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Influence of visual background complexity and task difficulty on action video game players' performance

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Abstract

The purpose of this study was to investigate the influence of visual background complexity and task difficulty on players' performance in a typical video game task, as a function of their expertise. Challenge in a video game is usually defined by the difficulty level of the main task. The use of low-level visual features of game interfaces to modulate the challenge has only been evaluated by a few studies. Two experiments were designed in which action video game players (AVGPs) and non-players of action video games (NVGPs) were engaged in a target-shooting task. The difficulty level of task as well as the complexity of visual background were manipulated. The enhanced attentional abilities of AVGPs allowed them to perform the task better than NVGPs. Both task difficulty and background complexity impaired task performance. However, this impairment was not modulated by player expertise. Recommendations are proposed to game designers to design the challenge around the low-level visual features of game interfaces.

Keywords

Game design; Challenge; Expertise; Attention; Visual features.

1. Introduction

Challenge is a key factor in player engagement and enjoyment of a video game [1,2]. Unlike traditional human-computer interaction (related to productivity), video game tasks should not be oversimplified. Rather, they must be tailored to the players' abilities and expectations to maintain their high level of motivation [3–6]. Challenge in a video game is usually defined by the difficulty of performing the main task. For example, game designers can vary the number of enemies displayed in the environment, the speed of their movements or their level of artificial intelligence [7,8]. The use of visual features of game interfaces to modulate the difficulty of the game has only been evaluated by a few studies [9,10].

Video games are virtual environments that display complex dynamic environments. Information is displayed in several modalities, but the visual channel is generally emphasized [11]. Typically, visual interfaces of video games include a main action area where players see the objects they interact with (e.g., avatars, enemies, targets), a scene background that may be complex or moving (e.g., building interiors, landscapes) and contextual information overlaid in a head-up display (e.g., score, status bar) [12–14].

Several studies have examined how visual interfaces features influence player performance, experience, or both. Only a few have addressed the influence of low-level visual features of these interfaces, such as color, contrast, or luminance. Yet, several areas of research, notably in cognitive psychology or human factors/ergonomics, investigate perceptive and attentional processes of humans in complex visual environments. Some of the results of these works could be very useful for designing optimal video game interfaces [1].

Furthermore, recent research has showed that the attentional abilities of video game players can vary depending on their expertise. In particular, several studies have shown that playing action video games (e.g., shooting games, racing games or platformers) on a regular basis can improve certain attentional abilities such as spatial attention or temporal attention [15–17]. These types of findings could be used by designers of games involving players' attentional abilities to optimize the challenge for each level of player expertise.

The goal of the present study was to understand how low-level visual features of video game interfaces can influence player performance, and how player expertise can modulate this influence. This study focused on a specific part of typical game interfaces: visual backgrounds. The objective was to investigate in two experiments the influence of visual background complexity and task difficulty on players' performance in a typical video game task (target-shooting task), as a function of players' expertise.

1.1. Influence of choices of visual interface design on player performance

Several studies have shown how isolated features of visual interfaces can influence player performance and experience (and more generally, user performance and experience), and how these features can be manipulated by designers to optimize player-video game interactions. Some of these studies focused on global features such as the player's point of view (first-person or third-person) [18,19], the quality of game graphics [20], or the stereoscopic 3D display [21,22]. Other studies have focused on more local features regarding the nature or spatial organization of head-up displays [12]. Finally, some studies investigated the influence of visual background features on player performance. To the best of our knowledge, color [23], luminosity [24], motion [25,26] and visual complexity [10] are factors that can have an influence on player performance. The influence of visual complexity of backgrounds on human behavior, and in particular on player performance, is developed below.

1.2. Influence of background visual complexity on player performance

The complexity of a visual scene is classically characterized by the density of visual information displayed. A visual scene is complex when it displays a lot of information and when the variability of this information is high [27,28]. Generally, the complexity of a visual scene has a negative influence on several tasks involving the detection and use of scene elements, such as in visual search, or when interacting with a video game [10,25,29,30].

