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ED DESPEG

Doctoral School in Law, Political Science, Economics and Management

Proposition de Sujet de Thèse 2021

2021 PhD Subject Proposition

Title of the PhD research project: Eye movements in response to different brain activities measured by eye-tracking: a prospective and modeling study.

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Subject description:

Vision is a dominant sense in humans over other senses, with the greatest number of visual receptors (around 100 million photoreceptors in the retina), and a large area of the cortex processing visual information. This might be why the eyes are often called: the "mirror of the soul". The eyes are in constant movement to optimize the encoding of the visual scene by the brain. **Eye movements are controlled by complex neural networks that interact with other areas of the brain.** Our brain activity (imagination, internal dialogue, activity, processing, memory, etc.) could thus influence the eye behavior and particularly the direction of our gaze (a brief movement that would be instinctive and unconscious). Conversely, different non-conventional practices such as Eye movement desensitization and reprocessing (EMDR) are using eye movements to treat problems such as post-traumatic stress disorders (PTSD) (Valiente-Gomes et al. 2017).

The relation between brain activity and eye movements has been hypothesized by Neuro Linguistic Programming (NLP) developed in the 1970s by Richard Bandler and John Grinder (psychologist and linguist respectively). This theory interprets gaze directions as revealing specific mental states such as recall of memories, imagination etc. (Figure 1, left). According to this theory, depending on the visual path observed, one could go back to the participant's thought and cognitive process. However, to date, although NLP is widely used in many disciplines (communication, psychology, psychotherapy, marketing, ...), few scientific studies have examined the validity of this theory which has many economic repercussions, and the existing studies used techniques with some biases (Buckner M., et al. 1987, Sharpley, C. F. 1984).

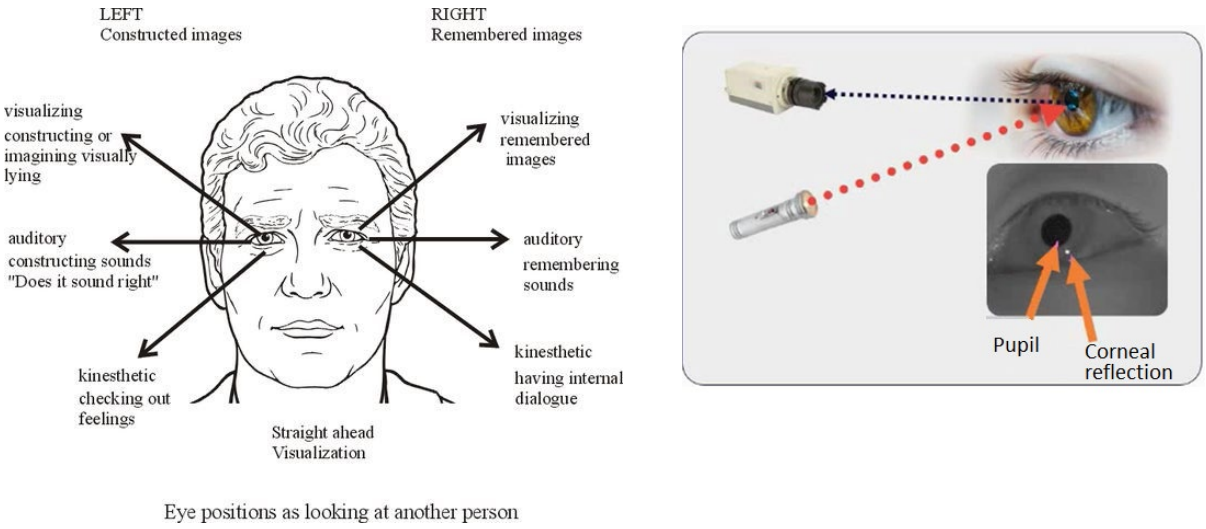

Figure 1: Left: Visual representation of the NLP hypothesis to be tested. Different mental activities lead to selective eye movements. Right: principle of the eye tracker. Infrared light beam reflected on the pupil and captured by sensors makes it possible to deduce the orientation of the gaze.

