Hemispheric differences in a novelty attention task.

Subtitle:

Attention asymmetries.

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Abstract

The purpose of this study was to determine the part played by each hemisphere in a novelty detection task and the role of sex in cerebral asymmetries. Letter and line pairs were presented to the left or to the right visual field and the subjects were instructed to report if the incoming stimulus had been a new one. Performance was scored according to nonparametric estimates of sensitivity and criterion. The main results were a) a clear-cut dissociation between the two measures b) a greater sensitivity for the right visual field presentation, irrespective of the type of material and c) different effects on detections 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 see how the two hemispheres perform a novelty task, that is the detection of changes in a sequence of neutral stimuli. Novelty detection 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 a cognitive change is involved.

Researches 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 and McGrath, 1963; Mackworth, 1970). Several hypotheses have been proposed to explain the nature of this decrement (see reviews in Mackworth, 1969, 1970), but any 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, due to 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, determines an habituation of neural responses, which may result in fewer events, either signals or non-signals, 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 to 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 vigilance decrement.

A considerable number of experiments have compared the relative accuracies of the left and right visual field in identifying and recognising verbal and nonverbal material (see reviews in Krashen, 1976; Springer, 1977), but few studies have been concerned with 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 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, the left hemisphere performance was better at a low signal density, while the right hemisphere was superior at a high signal density. Despite 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 very high signal density, we have found that 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 in a verbal attention task and for the right with nonverbal material. In the present study I want to see whether a very slow signal density and a fast event rate were able to show the predicted left hemisphere superiority, irrespective of the type of stimulus presented. Since many data are today available that show different asymmetries for men and for women, the sex of subjects was also studied.

METHOD

Subjects

Subjects for this experiment were 16 students, 8 men and 8 women, at the University of Padua, ranging in age from 18 to 25 years. 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), consisted of pairs of letters and pairs of lines, vertically arranged in order to prevent scanning effects (Bryden, 1966). Figure 1 shows the material used in the present experiment.

Insert Fig.1 about here

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

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 remainders were repeated presentations of the same pair. In order to habituate the subject, the first fifteen slides of every period were a repeated presentation of the habituating stimulus. The position of novel stimuli, or signals, in the sequence was random and the probability that a stimulus presented was in fact a new one was 0.2.

In order to make the test more sensitive to possible differences between the two hemispheres a fast event rate (1 stimulus every 2 seconds) and a very short time of presentation (10 msec) were used (see review in 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 right visual field were directed to the left hemisphere by the left temporal hemiretina, and stimuli presented to the left visual field were directed to the right hemisphere 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 fifty cm. They were instructed to fixate the central fixation point and, when the stimulus appeared, to press a key with their index finger only when they were sure to have seen a new stimulus and not to press the key to the habituating one.

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

Scoring

The total number of responses given by the subject in the first or in the second period, is divided into two parts: hits (H) and false positives (FP) or commission errors: hits refer to the number of novel stimuli correctly identified and false positives to the number of habituating not identified stimuli. Since we know nothing about the distribution of new and habituating stimulus, I preferred to use non-parametric estimates of sensitivity and response bias. 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). The simple HRs were also analyzed.

RESULTS

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

Hit rates

In terms of correct detections there was a significant difference between visual fields ($F(1,12) = 18.603$; $p < .005$) with a greater accuracy for the right visual field than the left (0.855 vs 0.717). Moreover, the significant interaction sex by visual field, shows that this difference depends on the sex ($F(1,12) = 5.052$; $p < .05$): the difference between visual fields for men was larger than for women (0.211 vs 0.066).

$P(\bar{A})$

For $P(\bar{A})$ measure there was only a significant difference for visual field ($F(1.12) = 6.716$; $p < .025$) showing a greater sensitivity for the right than for the left (0.923 vs 0.868).

FPRs

In the analysis of false positive rates or response bias two main factors were significant: the type of material ($F(1,12) = 12.857$; $p < .005$) with a larger false positive rate for lines than for letters (0.162 vs 0.028); and the period ($F(1.12) = 19.201$; $p < .001$) with a larger false positive rate in the second period (0.081 vs 0.108).

