Attentional orienting in real and virtual 360-degree environments

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Attentional orienting in real and virtual 360-degree environments: applications to aeronautics

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ABSTRACT

We investigate the mechanisms of attentional orienting in a 360-degree virtual environments. Through the use of Posner's paradigm, we study the effects of different attentional guidance techniques designed to improve information processing. The most efficient technique will be applied to a procedure learning tool in virtual reality and a remote air traffic control tower. The eye-tracker allows us to explore the differential effects of overt and covert orienting, to estimate the effectiveness of visual research and to use it as a technique for interaction in virtual reality.

CCS CONCEPTS

• **Human-centered computing → Virtual reality**.

KEYWORDS

attentional orienting, virtual reality, attentional cueing

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1 INTRODUCTION

When a friend says: "Be careful, behind!", you perform privileged processing of information coming from behind, and possibly turn around to avoid possible danger; it called "attentional orienting" [Posner 1980]. Such orienting can be guided, as in a movie. Camera framing and movements select the most relevant information from the scene. However, what happens in a 360-degree environment when the viewer can turn his head in any direction?

1.1 Research Objectives

How to effectively direct attention without cinematographic tools? We aim to understand the attention processes in 360° environments, such as a virtual world experienced through a head-mounted virtual reality (VR) display. This technology offers a realistic, perfectly controlled and configurable situation, all in good safety conditions. It is a promising tool for training or educational applications and we need to understand how attention works to design efficient tools adapted to our cognitive system limits. Specifically, we will determine the most effective ways to direct a person's attention outside the central visual field.

1.2 How we orient attention and measure it?

Attentional orienting can be studied via the visuospatial orienting paradigm called after Michael Posner [1980], in which participants are asked to detect as quickly as possible the occurrence of a target on a computer screen. This target is likely to appear on the left or right side. Before the target, the future location is cued. The cue can predict the target position (valid), indicate a wrong position (invalid) or be non-informative (neutral). Following a valid cue, we observe a processing benefit (speed and accuracy) compared with a neutral condition; if we focus on the wrong location, we observe processing costs [Chica et al. 2014]. The cost/benefit balance allows studying the attentional orienting. Two types of cues are generally used: exogenous cues that automatically capture attention, and endogenous cues that require top-down processing.

With VR and eye tracking, we can explore the person's visual paths (fixation and eye saccade that reflect overt orienting) and the subject's behavioral responses (that provide information on the speed and accuracy of information processing desired). We can also compare overt attention effect on behavioral performance (benefits in response times due to eye movement) and covert orienting effect (benefits in response times in the absence of eye movement).

1.3 Can we orient attention behind?

Can we direct a person's attention outside the visual field? What cues and perceptual modalities could be most advantageous for this purpose? What technique could a director of a 360° movie use to effectively guide viewers' attention to important information?

Unlike the eyes, the ears can simultaneously receive information from 360°. Some studies shown that visual and auditory orienting share common functions [Smith et al. 2010; Wu et al. 2007]; and that auditory cues can improve visual information processing [Frassinetti et al. 2002; McDonald et al. 2000; Van der Burg et al. 2008]. Many studies investigated the crossmodal cueing effect[Driver and Spence 1998a,b; Schmitt et al. 2001]. For this reason, we will observe intramodal (same modality for cue and target) and crossmodal (switching of modality across cue and target) effects that may exist. The literature in frontal space showed that benefits seem to vary depending on the modality, the cue type and the task being performed [Schmitt et al. 2000]. We could assume that used identical cue and target modality (intramodal) are the most effective [Chica et al. 2007] but this is not necessarily true when attention needs orienting in the rear space. We suppose that the auditory

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modality could be more effective to direct attention in 360° due to its wide reception field.

2 APPROACH AND METHOD

In this section, we present the preliminary study, two experiments in real-life and VR conditions, and two application cases.

2.1 Preliminary study

We performed the preliminary study [Soret et al. 2019] where we used a modified version of Posner's paradigm with a head-mounted display considering the visual and auditory modalities. We tested the transferability of Posner paradigm in VR. We expected to observe classic results: an information processing benefit (reduced response times) when the cue indicates the right target position and processing costs (increase response times) when it indicates an incorrect position. This effect could vary according to cues types (exogenous/endogenous) and modality (visual/auditory). We used directional arrows (endogenous auditory cue), voice instructions (endogenous visual cue), object highlighting (exogenous visual cue) and spatialized sounds (exogenous auditory cue).

