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HEMISPHERIC DIFFERENCES ON A NOVEL TASK REQUIRING ATTENTION

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Summary.—16 students, 8 men and 8 women, ranged in age from 18 to 25 yr., served as subjects in an experiment, where 320 pairs of consonants and 320 pairs of lines were presented tachistoscopically to the left and to the right visual field. One pair, both for letters and for lines, constituted the nonsignal event and the remainder the signals. A high event rate and a low signal density were used. Subjects were instructed to press a key when a signal had been presented. Performance was scored according to nonparametric estimates of sensitivity and criterion. The main results were a clear-cut dissociation between the two measures, a greater sensitivity for the presentation in the right visual field, irrespective of the type of material, and different effects on detection and response bias for men and for women. The importance of these findings with respect to lateralization and information processing is discussed.

The aim of this work was to infer the functioning of the two hemispheres, from performance on a novel task, requiring detection of changes in a sequence of neutral stimuli. Detection of novelty is an important factor in the everyday life of human beings. However, little is known about the mechanisms of the brain that allow us to detect novel stimuli, particularly when some cognitive changes are involved.

Researchers on the topic of sustained attention or vigilance (Jerison, 1977) have shown that the readiness of a subject to detect and respond to a signal declines over time (Buckner & McGrath, 7963; Mackworth, 1970). Several hypotheses have been proposed to explain the nature of this decrement; these have been reviewed by Mackworth (1969, 1970). However, none of these seem to account for all the data now available, particularly neural ones. One of these hypotheses suggests that the decline is at least in part caused by a lower activation, associated with the monotony of the stimulus conditions. As suggested by Jane Mackworth (1969, 1970), the repeated presentation of the same or very similar stimuli, as in a vigilance task, produces an habituation of neural responses, which may result in fewer events, either signals or nonsignals, reaching the subject's criterion for responding. If Mackworth's hypothesis is true, the initial repeated presentation of a stimulus and therefore the habituation to it, could accelerate the performance decrement or lower the performance efficiency. Some support of this hypothesis comes from the work by Siddle (1972), in which subjects with fast habituation showed a greater rate of decrement in vigilance.

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A considerable number of experiments have compared the relative accuracies of the left and right visual fields in identifying and recognizing verbal and nonverbal material (see reviews in Krashen, 1976; Springer, 1977), but few studies concerned stimulus detection or vigilance performance of each hemisphere. In a series of works Dimond and Beaumont (1971, 1973, 1974) postulated the existence of two different vigilance systems: a high level system with a rapid decrement, a function of the left hemisphere, and a low steady level system, a function of the right hemisphere. Lately, it has been proposed that the selective attention might be a left brain function and sustained attention, or vigilance, a right brain function (Jerison, 1977).

In a recent work Warm, Schumsky, and Hawley (1976) have shown that, with acoustic signals, performance by the left hemisphere was better at a low signal density, while the right hemisphere was superior at a high signal density. Although a decline over time was found, this effect was the same for the two hemispheres. In a previous study (Salmaso, Denes, & De Stavola, 1976) with a high signal density, we found the relative specialization of each hemisphere affects also the performance of an attention task. In that work the sensitivity was greater for the left hemisphere on a verbal attention task and for the right with nonverbal material. The present study was done to see whether a low signal density and a fast event rate would produce the predicted superiority of the left hemisphere, irrespective of the type of stimulus presented. Since many data that show different asymmetries for men and for women are available, the sex of subjects was also studied.

METHOD

Subjects

Subjects were 16 students, 8 men and 8 women, at the University of Padova. They ranged in age from 18 to 25 yr. All were right-handed as measured by the Edinburgh Handedness Inventory (Oldfield, 1971), with right eye preference. All had normal or corrected visual acuity.

Stimuli

The stimuli, similar to those used in a previous experiment (Salmaso, Denes, & De Stavola, 1976), were pairs of letters and pairs of lines, vertically arranged to prevent scanning effects (Bryden, 1966). Fig. 1 shows the material here used.

One pair, for the letters and for the lines, was used as nonsignal, or habituating stimulus, and all the others as signals. The stimuli were back-projected onto a translucent screen by a Kodak Carousel slide projector equipped with a photographic shutter. When projected the size of every pair was about $1 \times 0.5°$, and they appeared 9° to the left and to the right and on a level with a central fixation point.