Insert Table 1 about here

The interaction Sex by Material by Period was also significant ($F(1,12) = 7.935$: $p < .025$). As one can see in Table 1, the greater difference between the first and the second period was for men in the line task.

DISCUSSION

Hits and sensitivity

Correct detections and sensitivity measures show the presence of a clear superiority of the left hemisphere as regards its capability 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 to agree with the hypothesis of two different systems in the brain. A superiority of the left hemisphere for signal detection was also found by Dimond and Beaumont (1973) and by Warm et al (1976) with a low signal density. The difference with my previous experiment, where a different sensitivity was found for the two hemispheres according to the type of material, seems caused only by the signal probability. Many attention experiments (see review in Loeb and Alluisi, 1977) have shown that the performance is enhanced with higher signal densities. What I suggest is that with higher signal probabilities the typical relative superiority of each hemisphere may be shown, while with a lower signal density two different attention mechanisms may be at work. Support to this comes from two recent works, in which sensitivity has been found larger for the left hemisphere in a letter identification task (Robertshaw and Sheldon, 1976) and for the right in a spatial task or in a colour discrimination task (Robertshaw and Sheldon, 1976; Davidoff, 1976).

A significant interaction 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 proved, females seem more accurate than males. The present results do not agree with those found by Kimura (1969), who failed to show sex differences in a spatial localization task, nor with those of Bryden (1976), who has found male superiority in accuracy of localization. According to other investigators (Bryden, 1966; Lake and Bryden, 1976; Levy and 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.

The lack of a significant effect for period and for interaction field by period fail to show any possible difference between the two hemispheres over time as suggested by previous works (Dimond and Beaumont, 1971; 1973; 1974; Dimond, 1977). In my experiment the period is very short and perhaps the decrease in performance of the left hemisphere could be shown by a longer period. However, we must remember that other works have efficiently used short tasks (Singleton, 1953; Thompson, Opton and Cohen, 1963; Davies, 1968; Harkins et al, 1974) and that a decline in sensitivity is not very likely across a set of experiments (Sweet, 1977). Another hypothesis may be also advanced. The tasks where a cognitive process is involved (Davies and 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 and 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.

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. Greater FPRs are shown with lines than with letters (about 6:1). This difference does not seem due to the greater detection complexity of the lines, since, for hits and sensitivity, a similar difference was not proved. The results seem rather to confirm the independence of the two measures. Support to this comes also from the significant "period" factor: a greater number of FPR, and then a lower decisional criterion, is adopted in the second period. The significant interaction sex by period by material shows that this effect is mainly due to the men in the line task. 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 the FPRs and then a stricter decision criterion as the task goes on. But in other studies (Binford and Loeb, 1963; Howland and Wiener, 1963; Tune, 1966; Dornic, 1967) a progressive increase of the FP was also recorded. According to Dornic (1967) this effect may be due to a decrease in the trace strength of the signal, which makes more likely that a nonsignal can be misclassified as a signal. If we accept, as suggested by McGrath (1963), the assumption that the FPs 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 stimulus, and a wrong answer will then be given more easily (Krueger, 1978). According to this hypothesis the difference between the materials in the FPRs may be due to the greater similarity, among them, of the line pairs (as compared with letter pairs). Therefore, one can state that the accuracy of the comparison process depends on the level of the internal noise and on the difference between signal and nonsignal events.

Finally, in this experiment, the FPRs are due mainly to the men and this disagrees with Bryden's results (Bryden, 1976), where the contrary was found. The findings of sex differences on this topic are very little and inconsistent. Perhaps the women are more conservative than the men, that is they 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 of this distinction? The human brain is constructed in such a way to allow maximum sensitivity and responsiveness (Mackworth, 1969) to the new stimuli and not to respond 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 a categorization of the changes occurring in the stimuli. Support to this comes from information processing studies (see review in Krueger, 1978), where a faster "same" judgement than a "different" is generally reported. In this task, as for same-different responses, 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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FIGURE CAPTION

Letter pairs and line pairs used in the present experiment

Table 1. FPR means for the interaction sex-material-period

	1st Period	2nd Period
LETTERS		
MALES	0.033	0.045
FEMALES	0.016	0.018
LINES		
MALES	0.186	0.273
FEMALES	0.090	0.096

* F = 7.935 p = .025