did not report the data for each type.

To conclude, I believe that different mechanisms analyze vowels and stop-consonants, but how these mechanisms work and if they are lateralized is still a puzzle.

At the end of this talk, I want to present some other data about letter processing. In all these experiments, some differences in RTs among single letters have been found.

In the first work with stop-consonants and print-like material, there is a significant difference among letters and

$p < .001$

a significant interaction letters by match. In fact the difference between PI and NI matches changes with the letter used. As you can see in Table 2 this difference is larger for B, D, G than for P, T and C. A similar pattern was found in the second experiment with vowels and print-like material. Again in table 2 you can see that PI-NI differences are larger for A and E than for I, O, and U. The same trend is shown for script-like material, but there the effect is not significant perhaps due to the larger variability among RTs, caused by greater complexity of the stimuli.

At least in part these differences are brought about by visual perceptual problems. As suggested by Posner (1969), some NI matches are analog matches, i.e. the form of capital and lower-case letters is quite similar, and this may facilitate the match. IF < analog < IN

But I believe that this is not the only factor. Linguistic studies have shown that consonants and vowels may be analysed by distinctive features (phonetic and auditory parameters). One of these features is the "voicing". In the Italian language, B, D and G share the voice feature, while P, T and C are unvoiced (in It. "sorde"). As you can see in Table 2, B, D, G, all voiced have longer RTs than P, T and C that are unvoiced. But a longer RT means a more difficult discrimination process. That is, the letters that are voiced seem more difficult to analyze than those unvoiced.

Italian vowels are very different from English vowels and so it is difficult to make comparisons. However, we can note that A and E have longer RT than the others, that is they are more difficult to discriminate than the others. I don't know of any other work where a similar difference has been found and so it is quite difficult to explain these data. But, in both cases, for stop-consonants and for vowels, the sound of the letter seems to have some influence also here, that is also with visual presentation. The importance of a possible acoustic or phonetic codification also for visual stimuli is not known and so nothing else may be said.

In conclusion the left hemisphere is better to analyze NI matches, but only when stop-consonants are used. What is the nature of NI matches and why do not "different" responses give a superiority of the left hemisphere when the letters have to be named before responding "different"? Why does linguistic material give so large differences between hemispheres also with the same task? Why is not a right-hemisphere superiority found even with script-like material stop-consonants?

To this date we do not have a clear answer about the nature of the linguistic processing and how each hemisphere works. If the left hemisphere is a linguistic processor, why is not a parallel superiority for name matches found with vowels?

I end with these questions, hoping they are more fruitful questions than before.

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TABLE 1 : MEAN REACTION TIME FOR PRINT-LIKE AND SCRIPT-LIKE MATERIAL (SAME RESPONSES)

	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

[illegible] , 1980

TABLE 2 : DATA FROM LETTER EXPERIMENTS

Experiment "same-different" print-like GIP (1978)

NI

B	D	G	P	T
869	862	843	784	750

F = ns

Experiment "same-different" print-like BL (1980)

	B	D	G	P	T	C	
PI	613	632	688	638	530	594	615
NI	807	772	830	720	621	661	734
DIFF	194	140	142	82	90	67	

F = 3.62; P <.01

Experiment "same-different" print-like (1980) BL 1982

	A	E	I	O	U	
PI	612	647	599	662	673	638
NI	806	805	633	682	692	723
DIFF	194	158	34	20	19	

F =11.902;P <.001

Experiment "same-different" script-like (1980) BL 1982

	A	E	I	O	U	
PI	634	646	658	684	688	662
NI	777	793	740	747	738	759
DIFF	143	147	82	63	50	

F = 2.484; ns

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

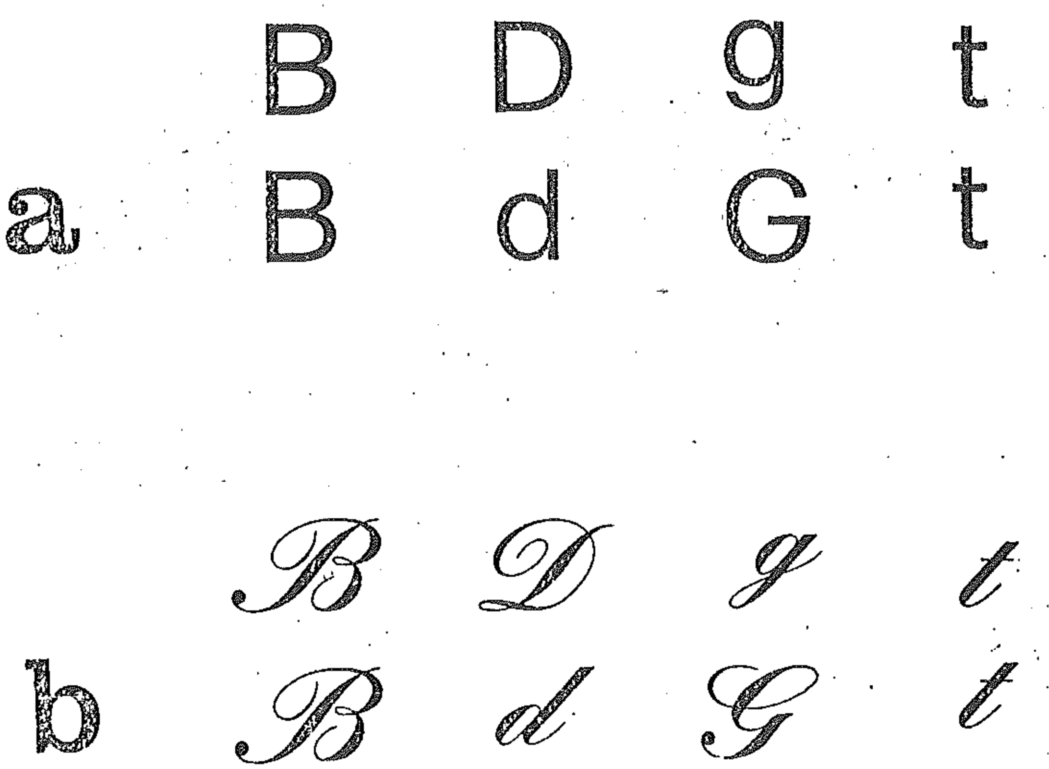

FIGURE 2: Examples of print-like (a) and script-like (b) vowel stimuli both in the PI and NI form.