ON THE HYPOTHESIS OF A DIFFERENTIAL HEMISPHERIC CAPACITY FOR SPATIAL FREQUENCY ANALYSIS

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ABSTRACT

Two experiments were conducted to test the hypothesis of an hemispheric specialization in the spatial frequency analysis. Reaction times were collected for gratings of different spatial frequencies presented to the left and to the right visual field. An interaction was found between visual fields and spatial frequencies, with a clear left visual field-right hemisphere advantage for high spatial frequency processing. Results are discussed in terms of the relative spatial/temporal properties of visual stimuli that could activate mechanisms specific of each hemisphere.

INTRODUCTION

In the research on cerebral hemisphere asymmetry, a new model has been proposed by Sergent (Sergent, 1983a; 1983b). According to this model the laterality effects in complex visual information processing might be explained by the different functional specialization of the two hemispheres for spatial frequency analysis, the right hemisphere (RH) being specialized in the processing of low resolution and low spatial frequency information and the left hemisphere (LH) in the analysis of high resolution and high spatial frequency information. Sergent has proposed the model on the basis of results obtained in experiments with complex visual information like faces and letters (Sergent, 1982a; 1982b; 1983a). In the discussion on Sergent's model (Hardyck, 1983; O'Boyle, 1985; Versace & Tiberghien, 1985), two points have not been adequately considered.

Firstly, the involvement of spatial frequency analysis in the processing of complex information, like letters and faces, by the two hemispheres is a very speculative hypothesis. Furthermore, although spatial frequency investigation was aimed to provide a model of visual perception on the basis of simple physical parameters (Maffei & Mecacci, 1983; Marr, 1982), there are not definite experimental results on the role played by spatial frequency analysis in the complex visual information processing. An exception is represented by face perception, where spatial frequency filtering appears to affect recognition (Fiorentini, Maffei & Sandini, 1983).

Secondly, the power of Sergent's hypothesis is strongly restricted by the fact that she has not used the stimuli best suited for this kind of research, i.e. gratings of different spatial frequencies.

The aim of this paper is to present data collected from two experiments with different gratings presented to the left (LVF) and to the right visual field (RVF). In the first experiment the spatial frequency of the gratings ranged from 1.4 to 14 cycles per degree (c/d), while in the second experiment spatial frequencies ranged from 0.9 to 13.0 c/d.

EXPERIMENT 1

Subjects - Subjects were 10 students (5 males and 5 females; 18 to 25 yr. old) of the University of Rome. All were right-handed as measured by a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971; Salmaso & Longoni, in press) with right eye preference and had normal or corrected visual acuity. They were paid for their participation.

Stimuli - Stimuli were 8 vertical gratings of various spatial frequencies (from 1.4 to 14 c/d). The gratings had all the same mean luminance (44.2 cd/m2) and the same contrast (0.5). The contrast is defined as Lmax-Lmin/Lmax+Lmin, where L is the luminance of the black and white bars measured on the screen. The gratings were mounted in slide holders for tachistoscopic projection on a back-projection screen, and were flashed through an aperture disk of 2.8 degrees of diameter. The centre of the disk was 4.2 degrees from the central point of fixation. Empty disks of the same mean luminance of the gratings were used as blank stimuli.

Procedure - The subjects were seated in front of a translucent screen at a distance of 60 cm and maintained a constant head position by holding their foreheads against a head-rest. An acoustic signal prompted the subjects to fixate a clearly marked central point on the screen. 500 msec after the warning signal a slide was projected for 90 msec. The interval between presentations was of 4 sec. Each frequency was randomly presented 16 times, while blank intermingled stimuli were totally 32. Presentations were evenly distributed between LVF and RVF. Subjects were instructed to respond by pressing a key with their right (or left) index finger as soon as they detected the gratings and to refrain from responding when a blank stimulus was presented. Eye movements were controlled via a TV camera.

RESULTS

Response latencies longer than 1 sec. and latencies on errors were eliminated from the analysis. They were below 3% of rials. Spatial frequency of presented gratings affected reaction times (RTs): latencies went from 344 msec for the lowest spatial frequency to 382 msec for the highest ($F=11.08$; $df=7,63$ $P<0.001$). The visual field interacted significantly with the spatial frequency of presented gratings ($F=4.34$; $df=7,63$; $P<0.001$).

EXPERIMENT 2

Subjects - Fourteen new subjects (18 to 25 yr. old; 7 males and 7 females) participated in the experiment. All subjects were classified as right-handed.