The results [Soret et al. 2019] revealed a main validity effect (faster RT in the valid condition compared to invalid condition) showing that Posner's paradigm is transferable in VR. We also observed that while flash and voice instruction seems to effectively direct a person's attention to the desired region of space, the directional arrow and spatialized sound seemed to have more difficulties directing attention to a specific location and instead direct attention to a particular hemifield (left or right). We did not observe any effect of subjects' eye movement in response times suggesting the deployment of covert attention.

2.2 Real-life study at 360°

In this study, we aim to understand the attentional orienting outside the visual field. Four "Posner boxes" with integrated speakers and LEDs will be placed around the participant: two in the rear space (one on the left and one on the right) and two in the frontal space. As previously, the cues will be endogenous and exogenous in visual and auditory modalities. For the rear space, a digital mirror system will be used, as studies shown that the stimuli reflected from behind are considered as coming indeed from behind [Spence et al. 2017].

The majority of studies used frontal space only, therefore we expect different effects depending on the crossmodal link. Only studies using an auditory cue and a visual target were conducted at 360° [Lee and Spence 2015]. We assume that using a visual cue and a visual target will be the most effective in frontal space [Chica et al. 2007; Schmitt et al. 2000], followed closely by using an auditory cue and a visual target [Driver and Spence 1998b; Tilak et al. 2008]. Auditory cue and visual target may be more effective than the intramodal visual condition for the rear space [Ho and Spence 2005; Lee and Spence 2015]. In contrast, the use of a visual cue and an auditory target, as well as the use of an auditory cue and an auditory target, should be less beneficial or even have no effect in frontal space [Posner 1978]; but can be effective for rear space. These effects could vary depending on cue type used (endogenous/exogenous) with the assumption of greater effects for endogenous cueing [Barbot et al. 2012].

For this experiment, an eye-tracker will help us to determine the ocular markers of overt and covert attention. It will also allow knowing if the advantage often observed in the processing of frontal information compared to dorsal information can be due to a benefit of overt attention in front of the person [Ho and Spence 2005].

2.3 VR study at 360°

This experiment is similar to the previous one with the difference that we performed it in VR. The choice of two experiments in real conditions and immersive environments was made given the relative weakness of the sound spatialization device integrated into the VR headset. We suppose that the lack of efficiency of spatialized cues in our first experiment may be due to a lack of precision in the sound localization. By comparing the results of the two 360° studies, we can explore this question.

The eye-tracker will have two functions here. As previously, it will allow the evaluation of covert and overt orienting process, but it will also serve as a modality of interaction. We will design a VR "asteroids" game where the "player" has to destroy asteroids by looking at them. These asteroids will appear at 4 different positions (front-right, front-left, rear-right, rear-left) as in the experiment 2.2. Asteroids will be cued using a spatialized sound (exogenous auditory), a vocal instruction (endogenous auditory), written instruction (endogenous visual) or a flash (exogenous visual).

2.4 Application

The best attentional orienting techniques from the previous studies will be integrated into an existing immersive environment to foster checklists learning for pilots. Procedural learning is guided by two essential factors: the transformation of declarative information (knowledge) into action [Anderson 2000; Carlson et al. 2015] and repetition through practice [Anderson 2014]. VR enables this repetition through practice in an unlimited way. Attentional orienting improves visual research and guides the learners to the important elements. Therefore, it could improve their indexing in memory, reduce the cost of processing and the cognitive load, improving the transformation of declarative information into actions [Hoareau 2016].

Second, we will develop guidance systems for aviation safety and, more specifically, for remote control towers. The new virtual control tower concept allows the addition of information on screen (that replace glasses) to direct controllers' attention to important information. The eye tracker could be used to find out where the controllers are drawing their attention and telling them where they should focus their attention instead.

3 CONCLUSION

In summary, we will study attentional orienting in 360° immersive environments using a Posner-like paradigm in virtual and real 360° environments to determine: if there are cues that can direct attention in this context; if there are cues that are more effective than others in this attentional guidance objective (cues types × modalities); if it's possible to direct attention outside the subject's visual field (360° real and virtual) and if this knowledge can help to create and/or improve VR procedure learning devices or build better warning signals for air or road safety, for example.

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