When observing a visual scene, the observer's attention does not move randomly. Two types of attentional guidance coexist [31]. Bottom-up guidance depends directly on the visual features of the scene. Top-down guidance depends on the observer's goals and knowledge. Generally, these two types of guidance are activated simultaneously and interact during the observation of the scene. A visually complex scene contains many elements that could primarily guide the attention in a bottom-up way. When the observer is performing a goal-directed task, the visual complexity of a scene or its background may disrupt top-down guidance and, therefore, impair task performance.

To the best of our knowledge, only two published studies investigated the influence of visual complexity on shooting task performance as it may exist in video games [10,29]. Jie and Clark [10] used an experimental game in which players had to shoot at objects superimposed on a complex background. The authors showed that shooting performance (time to hit the target) was lower when visual complexity was higher. In the study by Caroux et al. [29], participants had to detect and hit a target displayed among several distractors superimposed on backgrounds of different levels of complexity as quickly as possible. These authors also showed that response times were longer when the level of background complexity was higher.

The control abilities of attentional guidance can be modulated by factors internal to individuals. Some of these factors are related to expertise in a given task, including expertise in action video games.

1.3. Player expertise and attentional abilities

Numerous empirical studies have shown in recent years that regularly playing video games can improve the cognitive abilities of players [32]. Basically, these studies have shown that regular players better perform classical laboratory cognitive tasks and more ecological tasks in other domains than non-game players, even though the validity of these phenomena is still debated in the literature [33–36]. In particular, the literature has primarily investigated whether and how expertise in action video game play would be related to increased attentional abilities. The action video game genre is an important genre in the video game industry. It includes several popular sub-genres such as shooters, platformers or racing games. In this type of game, players have to deal with highly complex and dynamic visual and auditory environments that require accurate and fast responses [15–17,37–39]. One particular aspect of previous findings is that action video games players (AVGPs) perform better on attention tasks that involve top-down attentional control [15,40,41].

In contrast, very little is known about the effects of action video game players' expertise on bottom-up attentional control. The literature is unclear on whether and how AVGPs perform better on tasks that involve bottom-up control. Of these studies, some have shown that in the oculomotor capture task, AVGPs perform better than non-players of action video games (NVGPs) [42–45]. The findings from these studies suggested that AVGPs are less susceptible to attentional distraction than NVGPs. In this case, better top-down attentional control may modulate the negative effects of bottom-up attentional capture. However, studies that used a different experimental paradigm, such as the Posner cueing paradigm, did not find a difference in bottom-up attentional control between AVGPs and NVGPs [46,47].

1.4. The present study

The aim of the present study was to understand how low-level visual features of video game interfaces, and in particular their backgrounds, can influence players' performance in a typical video game task, and how player expertise can modulate this influence.

We designed two experiments in which participants were asked to perform a shooting task that primarily involved top-down attentional guidance. Participants had to find, aim at, and hit as quickly as possible successive targets displayed among several distractors, which shared visual characteristics (color and size) with the target. The task was either easy or difficult depending on the number of features that had to be considered to differentiate the target from the distractors. Indeed, classical visual search experiments have consistently shown that search is more difficult when the target differs from distractors by a conjunction of visual features (e.g., finding a red, large target among blue, large and red, small distractors) than if the target differs from all distractors by a single feature (e.g., finding a red, large target among blue, small distractors) [48]. In such visual search tasks, AVGPs are generally faster than NVGPs in both feature search and conjunction search [41,47].

These objects (target and distractors) were superimposed on a background of low or high visual complexity. Although this background did not contain any information necessary for the shooting task, the high-complexity version of the background was designed with elements that could attract the players' attention and thus disrupt top-down guidance.

Finally, action video game expertise was also studied. Two groups of participants (AVGPs and NVGPs) were recruited to assess how this expertise might modulate the influence of visual background complexity and task difficulty on task performance.

