Perception of Natural Scenes: Dynamics of Hemispheric Specialization for Spatial Frequency Processing as a Function of Temporal Constraints

Carole PEYRIN, Alan CHAUVIN, Christian MARENDAZ et Sylvie CHOKRON
Laboratoire de Psychologie Expérimentale (CNRS - UMR 5105)
Université Pierre Mendès France, Grenoble

Introduction

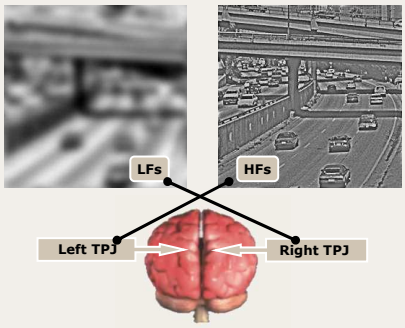


Figure1: *Hemispheric specialization for spatial frequency processing*

'CtF' processing and the 'TPJ' 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 (CtF): 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). However, CtF spatial frequency analysis could be modulated by task constraints and 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).

Research aims and hypotheses:

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

1. to investigate the hemispheric specialization for spatial frequency processing in natural scenes perception, by altering the picture frequency spectrum.
2. to test the influence of visual input presentation time on hemispheric specialization. In relation to the *CtF* design of visual processing and the temporal properties of Magno- vs Parvo systems, we expected an advantage of the right hemisphere for short time presentation displays (scene perception being mainly based on LFs) whereas an advantage of the left hemisphere for a longer time presentation display was hypothesized (scene perception mainly based on HFs).

Experiment

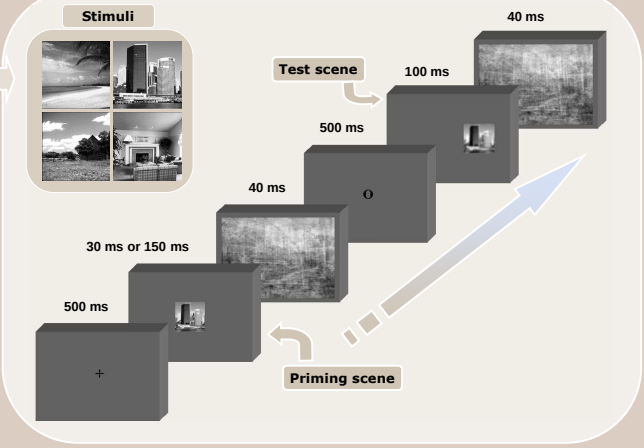
Subjects: 12 right-handed male students (6 per display time)
Stimuli: 4 natural scenes
Each of them belongs to a different perceptual / semantic category (beach, city, country, room).
Procedure: Matching task (Go / NoGo response)
Subjects had to press a button only if priming and test scenes were the same.

- Priming scene: Normal scene (N), central presentation, exposure time of priming scenes: **30** or **150** ms
- Test scene:
  - ✓ **Normal test scene (N)**
  - ✓ **LFs test scene** (cut-off frequency: 2 cycles per degree)
  - ✓ **HFs test scene** (cut-off frequency: 6 cycles per degree)

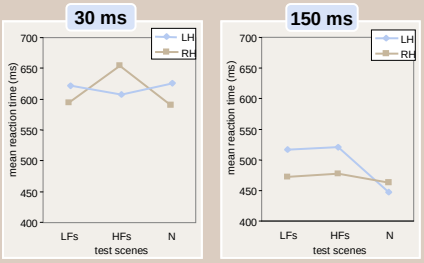
Lateral presentation (100 ms) in either left visual field/right hemisphere (**LVF/RH**) or right visual field/left hemisphere (**RVF/LH**)

Predictions:

- **30 ms:** Matching between priming scene and LFs test scene or N test scene should be faster in LVF/RH than in RVF/LH (no prediction concerning the HFs scenes)
- **150 ms:** Matching between priming scene and HFs test scene or N test should be faster in RVF/LH than in LVF/RH (no prediction concerning the LFs scenes).



Results



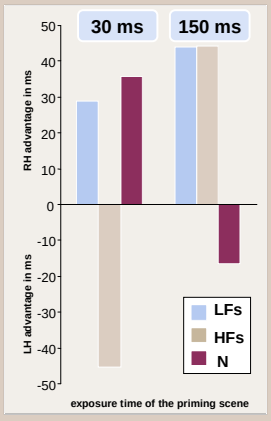
30 ms: As expected, the matching between priming scene and LFs test or N test scene was faster in LVF/RH than in RVF/LH. Interestingly, there was a LH advantage for HFs test scenes (the Filtered Scenes X Hemispheres interaction was significant).
150 ms: Unexpectedly, the matching between priming scene and LFs test or HFs test scene was still faster in LVF/RH than in RVF/LH. No hemispheric difference was observed for N test scenes.

Results showed that:

i. For **non-filtered** scenes (N test scenes), whereas a LVF presentation (RH) entailed a better performance than a RVF presentation (LH) for 30ms displays, this RH advantage in priming N test scene matching is absent for 150 ms displays, indicating that at this stage both hemispheres are equally able to perform the task.
However, the fact that at 150ms the filtering condition (filtered vs non-filtered scene) still significantly affects the LH processing (but not the RH processing) leads us to hypothesize that the two hemispheres do not perform in the same way the priming scene matching task although there is no effect of VF presentation on reaction times.

ii. For 30ms displays, an interaction between the filtering condition and the VF presentation emerged with a **RH advantage for LFs processing and a LH advantage for HFs processing**.

iii. Conversely, for 150 ms, there is no significant interaction between the filtered condition and the VF presentation and results show a **RH advantage** whatever the frequencies processed, confirming the ***RH superiority for spatial organisation***.



Discussion

The fact that subjects' performance in visual scene processing varies according to the visual field presentation, to the filtering condition but also to the presentation time of the stimulus, leads us to propose an ***alternative explanation to the CtF processing***.

We suggest that the nature of information processed by the perceptual system (or, in other words, the type of representation used by the system) varies according to each ***hemisphere functionality*** and ***the time course of the processing***. At early stages a 'frequential' analysis would occur with a LH superiority for HFs analysis and a RH advantage for LFs analysis. At later stages, a more integrated spatial analysis would be at work with a clear RH superiority independent on the frequency attributes of the visual scene to process.

'Frequential' analysis (which would here occur at 30ms) refers to Fourier domain and neuromimetic simulations confirm that this type of signal processing could be particularly useful to produce very fast categorization of natural scenes (categorizations based on amplitude spectra; Hérault & al., 1997). On the other hand, a ***'spatial' analysis*** (here occuring at 150 ms) more classically refers to local characteristics and properties of the stimulus at different spatial scales. Developing such experiments where the visual field of presentation, the time course of the presentation and the frequency characteristics of the visual scene are manipulated should help us to thoroughly test and develop such a model of visual scene perception.

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