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Title

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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.

Keywords

Video game; Challenge; Eye movements; Low-level visual features; Visual perception

Highlights

- Lateral background motion decreases player performance in shooting tasks
- The performance impairment tends to decrease when task-difficulty increases
- The data may be applied to control challenge in simple, shooting video games

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., 11,12,13] 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 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[2].

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

[2] 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).

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 34,35,36,37 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 a hypothesis that predicts an absence of difference would be incorrect, two separated experiments were conducted. The three hypotheses explained above were tested in the same way in both experiments.

2. Experiment 1: Green-colored background

2.1. Methods

2.1.1. Participants

Twenty-two volunteers (15 women) aged *M* = 20.1 years (*SD* = 3.0) participated in the experiment. All participants were native French speakers. They had normal or corrected-to-normal vision and did not suffer from colorblindness.

2.1.2. Apparatus

A head-free Tobii T120 eye-tracker with a 17-inch screen (approximately 27 deg of visual angle; 1280 x 1024 pixels; 75-Hz refresh rate) was used to mimic, as accurately as possible, natural interaction with a computer game interface. A single computer controlled the eye tracker and collected all the data. Gaze positions were obtained at 120 Hz with an average precision of 0.5 degree of visual angle (approximately 5 mm on the screen). Eye movements were analyzed using Tobii Studio 2.0.6 software. Eye fixations were defined as any period in which the gaze remained focused for 58 ms or more within an area of 30 pixels in diameter (approximately 9 mm or 0.9 deg of visual angle). According to the literature, the minimal useful duration of eye fixation for processing information is approximately 50-60 ms [41]. The sampling rate of the eye-tracker that was used in the present experiments was 120 Hz (i.e., one measurement was made every 8.33 ms). Therefore, the nearest value to 50-60 ms that is a multiple of 8.33 was 58 ms. A speaker located in front of the participant was used to display an auditory description of the target (see below). The participants performed the experimental task with a keyboard.

2.1.3. Material

The material was created with “Adobe Director 11” software. A visual background was designed with elements extracted from the video game “Child of Eden” (Ubisoft, 2011) (Figure 1). The background displayed a mainly green dotted pattern on which abstract objects were regularly scattered (main

HSV color scale of the screen: Hue = 120, Saturation = 100, Value = 0 to 100). The objects covered 50% of the surface of the dotted pattern. A stationary and a laterally moving version of this background were used. The laterally moving background moved leftwards at a speed of 121 mm/s (approximately 12 degrees of visual angle per second). The size of the entire visual display was 1280 x 1024 pixels. It was displayed on the 17-inch screen of a Tobii T120 eye-tracker, which was used to collect the eye movement data.

The target and distractors of the shooting task were taken from among four versions of a creature, which could be either blue (HSV: 228, 74, 25-84) or red (HSV: 7, 74, 25-84) and either small (85 x 66 pixels, approximately 22 x 17 mm on the screen) or large (85 x 99 pixels, approximately 22 x 26 mm). The cursor appeared as a weapon crosshair 114 pixels in diameter (approximately 30 mm). The four elements of target description were 0.5 second-long recordings of words uttered by a male voice, namely “blue”, “red”, “large” and “small” (“bleu”, “rouge”, “grand” and “petit” in French).

[Figure 1 near here]

2.1.4. Design and procedure

The experimental design was a 2 X 2 design with the presence/absence of background motion and the level of difficulty of the task (easy or difficult) as factors. These factors were manipulated within participants.

At the beginning of each trial, one of the backgrounds was displayed and an empty black square of 74 mm per side (approximately 7.4 degree of visual angle) was shown at the center of the screen for 1 second to orient the participant’s gaze toward the center of the display without cancelling the potential effects of background motion such as the OKN. The participants were instructed to focus their gaze as much as possible within the square. The two words that described the color and size of the target were uttered one after the other at the moment the black square was displayed. The order of the color and size words was counterbalanced. Then, the target, the four distractors and the cursor all appeared at the same random horizontal position on the screen. The cursor was located on the central vertical axis of the screen, whereas the target was displayed at a random distance to the right or left. Two of the distractors were located in the right half of the screen, and the two other distractors were located in the left half, again at random distances. When the task was easy, the target differed in size and color from all the distractors. When the task was difficult, two randomly determined distractors were the same size as the target but a different color. The two other distractors were the same color but a different size (see examples in Figure 1).