Two hypotheses were tested in the present study. The first hypothesis was that performance is impaired by task difficulty, but that this impairment is attenuated for AVGPs, due to more controlled and efficient top-down attentional guidance. The second hypothesis was that performance is impaired by the complexity of the visual scene, but that this impairment is attenuated for AVGPs, due to more controlled and less disruptive bottom-up attentional guidance.

These hypotheses were the same for both experiments. Both experiments investigated the performance of AVGPs and NVGPs in similar tasks with different levels of task difficulty and background complexity. The visual displays were designed using abstract objects that look like those one might encounter in simple video games. The main differences between the two experiments were the number and location of task distractors, and the sample size (much larger in Experiment 2).

2. Experiment 1

2.1. Methods

2.1.1. Participants

A total of 40 volunteers (22 men and 18 women) aged in average *M* = 27.0 years (standard deviation *SD* = 7.5) participated in the experiment. All participants were native French speakers. They had normal or corrected-to-normal vision and did not suffer from colorblindness. The participants were recruited via advertisements on the university campus, on online social networks, and through snowball sampling. The sample size was chosen on the basis of the recent studies on attentional abilities of AVGPs. In these studies, the number of participants vary around 15 to 20 per experimental group [e.g., 41,42,44].

The participants were categorized according to their expertise in action video games: AVGPs (*N* = 20) and NVGPs (*N* = 20). Expertise was determined by asking the participants the number of hours per week they played action video games in the last 6 months. Action video games are games in which players have to deal with highly complex and dynamic visual and auditory environments that require accurate and fast responses. According to the literature, they mainly include shooter, platformer, and racing games. This kind of categorization of video game expertise is typically used in the literature on the topic [e.g., 45,47]. Participants who played more than 4 hours per week on average in the last 6 months were categorized as AVGPs. Participants who did not played at all (i.e. 0 hour) in the last 6 months were categorized as NVGPs. As the expertise was considered as an inclusion criterion, potential participants who reported that they played between 0 and 4 hours were not included in the study and did not participate to the study.

This research complied with the tenets of the Declaration of Helsinki. Informed consent was obtained from each participant. An Institutional Review Board approval was not required by the authors' university of affiliation at the time this research was designed.

2.1.2. Material

The material consisted of a set of static visual scenes (size: 1280 × 1024 pixels) presented on a 21-inch computer screen. Each scene consisted of five creatures that represented one target of the shooting task among four distractors. These creatures were superimposed on a background of varying visual complexity. The design of the creatures and backgrounds was based on the material used by Caroux et al. [29]. The target and distractors of the shooting task were chosen from four versions of the same creature. The four versions varied by the color, blue (color on the screen according to the model HSV: Hue = 228, Saturation = 74, Value = 25-84) or red (HSV: 7, 74, 25-84), and the size, large (85 x 99 pixels) or small (85 x 66 pixels). Examples of these creatures are shown in Figure 1. Two backgrounds of low and high visual complexity were designed (Figure 1). The background of low complexity consisted only of a mainly green neutral frame (HSV: 120, 100, 10-70). The background of high complexity was composed of the same neutral frame on which were dispersed abstract objects (HSV: 120, 50-100, 40-100). These objects covered 25% of the surface of the background.