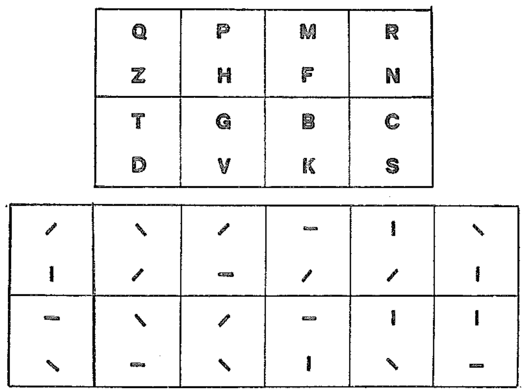

FIG. 1. Letter and line pairs used in the present experiment

Procedure

Subjects were divided in two groups (4 men and 4 women for each group): the first received only letter pairs and the second only line pairs. Two different sequences of 160 pairs were presented to every subject, one to the left visual field and the other to the right. In every sequence, subdivided in two equal periods, 32 stimuli were signals, for which an overt response was required, and the remainder were repeated presentations of the same pair. To habituate the subject, the first 15 slides of every period were a repeated presentation of the nonsignal stimulus. In the sequence, the position of novel stimuli, or signals, was random and the probability that a stimulus presented was in fact a new one was 0.2. To make the test more sensitive to possible differences between the two hemispheres a fast event rate (1 stimulus every 2 sec.) and a very short time of presentation (10 msec.) were used (see review by Loeb and Alluisi, 1977). Furthermore the stimuli were projected only to temporal hemiretinas, which seem to be less efficient than nasal hemiretinas (Harcum, 1978). In this way stimuli presented to the left visual field were directed to the right hemisphere only by the right temporal hemiretina.

Subjects were seated in front of the screen with the head positioned by a head and chin rest at a distance of 50 cm. They were instructed to fixate the central fixation point and, when the stimulus appeared, to press a key with the right index finger only when sure of having seen a new stimulus and not to press to the habituating one.

Before starting, a practice block of 15 trials was given. Half of the subjects began with presentation in the left visual field and the other in the right.

Scoring

The total number of responses given by the subject in the first and in the second period is divided in two parts, hits (H) and false positives (FP) or errors of commission: hits refer to the number of novel stimuli correctly identified and false positives to the number of "new" responses to the old stimulus. As a measure of sensitivity an estimate of the area under the ROC curve was used, i.e., $P(\bar{A})$ measure (McNichol, 1972) and as a measure of bias, the false positive rate (FPR) (Richardson, 1972). Simple hit rates were also analyzed.

Results

Three four-factor analyses of variance with two factors between groups (sex and material) and two within groups (field and period) were made.

Hit Rates

In terms of correct detections there was a significant difference between visual fields ($F = 18.60$, $df = 1/12$, $p < .005$) with a greater accuracy for the right visual field (0.885, $SD = 0.165$) than the left (0.717, $SD = 0.203$). Moreover, the significant interaction of sex $\times$ visual field shows that this difference depends on the sex ($F = 5.502$, $df = 1/12$, $p < .05$): the difference between visual fields for men is larger than for women (0.211 vs 0.066).

$P(\bar{A})$

For $P(\bar{A})$ measure there is only a significant difference for visual field ($F = 6.71$, $df = 1/12$, $p < .025$) showing a greater sensitivity for the right (0.923, $SD = 0.106$) than for the left (0.868, $SD = 0.126$).

False Positive Rates

In the analysis of false positive rates two main factors are significant: the type of material ($F = 12.857$, $df = 1/12$, $p < .005$) with a greater false positive rate for lines (0.162, $SD = 0.133$) than for letters (0.028, $SD = 0.029$) and the period ($F = 19.201$, $df = 1/12$, $p < .001$) with a larger false positive rate in the second period (0.081, $SD = 0.097$ vs 0.108, $SD = 0.132$).

The interaction of sex by material by period is also significant ($F = 7.935$, $df = 1/12$, $p < .025$). As one can see in Table 1 the greater difference between the first and the second period is for men on the line task.

TABLE 1
MEAN FALSE POSITIVE RATE FOR INTERACTION OF SEX, MATERIAL, AND PERIOD

Stimuli and Groups		Period 1	Period 2
		0.081 $SD = 0.05$	0.108 $SD = 0.07$
Letters	Males	0.033	0.045
	Females	0.016	0.018
Lines	Males	0.186	0.273
	Females	0.090	0.096
		$F = 7.93$, $df = 1/12$, $p < .025$	

Discussion

Hits and Sensitivity

Measures of correct detections and sensitivity show a clear superiority of the left hemisphere as regards its capacity to detect and report, by a manual response, the presence of a novel stimulus. This effect is also independent of the nature of the stimulus presented. Therefore, the results seem consistent with the hypothesis of a superiority of the left hemisphere for signal detection, as was also reported by Dimond and Beaumont (1973) and by Warm, *et al.* (1976) with a low signal density. The difference with our previous work (Salmaso, *et al.*, 1976), where different sensitivities were noted for the two hemispheres according to the type of material, seems caused only by the signal probability. Many experiments in attention, as mentioned in a review by Loeb and Alluisi (1977), have shown that the performance is enhanced under higher signal densities. So, what we can suggest is that with higher signal probabilities the typical relative superiority of each hemisphere may be shown, while with lower signal density two different attention mechanisms may be at work. Support for this comes from two recent works, in which sensitivity has been found larger for the left hemisphere in a letter identification task (Robertshaw & Sheldon, 1976) and for the right in a spatial task or in colour discriminations (Robertshaw & Sheldon, 1976; Davidoff, 1976).

