Hemispheric specialization for spatial frequency processing in natural scene perception and Hemianopia (a case study)

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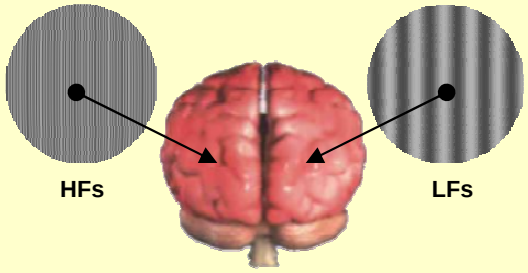
The hemispheric asymmetry hypothesis

Experimental data suggest that visual analysis begins with a parallel extraction of several visual attributes at different scales/frequencies [1-4]. Neuropsychological studies have revealed that each hemisphere (at the level of temporo-parietal junctions-TPJ) could play a key role in spatial frequency processing: The right TPJ would be predominantly involved in low spatial frequency (LFs) analysis whereas the left TPJ would be involved in high spatial frequency (HFs) analysis [5]. Functional imagery data have, however, suggested that the cortical asymmetry in spatial frequency processing could appear earlier (at the occipital level) [6].

Research aims

This functional hemispheric asymmetry hypothesis of spatial frequency processing had been inferred from data obtained with the hierarchical form paradigm, *without any explicit spatial frequency manipulation* per se. The aims of the present research were to investigate, both in healthy subjects and neurological patients, the hemispheric specialization for spatial frequency processing in natural scene perception, by altering the picture frequency spectrum.



Cognitive Psychology study

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).

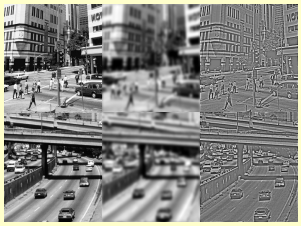
Procedure
Categorization task; Go / NoGo response: Subjects had to press a button only if the target scene is present. The stimulus was displayed for 100 ms.

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)

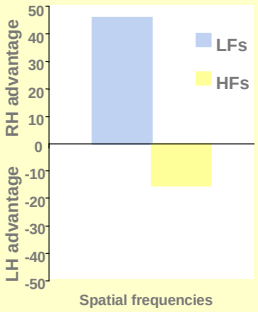
Visual field of presentation / Hemisphere

- **Central visual field** (CVF)
- **Left visual field** (LVF) / Right hemisphere (RH)
- **Right visual field** (RVF) / Left hemisphere (LH)



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



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].

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

Conclusion

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. This cognitive psychology study confirmed the hemispheric asymmetry hypothesis by directly manipulating the spatial frequency of the presented scenes [7].

Neurospsychological study

Recently, Pambakian et al. [8] studied the natural scene processing of homonymous hemianopic patients and showed that only low filtered natural scenes recognition was more impaired in patients than healthy control subjects. Therefore, these results suggested that the primary visual cortex should be at least involved in low spatial frequencies processing.

Moreover, preliminary results of the event-related **functional Magnetic Resonance Imaging** (fMRI) study we are currently conducting suggest that the primary visual cortex would be asymetrically involved in spatial frequency processing: LFs processing shows a larger activation in the right primary visual cortex whereas HFs processing shows a larger activation in th left primary visual cortex.

In this way, study of patients suffering from left or right homonymous hemianopia should allow us to specify the part played by the primary visual cortex in spatial frequency processing.

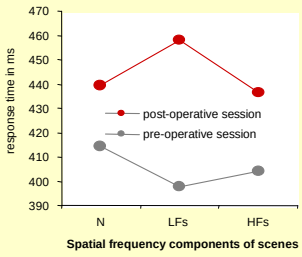
A case study

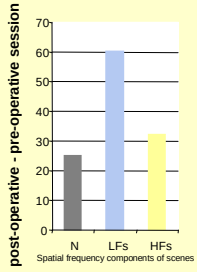
Experiment

Patient
Patient JM who underwent an embolization of the right primary visual cortex. As a consequence, she suffered from a left homonymous hemianopia.

Stimuli and Procedure
The cognitive psychology study paradigm was presented to JM.
The experimental paradigm was presented to JM on week before the intervention (**pre-operative session**) and six months after (**post-operative session**).
The scenes were always presented in the healthy right visual field.

Results





Categorization of scenes was slower for the post-operative session than the pre-operative session [F(1;30)=10.33, p<.004]. Nevertheless, this effect was significative only for filtered scenes: [F(1;30)=11.99, p<.002] and [F(1;30)=7.75, p<.01] for LFs and HFs, respectively.

No difference was observed between spatial frequency components of scenes for the pre-operative session and the post-operative session [F(1;30)<1, p=0.42 and F(1;30)=1.75, p=0.18, respectively].

Nevertheless, there was a significative interaction between the experimental session and the filtered scene (LFs and HFs) categorization [F(1;30)=4.81, p<.04].

This interaction is due to a significantly slower LFs scenes categorization than HFs scenes categorization [F(1;30)=5.81, p<. 03].

Conclusion and Discussion

Only the filtered scenes were slowed after surgical intervention. In addition, LFs target scenes categorization was more impaired than HFs target scenes.

As a whole, these Cognitive Psychology and Neuropsychological studies confirmed the role of the right visual cortex for low spatial frequency analysis.

We are currently testing other hemianopic patients with filtered and no-fltered scenes to add evidence to the hemispheric asymmetry hypothesis for spatial frequency perception.

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