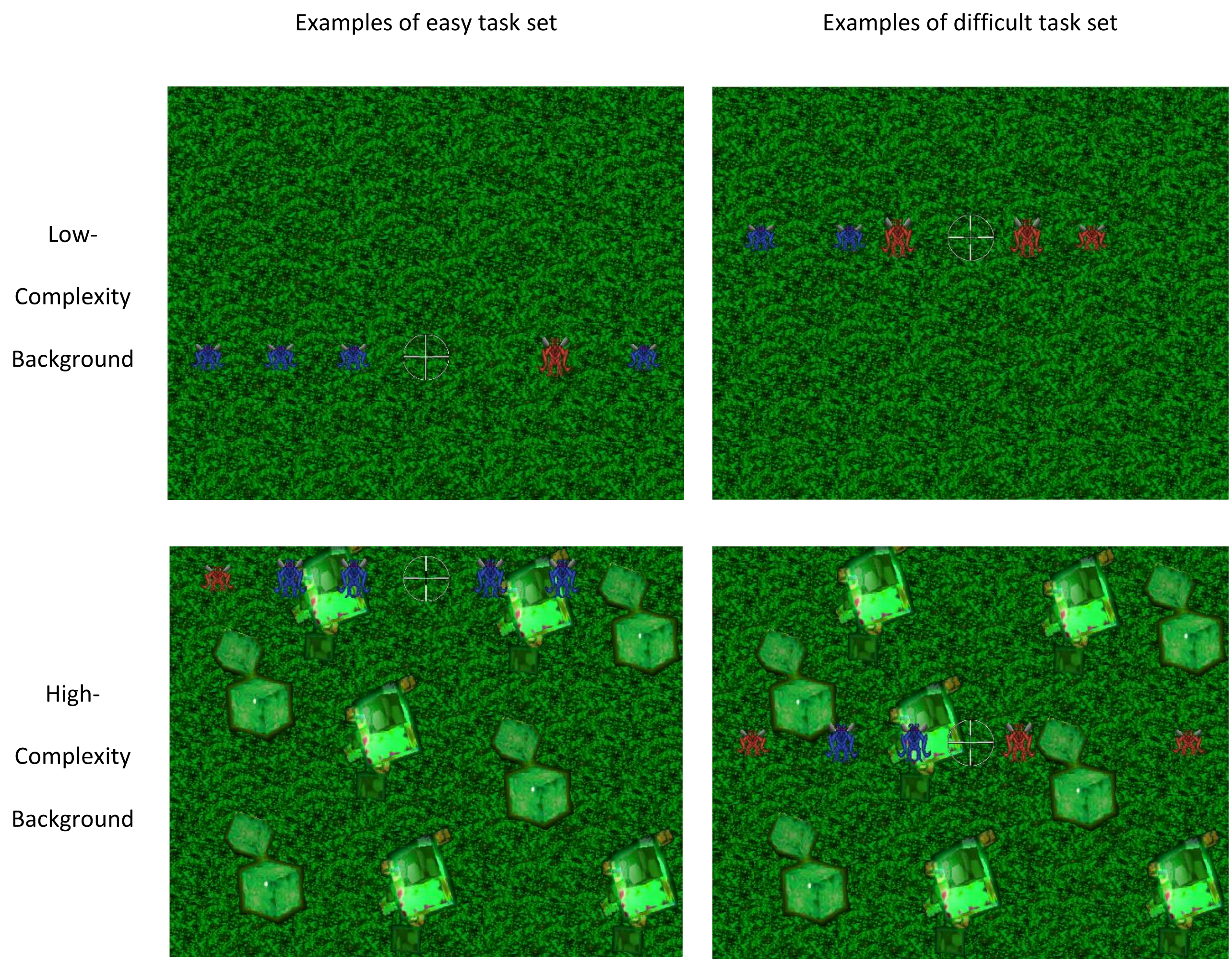

Figure 1. Backgrounds used in Experiment 1, with various examples of locations of the target and distractors according to task difficulty.

2.1.3. Experimental design and procedure

Task difficulty (easy or difficult) and visual complexity of the background (low or high) were manipulated within participants. The expertise of action video games (AVGP or NVGP) was studied between participants.

