Hemispheric specialization for spatial frequency processing in the analysis of natural scenes

Carole PEYRIN, Alan CHAUVIN, Christian MARENDAZ and Sylvie CHOKRON
Laboratory of Psychology & NeuroCognition (CNRS - UMR 5105)
Pierre Mendès France University, Grenoble

Introduction

The hemispheric asymmetry hypothesis

Data from psychophysics (Ginsburg, 1986), functional neuro-anatomy of magnocellular and parvocellular pathways (Van Essen & De Yoe, 1995), ultra-rapid categorizations in humans and monkeys (Fabre-Thorpe & al., 1998) and simulation militate in favour of the idea that visual analysis starts with a parallel extraction of different elementary visual attributes at different spatial scales, with a coarse-to-fine processing design: A rapid extraction of low spatial frequencies (LFs) allows an initial categorization that is to be confirmed or refuted by the information conveyed by high spatial frequencies (HFs).
Moreover, neuropsychological and functional imagery data have suggested that each hemisphere (at the level of the temporo-parietal junctions - TPJ) could play a key role in spatial frequency processing (Fig. 1): **The right TPJ would predominantly be involved in LFs analysis and the left TPJ in HFs analysis** (Ivry & Robertson, 1998).

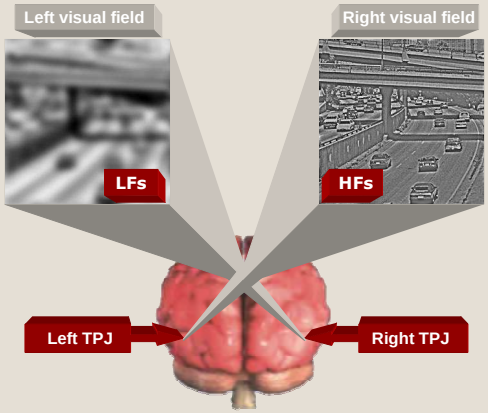


Figure1: *Hemispheric specialization for spatial frequency processing*

Research aims and hypotheses

However, the hemispheric / TPJ hypothesis of spatial frequency processing has never empirically been demonstrated, but rather inferred from data obtained with the hierarchical form paradigm, *without any explicit spatial frequency manipulation* per se. The aims of the present research were:

(i) to investigate, in healthy subjects, the hemispheric specialization for spatial frequency processing in natural scene perception, by altering the picture frequency spectrum.

(ii) to examine whether the 'precedence effect' (the relative rapidity of LFs and HFs processing) depends on the visual field of scene presentation or not.

Experiment

Subjects:
10 right-handed male students (5 per target scene).

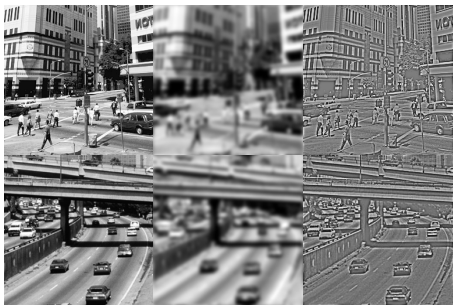
Stimuli:
2 natural scenes, each of them belongs to a different perceptual / semantic category (city and highway).

Procedure:
Identification task; Go / NoGo response: Subjects had to press a button only if the target scene is present. The stimulus was displayed for 100 ms.

- Spatial frequency components of scenes:
  - **non-filtered scene (N)**
  - **LFs scene** (cut-off frequency: 4 cycles per degree)
  - **HFs scene** (cut-off frequency: 6 cycles per degree)
- Visual field of presentation / Hemisphere
  - **Central visual field** (CVF)
  - **Left visual field** (LVF) / Right hemisphere (RH)
  - **Right visual field** (RVF) / Left hemisphere (LH)

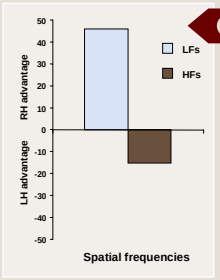
Predictions:
According to the hemispheric asymmetry hypothesis, identification of LFs target scenes should be faster in LVF/RH than in RVF/LH, whereas identification of HFs target scenes should be faster in RVF/LH than in LVF/RH.