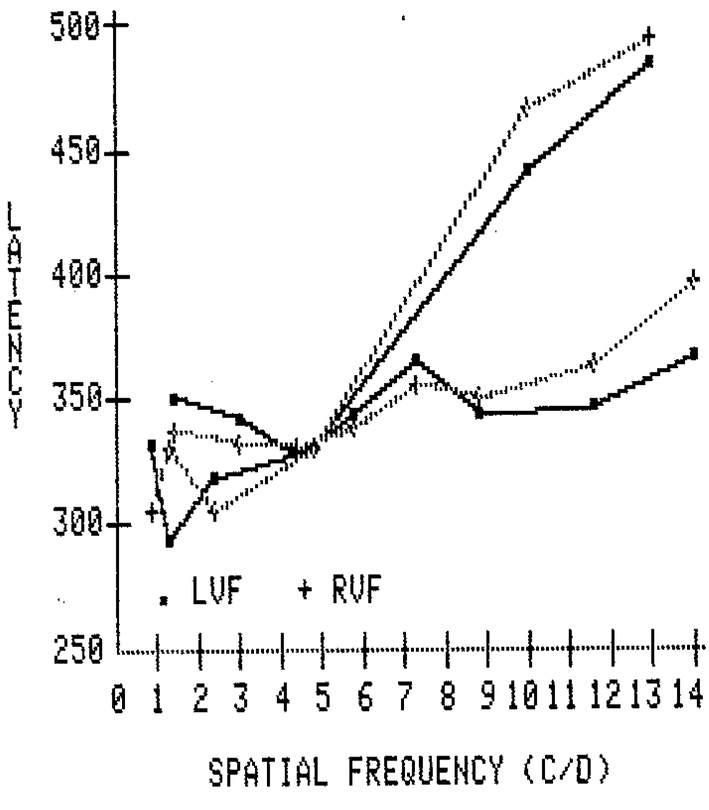
Stimuli - In this experiment we used a set of six new vertical gratings of various spatial frequencies (from 0.9 to 13 c/d). The gratings had a mean luminance of 450 cd/m2 and the same contrast (0.4). The gratings were flashed through a disk of 2.3 degrees of visual angle in peripheral presentation. The centre of the disk was 2.1 degrees from the fixation point.

Procedure - Each frequency was randomly presented 24 times, while blank stimuli were totally 16. Presentations were evenly distributed between LVF and RVF.

RESULTS

RTs varied significantly as a function of spatial frequency (F=91.6; DF=5,65; P<.001) going from 391.5 msec for the lowest frequency to 493.6 msec for the highest. A significant interaction was present between spatial frequency and visual field (F=4.55; DF=5,65; P<.005).

FIGURE CAPTION: RTs to gratings projected in the LVF and RVF for two different sets of spatial frequencies.



DISCUSSION

Both experiments confirm the increase of RTs going from low spatial frequencies to high spatial frequencies as previously reported for centrally presented stimuli (Breitmeyer, 1975; Parker, 1980). As discussed in a recent article (Salmaso & Mecacci, in press) peripheral presentations increase RTs, but they do not selectively affect spatial frequency analysis.

The above experiments show an interaction between spatial frequency and visual fields: this interaction, however, is not in the direction suggested by Sergent's hypothesis. In fact both experiments, as shown in the figure 1, reveal an advantage of the LVF, i.e. the RH, for higher spatial frequencies, while for medium and low frequencies the results are much less clear. The use of a different set of spatial frequencies in the two experiments did not modify the basic pattern of responses, even if longer RTs to high spatial frequency gratings appeared in the experiment 2. In agreement with psychophysical data (Vassilev and Mitov, 1976) this last result may be due to the lower contrast an
d/or higher luminance of the gratings in the second experiment.

The main proposal of a differential effect for elementary parameters of the visual input on hemispheric processing cannot be discarded. Our findings do not support the idea that hemispheric asymmetries in information processing emerge only at a higher level of analysis (Moscovitch, 1979), thus confirming previous results obtained with very simple stimuli (e.g. Brown et al, 1984; Davidoff, 1982; Davis & Wada, 1974; Umilta et al., 1979). In this respect, a particular consideration should be devoted to the hemispheric asymmetry of spatial frequency analysis. This hypothesis cannot simply postulate a dissociation between low and high frequencies. As evidenced by neurophysiological and psychophysical studies (Ikeda & Wright, 1975; Todd and Van Gelder. 1979) spatial frequencies are analyzed by two different systems: the transient and sustained visual systems. The two systems are characterized by different capacities in dealing with temporal and spatial parameters and both parameters are used in normal vision. The same properties were indicated by Davis and Wada (1977, 1978), recently reproposed by Brandeis and Babkoff (1984), as specific of each hemisphere, i.e. temporal characteristics should be associated with LH activity, while spatial characteristics should be better analyzed by the RH. Davis and Wada also suggested that the relative amount of spatial and temporal information present in visual stimulation calls for the activity of the LH or the RH. The spatial/temporal relationship is particularly evident in spatial frequency analysis. The transient system that seems more suitable for low spatial frequency analysis, is more sensitive to high temporal frequencies, while the sustained system, relatively insensitive to temporal modulation, is better suited for high spatial frequency analysis. The RT increase as a function of spatial frequency was interpreted by Breitmeyer (1975) as evidence of a shift from the transient to the sustained systems. In agreement with previous results (Breitmeyer & Julesz, 1975; Kulikowski & Tolhurst, 1973; Vassilev & Mitov, 1976) the distinction between the two systems appears at about 5 c/d. And, in our findings, this spatial frequency seems to correspond to the change in predominance of the hemispheres.

However, it is worth noting that visual stimulation, like that used most often in RT studies, is well above to the critical conditions for each systems and therefore it is unlikely that the mechanisms for responding are restricted to a single system (Parker, 1980). Changes in critical parameters like luminance, contrast or exposure duration could modify this situation determining a more clear prevalence of one or the other system with a more definite advantage of one or the other hemisphere.

To conclude, the advantage of the spatial frequency model for the understanding of hemispheric asymmetries resides in the possibility to link some aspects of hemispheric specialization to differences in basic neuronal organization. However, much has to be done before understanding the validity and implications of this model for the knowledge of the brain.

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FOOTNOTE

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