The task used in this experiment was presented to the participants as a game where they had to locate and hit targets as quickly as possible with a viewfinder. This task is based on the one used by Caroux et al. [9]. Each participant had to perform 256 trials, divided into 4 blocks of 64 trials. Each block of trials corresponded to a type of background complexity (2 blocks for low complexity background and 2 blocks for high complexity background). At the beginning of each trial, participants were asked to look at the center of the screen. A square was displayed in the center of the screen to assist them. The color and size of the upcoming target were pronounced in two words ("blue" or "red," "large" or "small"; respectively “bleu”, “rouge”, “grand” and “petit” in French) by a recorded male voice. Word order was randomized. The target, distractors and viewfinder were then presented on the same horizontal line (not materialized), whose position on the screen was randomized. The viewfinder was displayed in the center of this line. The distractors were displayed on both sides of the viewfinder. The target was randomly displayed to the left or right of the viewfinder. As a result, there were always three creatures on one side of the viewfinder and two other creatures on the other side. These specifications being taken in account, the positions of the target and distractors on the horizontal line were random. Participants had to control the viewfinder horizontally on the screen using the "left arrow" and "right arrow" keys on a computer keyboard. They had to press the space key to hit the target. Participants could control the viewfinder and shoot without limits until the target was hit. The trial stopped when the target was hit. A new trial started then.

When the task was easy, the target was presented among distractors who did not share any visual criteria of color or size with the target (e.g., a large, red target among small and blue distractors). When the task was difficult, the target was presented among distractors who shared with the target a visual criterion of color or size (e.g., a large and red target among two large and blue distractors and two other small and red ones). See examples in Figure 1.

Each of the 4 trial blocks was presented in a randomized order, thus different for each participant. Similarly, within each block, the difficulty of the trials was randomized while controlling that half of the tests corresponded to an easy task and the other half corresponded to a difficult task. Any order effects were thus cancelled out.

2.1.4. Dependent measures

The main dependent measure of performance of the shooting task was the average time needed to shoot at each target. The measured time started when the visual scene appeared on the screen and ended when the participant actually hit the target (by pressing the "space" key). The average number of shots per trial was also measured. These variables were analyzed using repeated measures ANOVAs with task difficulty and visual complexity of the background as within participants factors and the action video game expertise as a between participants factor. As is often observed in reaction time experiments, the response times followed a non-normal, asymmetrically positive distribution. As a result, the response time data was logarithmically transformed before performing ANOVA.

2.2. Results

All premature (response times shorter than 100 ms) and late responses (response times greater than 5000 ms) were considered as errors and were excluded from analyses. The mean proportion of excluded trials per participant was 2.5%.

2.2.1. Number of shots

The mean number of shots per trial was M = 1.14 (SD = 0.07). No factor had significant impact on the mean number of shots made by the participants, $Fs(1,38) < 1$.

2.2.2. Shooting time

As in classical visual search studies, response times were longer for difficult tasks (*M* = 1700 ms, *SD* = 365) than for easy tasks (*M* = 1469 ms, *SD* = 374), $F(1,38) = 186.89$, $p < .001$, $\eta^2_p = .83$ (Figure 2).