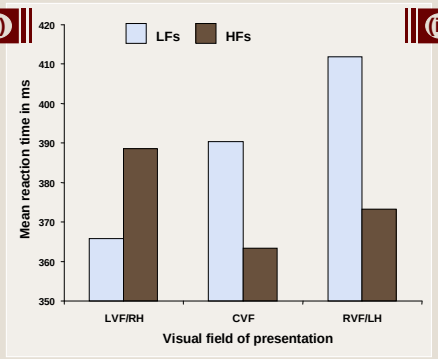
Stimuli

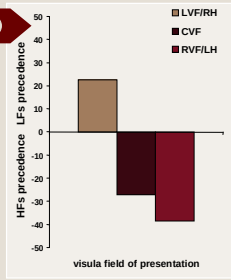


From left to right and top to bottom a non-filtered city, a LFs filtered city, a HFs filtered city, a non-filtered highway, a LFs filtered highway and a HFs filtered highway.

Results







(i) Hemispheric specialization

As expected, there was a significant interaction between the lateralized presentation (LVF and RVF) and the spatial frequency components of target scenes (LFs and HFs) [F(1;8)=10.57, p<.02].

- Identification of LFs target scenes was significantly faster in LVF/RH than in RVF/LH.
- Identification of HFs target scenes was faster in RVF/LH than in LVF/RH, although this difference did not reach significance.

(ii) Precedence effects

There was a significant interaction between the visual field of presentation and spatial frequency components of target scenes [F(2;16)=4.58, p<.03].

- In LVF/RH, LFs target scenes were identified faster than HFs.
- In CVF, HFs target scenes were identified faster than LFs.
- In RVF/LH, HFs target scenes were identified significantly faster than LFs.

Discussion

Results showed that the two hemispheres differed significantly in the way they processed spatial frequencies. There was a right hemisphere superiority in LFs processing, whereas a left hemisphere superiority was observed for HFs. Moreover, we found a 'precedence effect' similar to what had been reported with hierarchical forms (Sergent, 1982), which depends on the visual field of presentation. In conclusion, our study provides the first empirical evidence of a hemispheric specialization for spatial frequency processing when altering the picture frequency spectrum of natural scenes.
Using the same 'ecological stimulus' and the same type of task, we are currently trying to better understand this hemispheric specialization. Firstly, we examine the role of the temporo-parietal junctions in the spatial frequency processing by using neurofunctional imaging (fMRI). Secondly, we analyse the temporal dynamics of the hemispheric specialization by manipulating the duration of the presented stimulus. Actually, preliminary results lead us to think that the nature of the information processed by the perceptual system radically changes during the time course processing, going from a 'frequencial' to a 'spatial' format, and as a result modifies very quickly the hemispheric specialization pattern (Peyrin et al., 2001).

Bibliography:

- **Fabre-Thorpe, M., Richard, G., & Thorpe, S.** (1998). On the speed of scene categorization in human and non-human primates. *Current Psychology of Cognition*, 17, 4, 791-807.
- **Ginsburg, A. P.** (1986). Spatial filtering and visual form perception. In L. K. J. T. K. Boff (Ed.), *Hanbook of perception and human performance* (Vol. II, chap.34, pp. 1-41). NY: Wiley.
- **Ivry, R. B., & Robertson, L. C.** (1998). *The two sides of perception*. Cambridge, MA: MIT Press.
- **Peyrin, P., Chauvin, A., Marendaz, C., & Chokron, S. (2001).** Dynamics of Hemispheric Specialization for Spatial Frequency Processing as a Function of Temporal Constraints. RISC, Paris, October, 2001.
- **Sergent, J.** (1982). The cerebral balance of power; Confrontation or cooperation? *Journal of Experimental Psychology: Human Perception and Performance*, 8 (2), 253-272.
- **Van Essen, D. & DeYoe, E.** (1995). Current processing in the primate visual cortex. In M. Gazzaniga (Ed): *The Cognitive Neurosciences* (pp. 383-400). Cambridge: Bradford Book.