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How visual background motion and task difficulty modulate players' performance in a shooting task

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ABSTRACT

In many virtual environments, such as those of video games, the scene background moves to give the illusion of movement. In the present study, two experiments were designed to investigate the combined impact of lateral background motion and task difficulty on players' performance in a target-shooting task. Participants had to perform the task on either the moving or the stationary version of a patterned background that was either green (Experiment 1) or black-and-white (Experiment 2). The difficulty of the task was manipulated by varying the number of visual features shared between the target and distractor items. In accordance with the literature, the participants' performance was worse, and the number and duration of participants' fixations increased when the task was difficult. Background motion had an additive, negative impact on performance. When the background was black-and-white, background motion had an impact only when the task was easy but not when it was difficult. Design recommendations based on manipulations of the background characteristics are proposed to establish the level of difficulty in simple video games that use lateral background motion.

1. Introduction

Because challenge is a main factor in players' engagement in a game e.g., [1], optimal player-video game interaction is obtained when the game presents a challenge for players. In contrast with typical human–computer interactions (i.e., linked to productivity), video game displays do not need to be simplified as much as possible to optimize the interaction but must rather be adapted to players' abilities and expectations to maintain their high level of motivation [2,3].

Many studies have shown that challenge is generally set by the difficulty of execution of the main task, which may depend on the number of enemies to hit or avoid, the speed of the enemies' motion, or their level of artificial intelligence e.g., [4,5–10]. However, only few studies e.g., [11–13] have assessed how the characteristics of the game interface, including the visual background, can also be used to modulate game difficulty.

For example, in many video games, the overall scene background moves either periodically or continuously. As detailed below, many studies have shown that the features of the visual background, including background motion [14–18], could impair people's performance in various tasks and situations. Generally, the negative impact of background motion can be explained by people's visual behavior, which reflects attentional processes e.g., [19]. However, few studies have investigated the combined effect of background motion and the difficulty of the game on players' performance. The objective of the present study was to focus on how lateral background motion interacts with the level of difficulty of a simple game to influence players' performance.

1.1. Influence of the design of visual interfaces on players' performance

Several studies have investigated how the characteristics of visual interfaces, such as the position of heads-up displays on the screen e.g., [20,21], 3D stereoscopy e.g., [22], screen size e.g., [23], or the point of view e.g., [24,25], influence players' performance, players' experience, or both. The results are potentially interesting for designers who may better control the challenge presented by games by adjusting the parameters of the visual displays.

Only few studies have addressed the influence of background characteristics on players' performance [11–13]. Knez and Niedenthal [12] studied the impact of background lighting in video games. They showed that better performance was obtained with a warm, reddish lighting than with a cool, bluish lighting. The warm background lighting increased performance because the players found

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it more pleasant than the cool lighting. Wolfson and Case [13] assessed the impact of background color on players' performance across many successive games. When the background was blue, performance increased regularly until the end of the session. When the background was red, the performance increased faster but decreased in the second half of the session. This impact of background color was associated with the players' level of arousal. Red provoked a faster arousal, but habituation effects provoked a decrease in performance after a large number of games were played. Jie and Clark [11] tested the impact of background complexity on players' performance. Participants had to hit targets that were displayed in areas of the screen with either a high or low density of background visual information. The time needed to hit targets was shorter when the target appeared at locations of lower background density. High background complexity disturbed the participants' visual information processing and slowed the target detection processes.

All visual information displayed on the screen, including background information, may have a significant impact on players' performance. According to our knowledge, however, no study has yet investigated the combined impact of visual background motion and the difficulty of the main game task on players' performance.

1.2. Impact of background motion on users' performance

Video game displays are dynamic as all their elements can be modified and they can appear or disappear at any time. The scene background often moves to simulate motion of the player or of the player's avatar within the virtual environment of the game. Several types of apparent motion occur in video games. One of the most frequent motions is lateral motion toward the left or right, which is simulated by a lateral movement of the entire background toward the opposite direction[1].