After the target and distractors were displayed on the screen, the participants could move the cursor to aim at the target. The participants had to aim at the target of the color and size given by the two words. To do so, they could move the cursor to the left or to the right of the screen by pressing the left and right arrow keys of the keyboard, respectively. The participants could shoot when they wanted by pressing the “space” key of the keyboard. They could move the cursor and shoot as often as they wished until the target was hit (i.e., as long as the cursor and target were not superimposed when the shot was fired). When the target was hit, the target, distractors and cursor disappeared from the screen, and another trial began.

The shooting task was presented as a simple video game. The participants were asked to shoot the enemy (the target) as fast as possible. A set of 64 trials was presented to the participants as one game. Each participant performed four games, with a pause between each game. A global score was given after the four games had been performed. All trials in a game were performed on the same background, which stayed visible between each trial. If a moving background was used, the motion was continuous for the entire game. The order of presentation of the 4 games (2 games on the moving background and 2 games on the stationary background) was randomized. Within each game, task difficulty was also randomized so that half of the trials were easy, and the other half were difficult.

2.1.5. Dependent measures

The participants' performance was assessed using the average time needed to hit the target (shooting time) as the dependent measure. Additionally, the average number of shots per trial was also measured to assess task accuracy. The participants' eye movements were analyzed using the average number of fixations per trial and their mean duration as dependent measures. For each trial, only the eye fixations that were made while searching for the target were analyzed. Specifically, neither the fixation that was interrupted by the appearance of the target and distractors nor the fixation that was ongoing when the target was hit were included in the analysis. All variables were analyzed using repeated measures ANOVAs with the background motion (presence or absence) and the task difficulty (easy or difficult) as within-participant factors. As is often observed in reaction time experiments, the shooting times followed a non-normal, positively skewed distribution. Therefore, the shooting time data were logarithmically transformed before ANOVAs were performed.

2.2. Results

All premature (shooting times shorter than 100 ms) and late responses (shooting times greater than 3000 ms) were considered errors and were excluded from analyses. Data from one participant for whom the proportion of excluded trials exceeded 15% were not analyzed. For the 21 other participants, the proportion of excluded trials ranged from 0.0% to 9.8% (M = 2.5%) and did not vary significantly across conditions.

2.2.1. Shooting time

As shown in Figure 2, task difficulty had an impact on shooting times, $F(1,20) = 188.00$, $p < .001$, $\eta^2_p = .90$. Shooting times were longer when the task was difficult (M = 1592 ms, SD = 225) than when it was easy (M = 1392 ms, SD = 239). Background motion also had an influence on shooting times, $F(1,20) = 35.50$, $p < .001$, $\eta^2_p = .64$, which were longer with the moving (M = 1546 ms, SD = 247) than with the stationary background (*M* = 1439 ms, *SD* = 247). The interaction between the two factors did not reach significance, $F(1, 20) < 1$.

[Figure 2 near here]

2.2.2. Number of shots

Background motion influenced the number of shots made by the participants, $F(1,20) = 14.02$, $p < .01$, $\eta^2_p = .41$, which was higher with the moving (*M* = 1.20, *SD* = .12) than with the stationary background (*M* = 1.13, *SD* = .11). In contrast, there was no impact of task difficulty on the number of shots, $F(1,20) < 1$. The interaction between the two factors did not reach significance, $F(1, 20) < 1$.

2.2.3. Number and duration of eye fixations

Qualitative observation of the eye movement data displayed by a sample of participants showed that when the background was moving, an OKN consisting of slow phases oriented leftwards interrupted by quick phases oriented rightwards was present between trials. The maximum velocity of slow phases reached 5 to 10 deg/s depending on the participants. When the target and distractor appeared, the OKN disappeared, and only fixations and saccades were visible, most likely because the target and/or distractors were used as stationary "anchoring points" to cancel the nystagmus [19].