Eye-tracking is a method that consists of seeing in real time where our gaze is directed (Figure 1, right). It is a process that has been used in research, especially in behavioral studies, for many years (there are traces of eye-tracking in scientific writings since 1946 (see Tinker, 1946; Yarbus, 1967). Many studies converge to say that gaze position and fixation duration reveal the type and dynamics of processing of information such as image and lexical processing (Koëning, 2016), contextual recall and meaning integration (Staub & Rayner, 2007; Albrengues et al., 2019), prediction and imagination (Lavigne et al., 2000; Rodionov et al., 2004; Sprenger et al., 2010). The applications of eye movements are diverse: in neurological and sociological studies, but also in more marketing applications.

During this thesis, with the help of the eye tracking system, we will test the hypothesis that eye movements in different directions could be correlated to different mental activities supposed to engage different brain areas (for instance imagining or remembering visual, auditory or tactile events), one of the pillars of NLP on visual language. We will use a protocol in which the participants have to listen to a series of questions of different types, supposed to activate selected brain neural networks, while looking at a cross on a screen. We will record the oculomotor behavior and gaze direction (using Tobii system) at the end of each question. Preliminary results using such protocol show that 1) Complex questions elicit significantly more eye movements than control question that do not necessitate reflection, 2) According to the different question types, the movements are not random but are orientated in selected directions 3) The orientations observed are not those predicted by the NLP theory.

This pilot experiment paves the way for deeper investigations. To understand better the relation between eye movements and brain activity (Dimigen et al., 2011), **we will use eye tracking coupled to a virtual reality helmet** (allowing more flexibility in the eye movements recordings and reducing the bias of head movements), together with **EEG techniques with localization of the sources of emission** (in collaboration with Theodore Papadopoulo from the Athena team of INRIA, Clerc et al.2012), in order to correlate the gaze orientation with selected cerebral activity. We will also use *a-posteriori* **micro-phenomenology techniques,** a new scientific discipline that enables to explore our lived experience very finely, like a “psychological microscope” (using the experience of Michel Bitbol). This will allow us to reconstruct what were the strategies adopted by the participants to answer to the

questions. We also plan to use **functional MRI coupled to eye tracking** (in collaboration with Stephen Ramanoel from University Côte d'Azur, Delaux et al. 2021) in order to decipher the tight links existing between eye movements and brain neural network activities.

Using the actual knowledge on the neural networks governing eye movements and their interconnections with different brain neural networks, and with the help of Bruno Cessac team in INRIA (Souhiel and Cessac 2021), we will build a ***mechanistic computational model*** (containing a populations of neural elements, interconnected in a biologically plausible manner, targeting muscles governing eye movements) to progress in our understanding on the correlations between different brain activities and the gaze orientations. This model could allow predicting the gaze orientation when we are thinking to the answer to new questions.

This transdisciplinary project, which combines the use of new technologies, modeling and human sciences, could lead to numerous applications in the fields of **neuroscience** (comprehension of the interactions between neural network involved in specific mental activities and those controlling eye movements), **psychology and sociology** (improvement of the knowledge in non-verbal communication: observing eye movements could give precious information on conscious or unconscious mental activity) and **health** (better comprehension of the underlying mechanisms of practices such as EMDR and other practices using eye movements to regulate the brain activity).

In addition, it will bring new insights in **innovative technologies for research**. On the one hand, we will be using **virtual reality coupled to eye tracking, together with digital analysis of active brain areas (source localization in EEG and fMRI)** in order to progress in the knowledge of the links between eye movements and brain activity. On the other hand, this work could be relevant for **improving technologies for research** coupling virtual reality helmet, eye tracking and online brain activity recording, as we will have to synchronize the recorded data and optimize their analysis.

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