

# NAVIGATING IN THE COGNITIVE SPACE OF WORDS : ORIENTATION MECHANISMS AND REPRESENTATIONS

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**Related research areas:**

- Neuro-ophtalmology
- Language: Dyslexia

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**Abstract**

The present proposal aimed at determining the mechanisms and representations that underlie eye guidance in reading. It was based on a multi-disciplinary approach, combining knowledge and methods issued from different research domains such as the psychology of reading and the neuro-physiology of eye movements. Conducted research served first to complement previous research on the determinants of eye guidance in reading by the expert reader, and second to characterize the quality of oculomotor control for patients presenting neuro-ophtalmic deficits.

Research on expert readers showed that the ocular behavior in reading is for a great part dependent upon both the properties of the saccadic system and the low-level visual characteristics of the text, with the latter serving as a reference framework for saccade programming. Ongoing cognitive processes associated with the identification of the encountered words would also modulate the eye behavior, but this would occur only occasionally given the slowness of language-related processes. On the other hand, the research conducted on patients showed that neuro-ophtalmic deficits have strong repercussions on the control of saccades and vergence, hence suggesting the need to extend our observations to the reading situation. As a first step, we developed a theoretical and methodological framework for the study of eye behavior in reading with patients presenting different types of deficits. This work proposes new and innovative perspectives for the study of reading that will be conducted in a near future by the different researchers involved in the project.

In conclusion, the present work has served as a starting point for a new research framework that will form the basis for further collaboration and student research training. This multi-disciplinary approach may have in a long run, strong implications in domains related to education and public health.

*Key words:* Reading, Oculomotricity, Vision, Saccades, Vergence, Strabismus, Retinal and Extra-retinal Informations, Word recognition.

*Number of participants:* Psychology: 5; Neuro-physiology: 7.

**Aims and Scopes of the original project.**

Reading is a very complex task which relies on different processes going from low-level visual extraction to higher-level word identification and language-related processes. Reading is however in a first place, an oculomotor activity that enables perceptual and cognitive processes. Indeed, given the strong decrease of visual acuity with retinal eccentricity, the information that can be extracted on a given eye fixation is restricted to a very small region of text. More information becomes available for further processing only through the execution of very quick eye movements or 'saccades' which move the point of maximal acuity along the lines of text.

The eye behavior being fundamental to reading, the question of the characteristics and determinants of the eye movement pattern of expert readers is therefore central for a complete understanding of the reading process. A model of eye movement control for expert readers could in addition serve the perspective of developing new tools and methods to diagnose and re-mediate the reading deficits that arise from different sources. A first step would require to isolate the variables that are responsible for the ocular behavior in reading, including those that favor an optimal reading behavior. On the other hand, it should be determined whether and how ocular deficits can affect the quality of both oculomotor control and reading.

The present proposal was designed in reference to that framework. The first goal was to provide a detailed analysis of the variables that strongly influence the eye behavior in reading for the expert reader, and most likely the variables that determine the spatial characteristics of saccadic eye movements. Three steps were planned in order to study (1) the autonomy of eye behavior as regards to ongoing language processes, (2) the role of low-level visuo-motor factors in determining saccade amplitude (with a distinction being made between retinal and extra-retinal information), (3) the characteristics of regressive saccades that are often made in response to an inappropriate positioning of the eyes on the line of text. The present approach combined expertise in different research domains, including vision, psycholinguistics, and oculomotor control.

The second goal was to investigate the quality of oculomotor control for people presenting ocular deficits such as strabismus, vertical hyperphoria, or insufficient vergence. Both simple oculomotor experiments and reading studies were planned, although the latter first required to develop an appropriate and simple experimental paradigm.

### **Summary of obtained results**

A first set of studies was designed to determine the variables that are critical to eye guidance and saccade programming in reading. These revealed, in contradiction with a cognitive control hypothesis, that low-level visual and oculomotor factors intervene in the first place in determining where the eyes move next. Ongoing perceptual and linguistic processes associated with the words in parafoveal vision being relatively slow, these would only intervene punctually by modulating the length of a default forward saccade. The eyes would be driven along the lines of text in a relatively autonomous manner, being pulled forward by the visual information ahead of visual fixation. Rather than aiming for a precise target word location, saccades would be programmed in reference to the screen frame, or the frame of the visual display. These would also make no recourse to internal or extra-retinal references such as the position of the eyes in the head. Indeed, as shown in a series of experiments, when forward saccades were executed to an isolated word or meaningless letter string presented initially in parafoveal vision, these were systematically biased towards the center of the screen. However, when the position of the initial fixation point and the target word were manipulated relative to the primary or straight-ahead position (with the initial fixation point being always at the center of the screen), no bias could be observed. More than having strong theoretical implications, the present data may be of great interest at an applied level since they suggest that the center of the screen or the center of the page of text is the optimal location for the presentation of critical information.

The second set of studies was concerned with the quality of oculomotor control for people presenting neuro-ophthalmic deficits. These revealed the strong repercussions of deficits such as strabismus, vertical hyperphoria, and insufficient vergence on the control of both saccadic and vergence movements, and the main role exerted by high-level cortical mechanisms. First, a motor strategy such as the range effect applies to the saccades made by the two eyes of strabismic patients, while only one eye can accurately fixate a visual target. On the other hand, the control of vergence depends on both sub-cortical and cortical structures, hence suggesting the need to investigate saccade and vergence control in reading. At a more applied level, the present research has proposed new objective methods to measure scope and limitations of both surgery (in the case of strabismus) and orthoptic re-mediation (for problems associated with insufficient vergence).

In parallel, a considerable amount of work was devoted to define the theoretical and methodological frameworks for the study of eye guidance in reading by patients presenting ocular and visual deficits. This work has led us to propose new and innovative perspectives for the study of reading. In a short run, a series of experiments is planned in order to measure the quality of saccadic and vergence control for neuro-ophthalmic patients in a reading task. These experiments will also examine whether the eye movement pattern of patients differs from that adopted by expert readers. Similar tests are planned with both normal and dyslexic children. This long term project will be conducted by the different researchers involved in the present project.

### **Related Publications**

Bucci MP., Kapoula Z., Yang Q., Bremond-Gignac D. & Roussat B. (2001) Binocular coordination of saccades in strabismic children before and after surgery. 8th Child Vision Research Meeting (CVRS), 14-16 juin, Paris.

Bucci MP, Kapoula Z, Yang Q, Wiener-Vacher S & Bremond-Gignac D. Eye movements in 3D space in a young subject with Congenital Central Hypoventilation Syndrome (CCHS). Submitted to Neuro-Ophthalmology.

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Kapoula, Z., & Vitu, F. (2000). La lecture et la mobilité du regard. Tribune Internationale des Langues Vivantes, 28, 10-17.

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Yang Q, Bucci MP & Kapoula Z. (2002). The latency of saccades, vergence and combined movements in children and in adults. Investigative Ophthalmology & Visual Science, 43, 2239-2949.