As shown in Table 1, task difficulty impacted the number of fixations per trial, $F(1,20) = 36.43$, $p < .001$, $\eta^2_p = .65$, which was greater when the task was difficult (*M* = 3.22, *SD* = 1.32) than when it was easy (*M* = 2.67, *SD* = 1.16). There was a marginal effect of background motion, $F(1, 20) = 3.19$, $p = 0.09$, so that the number of fixations per trial tended to be higher with the moving (*M* = 3.10, *SD* = 1.24) than with the stationary background (*M* = 2.79, *SD* = 1.28). The interaction between the two factors did not reach significance, $F(1, 20) < 1$.

Task difficulty had no significant impact on the mean duration of fixations, $F(1,20) = 1.26$, $p = .26$, which was $M = 201$ ms, $SD = 55$ when the task was difficult and $M = 197$ ms, $SD = 64$ when it was easy. There was no significant effect of background motion, $F(1, 20) < 1$, or any significant interaction between the two factors, $F(1, 20) < 1$.

[Table 1 near here]

3. Experiment 2: Black-and-white background

3.1. Methods

The apparatus, design, procedure and participants of Experiment 2 were the same as those of Experiment 1. The material was the same as in Experiment 1, but a black-and-white version (HSV: 0, 0, 0-100) of the background of Experiment 1 was used.

3.2. Results

As in Experiment 1, all premature (shooting times shorter than 100 ms) and late responses (shooting times greater than 3000 ms) were considered errors and were excluded from analyses. Data from one participant for whom the proportion of excluded trials exceeded 15% were not analyzed. For the 21 other participants, the proportion of excluded trials ranged from 0.0% to 9.8% (M = 2.8%) and did not vary significantly across conditions.

3.2.1. Shooting time

As shown in Figure 3, task difficulty impacted shooting times, $F(1,20) = 199.13$, $p < .001$, $\eta^2_p = .91$. Shooting times were longer when the task was difficult ($M = 1{,}586$ ms, $SD = 240$) than when it was easy ($M = 1{,}381$ ms, $SD = 239$). Background motion also influenced shooting times, $F(1,20) = 8.16$,

$p < .001$, $\eta^2_p = .29$, and the interaction between the two factors was significant, $F(1, 20) = 6.90$, $p < .05$, $\eta^2_p = .26$. Planned comparisons demonstrated that background motion had an impact only when the task was easy. In this case, shooting times were longer with the moving background than with the stationary background, $F(1, 20) = 14.80$, $p < .05$. When the task was difficult, shooting times were not significantly different between the moving and stationary backgrounds, $F(1, 20) = 1.71$, $p = .21$.

[Figure 3 near here]

3.2.2. Number of shots

Background motion influenced the number of shots made by participants, $F(1,20) = 7.37$, $p < .05$, $\eta^2_p = .27$, which was higher with the moving ($M = 1.18$, $SD = .12$) than with the stationary background ($M = 1.14$, $SD = .11$). In contrast, there was no impact of task difficulty on the number of shots, $F(1,20) < 1$. The interaction between the two factors did not reach significance, $F(1, 20) < 1$.

3.2.3. Number and duration of eye fixations

As in Experiment 1, qualitative observation of the eye movement data displayed by a sample of the participants suggested that when the background was moving, an OKN was triggered between trials.

As shown in Table 2, task difficulty impacted the average number of fixations per trial, $F(1,20) = 57.21$, $p < .001$, $\eta^2_p = .74$, which was greater when the task was difficult ($M = 3.05$, $SD = 1.13$) than when it was easy ($M = 2.53$, $SD = 1.06$). There was no significant effect of background motion, $F(1, 20) < 1$, but there was a marginal interaction between the two factors, $F(1, 20) = 3.13$, $p = 0.09$, so that the impact of background motion on the number of fixations per trial tended to be higher when the task was easy ($M = 2.69$, $SD = 1.32$ with the moving background versus $M = 2.38$, $SD = .71$ with the stationary background) than when the task was difficult ($M = 3.10$, SD = 1.44 with the moving background versus $M = 3.00$, SD = .73 with the stationary background).

Task difficulty had an impact on the mean duration of fixations, $F(1,20) = 5.55$, $p < .05$, $\eta^2_p = .22$. Fixations were longer when the task was difficult (M = 195 ms, SD = 56) than when it was easy (M = 187 ms, SD = 47). There was no significant effect of background motion, $F(1, 20) < 1$, or any significant interaction between the two factors, $F(1, 20) < 1$.