Both in natural scenes and virtual environments, large-scale motion of the visual background triggers the optokinetic nystagmus (OKN) [26,27]. The OKN is a reflexive, conjugate movement of both eyes in which two phases alternate. During the slow phase, the eyes move in the direction of background motion, ideally at the same velocity, whereas the fast phase regularly returns the eyes to the opposite direction [19,28]. The slow phase of the OKN is a compensatory eye movement that allows the observer to maintain visual input on the retina.

The existence of the OKN has strong implications for activities performed on moving visual backgrounds. Indeed, triggering the OKN negatively affects observers' performance in simple perceptual tasks. Kaminiarz et al. [17] and Tozzi et al. [18] studied the impact of OKN on a target localization task. Participants had to localize a briefly flashed target that was displayed on a laterally moving, patterned background. Because the moving background triggered the OKN, large errors of localization were observed compared with the fixed version of the same background. Caroux et al. [14,15] studied the effect of background motion on the perception of superimposed items during a shooting task. Participants had to detect targets that appeared randomly on patterned backgrounds and shoot them as rapidly as possible. They showed that performance (time to shoot targets) was worse when the background was laterally moving than when it was stationary. Similarly, Harrison et al. [16] demonstrated that background motion decreased performance in a simple task involving the integration of brief auditory and visual signals. Therefore, moving backgrounds decrease performance in tasks that are rather simple, namely tasks that involve transient presentations of stationary items and do not mobilize many attentional resources.

However, moving visual backgrounds do not always have a negative impact on performance, most likely because human observers are able to voluntarily suppress the OKN by fixating any visual item that is superimposed on the moving background e.g., [19,29–31]. Menozzi and Koga [32] compared how people read a text displayed on a laterally moving, patterned background to a fixed version of the same background. Background motion had no effect on reading times or on the eye movements while reading. The main difference with the previous studies was that reading demands many more attentional resources than localizing a briefly flashed target and involves sustained attention to many fixed words and letters that are continuously superimposed on the background. The fact that readers must constantly fixate on text words was apparently sufficient to cancel the OKN and suppress its negative impact on the task. Finally, from a broader point of view, more attention-demanding visual tasks can override automated biological behaviors in general. For example, the effect of background motion on individuals' postural sway (when they are standing) is minimized when the tasks require more foveal fixation [33].

1.3. The present study

Two experiments were designed to simultaneously assess the impact of lateral motion of the scene background and of the difficulty level of the task on participants' performance and eye movements in a video game-like environment. The shooting task was designed with two different difficulty levels. The goal was to find, aim at and hit as fast as possible successive targets, which were always displayed among four distractors. The task difficulty was set by the number of visual features that had to be considered to differentiate the target from distractors. Indeed, visual search experiments have consistently shown [see 34–37 for reviews] that search is more difficult when the target differs from distractors by a conjunction of visual features (i.e., finding a red, vertical bar among green, vertical bars and red, horizontal bars) than if the target differs from all distractors by a single feature (i.e., finding a red bar among green bars or a vertical bar among horizontal bars).

According to visual search experiments [34,35], the first hypothesis was that the performance would be lower when the task is difficult (i.e., when the target differs from distractors by a conjunction of visual features) than when the task is easy (i.e., when the target differs from distractors by a single visual feature). Eye movement recordings have consistently shown that both the number and average duration of eye fixations increased with task difficulty, both during reading and visual search [for review, 38]. Therefore, the second hypothesis was that the number and average duration of fixations are greater when the task is more difficult. Generally, the number of participants' fixations was expected to increase in parallel with shooting times. Although the OKN decreases performance in simple target detection tasks e.g., [17,18], its negative impact can be suppressed when the visual task involves more sustained attention on stationary items [32]. Therefore, the third hypothesis was an interaction hypothesis, which stated that the performance would be lower when the background is moving than when it is stationary but only for the lower level of task difficulty.

An additional goal of the present study was to investigate whether these factors had an effect regardless of whether the background was in black and white or in a "neutral" color. Green was chosen because the literature states that this color has a lower impact on individuals' arousal levels and emotions than red or blue [13,39,40]. Therefore, the findings were expected to be the same regardless of the background color. Consequently, because making

[1] Examples of recent, best-selling video games that use lateral background motion include platform games (e.g., *New Super Mario Bros U*, Nintendo, 2012) or shoot'em ups (e.g., *Sine Mora*, Microsoft Studios, 2012)