The lack of a significant effect for period and for interaction of field by period does not show any difference between the two hemispheres over time as suggested by previous works (Dimond & Beaumont, 1971, 1973, 1974; Dimond, 1977). In this experiment the period is very short and perhaps the decrease in performance of the left hemisphere could be shown by a longer one. However, we must remember that other works have efficiently used short tasks (Singleton, 1953; Thompson, Opton, & Cohen, 1963; Davies, 1968; Harkins, *et al.*, 1974) and that a decline in sensitivity is not very likely across a set of experiments (Swets, 1977). Another hypothesis may be also advanced. The tasks where a cognitive process is involved (Davies & Tune, 1970) or sufficiently interesting (Montague, *et al.*, 1965) may not show a decline with time. The task here used can fit into this class, especially for two reasons: first, the greater complexity of the material used with respect to that of other authors (Dimond & Beaumont, 1971, 1973; Warm, *et al.*, 1976), and second, the fact that the signal is made of novel stimuli. As shown by Neisser and Lazar (1964) subjects find more quickly a prespecified target than a plurality of targets. Since the brain is constructed as to pay greatest attention to new stimuli, not identified and potentially dangerous, it is therefore possible to hypothesize that the novelty detection does not cause a time decrease.

A significant interaction of sex by field is also found. The difference between the two hemispheres is greater for men than for women and, although a significant effect for sex was not shown, females tend to be more accurate than males. The present result does not agree with those found by Kimura (1969), who reported no sex differences for a spatial localization task, nor with those of Bryden (1976), who found males superior in accuracy of localization. According to other investigators (Bryden, 1966; Lake & Bryden, 1976; Levy & Reid, 1976; Ray, *et al.*, 1976; Davidoff, 1977), this experiment does not give evidence of a minor specialization of females, but, on the contrary, suggests a different hemispheric organization as a function of sex.

Response Bias

As suggested by Richardson (1972), the false positive rates may be taken as a measure of response bias or criterion. For this parameter no differences between the two hemispheres were found, although other significant effects were shown.

The two materials cause a very different number of false positive rates. More false positives are shown with lines than with letters (about 6:1). This difference does not seem due to the greater complexity in detection of the lines, since for hits and sensitivity a similar difference was not proved. This finding seems rather to confirm the independence of the two measures. Support for this comes also from the significance of the "period:" a greater number of false positives occur, and then a lower decisional criterion is adopted in the second period. These data do not agree with those reported by other authors (Mackworth, 1969, 1970; McGrath, 1963; Swets, 1973, 1977), which have shown a decrease in false positives and then a stricter decision criterion as the task goes on. But, in other studies (Binford & Loeb, 1963; Howland & Wiener, 1963; Tune, 1966; Dornic, 1967) a progressive increase in false positives was also recorded. According to Dornic (1967) this effect may be associated with a decrease in the trace strength of the signal, which makes more likely that a nonsignal could be misclassified as a signal. If we accept, as suggested by McGrath (1963), the assumption that false positives are an index of learning of the requested discrimination, one can say that a progressive decline occurred. In fact, since at the beginning of the second period there was a rehabituation of the subject to nonsignal stimulus, one can hypothesize that, especially in the second part, an increase of internal noise may appear for the habituation (Mackworth, 1969). This increase affects the accuracy of the comparison process, allowing only a rough comparison between the habituating and the incoming stimulus. However, if this rough comparison is sufficient when a new stimulus is presented, due to its very dissimilarity, it is not so for the habituating one, and a wrong answer will then be given more easily (Krueger, 1978). According to this hypothesis the difference between stimuli for false positives may be due to the greater similarity, among them, of the line pairs as compared with letter pairs. Therefore the accuracy of the comparison may depend on the level of the internal noise and the difference between signal and nonsignal events.

Finally, false positives are due mainly to the men and this disagrees with Bryden's results (Bryden, 1976), where the contrary has been proved. Unfortunately the reports of sex differences are few and inconsistent. As suggested by Swets (1973) the women can be more conservative than the men, that is, they can adopt a more stringent criterion to decide if a signal has been presented.

Conclusions

The findings of the present experiment show a clear-cut dissociation between sensitivity and criterion: in fact, while the former was lateralized, the latter was not. Both hemispheres efficiently process the habituating stimuli, but in the identification of a novel stimulus the left hemisphere is more accurate than the right.

What are the reasons for this distinction? The human brain allows maximum sensitivity and responsiveness (Mackworth, 1969) to new stimuli and less response to a repetitive event (Sokolov, 1963). According to Broadbent (1975) one can suppose that the former function is mainly sustained by the left hemisphere with categorization of the changes occurring in the stimuli. Support for this comes from information processing studies (Krueger, 1978), where faster "same" judgments are generally reported. In the present task, as for "same-different" paradigm, two different processes seem to account for these findings: one which compares the incoming stimulus to the habituating one, perhaps by template matching, and another which, although not apparently necessary for the response, rechecks the incoming stimulus to determine not only "where" the difference lies (Tversky, 1969) but also "what" it is.

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