[Table 2 near here]

4. Discussion

4.1. Combined impact of lateral background motion and task difficulty on participants' performance and eye movements

The first hypothesis was supported. The participants' performance was lower when the task was more difficult, in accordance with results of previous visual search studies [34,35–37]. The present data confirm that the enemies' visual features may be used to set task difficulty in the present situation. The second hypothesis was also supported. The present data confirm that the number and duration of fixations increases or tends to increase with task difficulty during visual search as well as in most visual tasks, in accordance with the literature [38].

The third hypothesis was that the performance would be lower when the background is moving than when it is stationary but only in the lower level of task difficulty. This hypothesis was confirmed only with the black-and-white background (Experiment 2), in which shooting times were longer with the moving background only when the shooting task was easy. In contrast, the hypothesis was not supported with the colored background (Experiment 1), in which the simple effect of background motion on shooting times was observed whatever the difficulty of the target detection task.

The simple, negative effect of background motion on performance, which was observed with both the black-and-white and colored backgrounds, confirmed previous studies that demonstrated the negative impact of background motion on simple visual tasks that involve only transient presentations of stationary items [16–18]. The shooting times and number of shots were higher when the background was moving. In the present situation, background motion should trigger the participants' OKN [14], which would decrease the shooting performance. Altogether, the present data show that in addition to other low-level features of the background, such as its complexity and color [11–13], lateral background motion can be used to modulate the difficulty of a simple shooting game.

The data obtained on the black-and-white background supports previous studies. Indeed, Ilg [19] and Menozzi and Koga [32] demonstrated that when the main visual task involves sustained attention on fixed items superimposed on a moving background, participants can suppress the OKN and eliminate its negative impact on performance. The reason why the same interaction pattern was not observed with the colored background is not clear. Compared to the reading task used by Menozzi and Koga [32], the level of sustained attention on stationary items involved in the difficult version of the shooting task may be insufficient to observe the expected interaction whatever the visual characteristics of the background. According to the literature, green has a lower impact on participants' arousal levels and emotions than red or blue [13,39,40], which should not have a significantly different impact from that of black-and-white. Another explanation may be that the two backgrounds used in the present experiment were actually different in terms of color "hue" and "saturation". Because hue and saturation were higher in the colored background, the contrast between the background and the creatures was therefore lower for the colored than for the black-and-white background. Therefore, all creatures were most likely more difficult to discriminate from the colored than from the black-and-white background. Indeed, the number of participants' fixations per trial and their average duration tended to be higher with the colored than the black-and-white background.

An additional statistical analysis (i.e., a repeated measure ANOVA) of shooting time data with a three-factor 2 X 2 X 2 design (background color X background motion X task difficulty) was made *a posteriori* to better clarify the influence of background color in the present study. The analysis did not show any significant simple effect or interaction involving background color on the participants' performance. Further experiments are needed to clarify the impact of background color on shooting tasks.

The eye movement data revealed that the shooting time and the number of fixations per trial tended to behave in a similar way whatever the color of the background. This finding is in accordance with the idea that increased response times often reflect an increase in the number of fixations that are needed to complete the task, as stated in the introduction. In contrast, the average duration of the participants' fixations was not significantly impacted by background motion.

4.2.Application to video game design

The present data can be used to generate recommendations for video game designers creating simple shooting tasks performed on laterally moving backgrounds. In addition to the other features that game designers can use to control challenge in games, background motion and task difficulty may be manipulated together. For example, when the main task is easy, the presence or absence of background motion should modify task difficulty. In contrast, when the main game task is more attention-demanding (i.e., more difficult), using a moving background will not increase task difficulty, at least on a black-and-white background, or will increase it less than when the task is easier. However, further research is needed to generalize these recommendations to other video game contexts.

4.3.Conclusion and future studies

The present study demonstrated that performance in a shooting task may be impaired by lateral background motion, in accordance with previous studies performed using other visual tasks in various environments [e.g., 15,16–18]. On the black-and-white background, background motion impaired performance only when the main target detection and shooting task was easy. Background motion did not have an additive impact on participants' performance when the main task was already difficult.

Further experiments should be made to extend these findings to the other types of background motion that exist in commercial video games. For example, some games display forward or backward motion, simulated by a radial expansion or contraction of the entire background. Additionally, as stated above, the impact of background color must be explored in more detail.

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Figures

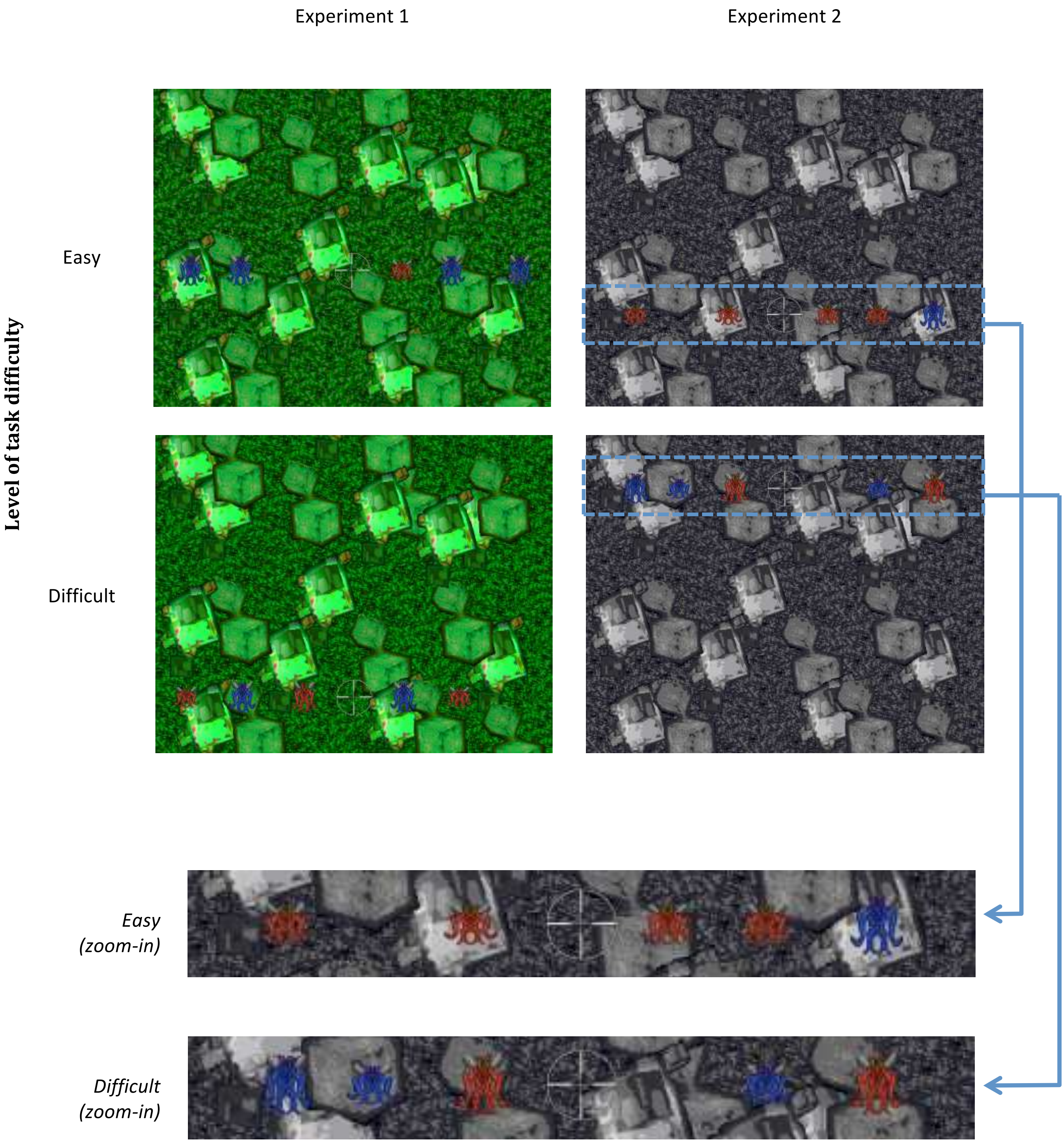


Figure 1. Backgrounds used in Experiments 1 and 2, with various examples of locations of the target, distractors and cursor. The zoom-in frames display examples of easy and difficult conditions of the task. If the task was easy, the target differed in size and color from all the distractors (here: a large, blue target with four small red distractors). If the task was difficult, two of the distractors were the same size as the target but a different color, whereas the two other distractors were the same color but a different size (here: a large, blue target with two large, red and two small, blue distractors).

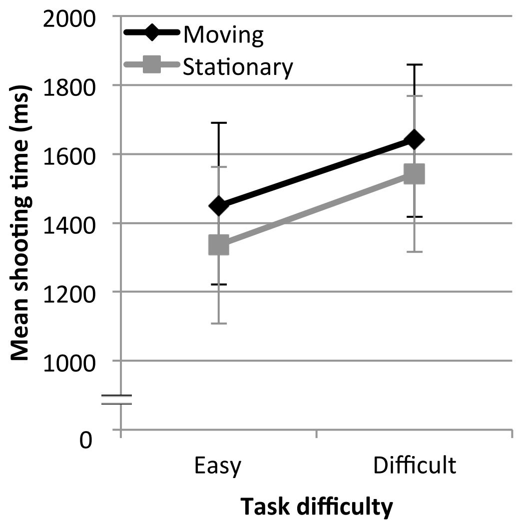


Figure 2. Mean time (in ms) needed to hit each target in each condition of task difficulty and background motion in Experiment 1 (colored background). The error bars represent ±1 standard error of the mean.

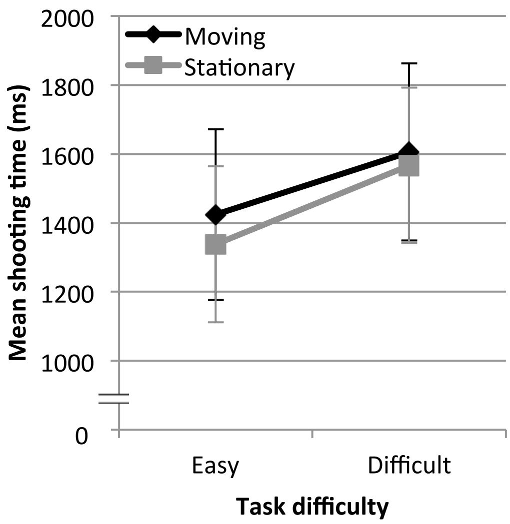


Figure 3. Mean time (in ms) needed to hit each target in each condition of task difficulty and background motion in Experiment 2 (black-and-white background). The error bars represent ±1 standard error of the mean.

Tables

Table 1. Means (M) and standard deviations (SD) of number and duration of eye fixations according to task difficulty and background motion in Experiment 1 (colored background).

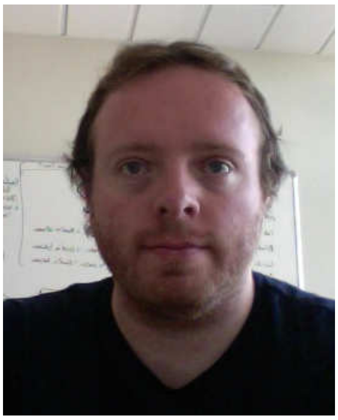
	Easy task		Difficult task	
	M	SD	M	SD
Mean number of fixations				
Stationary background	2.50	1.14	3.08	1.38
Moving background	2.84	1.17	3.37	1.28
Mean duration of fixations (in ms)				
Stationary background	201	76	204	63
Moving background	193	51	198	46

Table 2. Means (M) and standard deviations (SD) of number and duration of eye fixations according to task difficulty and background motion in Experiment 2 (black-and-white background).

	Easy task		Difficult task	
	M	SD	M	SD
Mean number of fixations				
Stationary background	2.38	0.71	3.00	0.73
Moving background	2.69	1.32	3.10	1.44
Mean duration of fixations (in ms)				
Stationary background	189	43	198	52
Moving background	186	51	191	60

Vitae

Loïc Caroux is a postdoctoral research fellow at INRIA Bordeaux Sud-Ouest, Talence, France. He received his Ph.D. in cognitive ergonomics in 2012 from the University of Poitiers, France. After completing his Ph.D., he served as a postdoctoral research fellow at New York University, New York, USA. His research interests are human factors/ergonomics and human-computer interaction.



Ludovic Le Bigot is Professor at the University of Poitiers. He conducts his research in the CeRCA, a research center on cognition and learning. His research interests are focused on human–computer interaction and human dialogue.

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