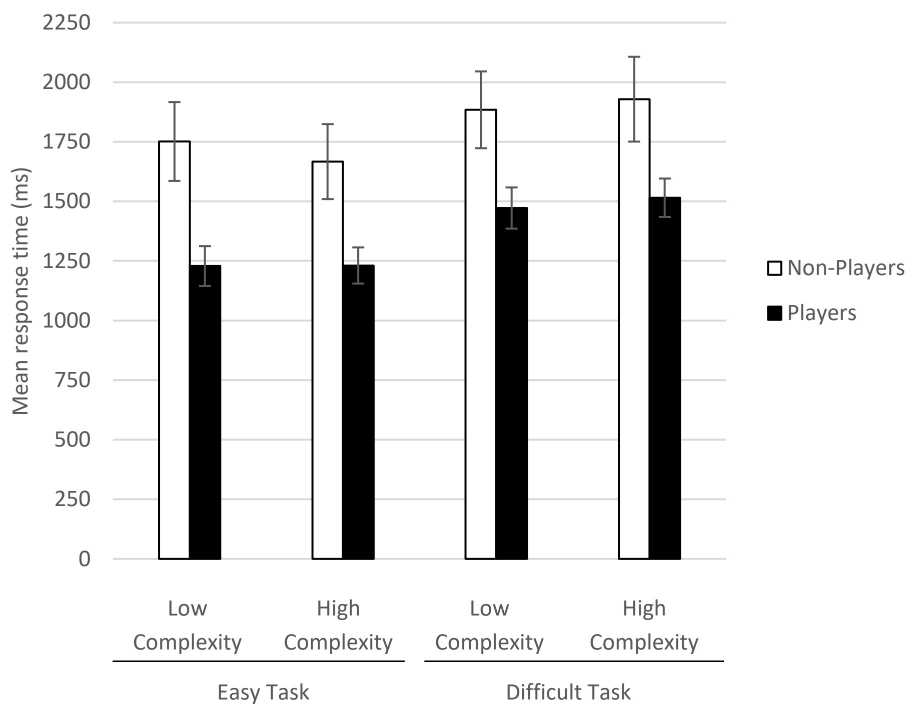

Figure 2. Mean response time (in milliseconds) needed to hit each target in each condition of task difficulty, background complexity and action video game expertise in Experiment 1. The error bars represent 95% confidence intervals.

As it was expected in hypothesis 1, response times were shorter for AVGPs (*M* = 1362 ms, *SD* = 227) than for NVGPs (*M* = 1808 ms, *SD* = 385), $F(1,38) = 28.77$, $p < .001$, $\eta^2_p = .43$. Also, the interaction between action video game expertise and task difficulty was significant, $F(1,38)$ =

14.19, $p < .001$, $\eta^2_p = .27$. However, contrary to what was expected in hypothesis 1, response times were more extended by difficult tasks for AVGPs (M = 1230 ms, SD = 180 for easy tasks; M = 1494 ms, SD = 190 for difficult tasks) than for NVGPs (M = 1709 ms, SD = 366 for easy tasks; M = 1906 ms, SD = 383 for difficult tasks), as shown in Figure 2.

Contrary to what was expected in hypothesis 2, background complexity had no influence on response times, $F(1,38) < 1$. The interaction between action video game expertise and background complexity was not significant either, $F(1,38) = 1.42$, $p = .240$.

Otherwise, there was a significant interaction between background complexity and task difficulty, $F(1,38) = 11.24$, $p = .002$, $\eta^2_p = .23$. Planned comparisons showed that response times were longer when the background complexity was high (M = 1722 ms, SD = 375) than when it was low (M = 1678 ms, SD = 358) only in the difficult task condition, $F(1,38) = 4.47$, $p = .041$. There was no significant difference in the easy task condition (M = 1449 ms, SD = 355 in the high complexity condition; M = 1490 ms, SD = 396 in the low complexity condition), $F(1,38) = 1.82$, $p = .185$. Finally, the interaction between the three factors, action video game expertise, task difficulty and background complexity, did not reach significance, $F(1,38) = 2.49$, $p = .123$.

3. Experiment 2

Experiment 2 was designed in order to replicate the results obtained in experiment 1. Therefore, the hypotheses were the same. The three factors, action video game expertise, task difficulty and background complexity, remained the same and they were operationalized in a similar way. An additional factor regarding the number of distractors displayed on the visual scene was manipulated. The task and materials were similar to those used in Experiment 1. The similarities and differences between both experiments are described in the following sub-sections.

3.1. Methods

3.1.1. Participants

A total of 534 volunteers (291 men and 243 women) aged in average *M* = 23.7 years (*SD* = 7.5) participated in the experiment. All participants had normal or corrected-to-normal vision and did not suffer from colorblindness. The participants were recruited via advertisements on the university campus, on online social networks, and through snowball sampling. The sample size was much larger than in experiment 1 because there was an opportunity at the time of data collection to recruit many participants for the present experiment.

The participants were categorized according to their expertise in action video games: AVGPs (*N* = 267) and NVGPs (*N* = 267). Expertise was determined in the same way than in Experiment 1.

This research complied with the tenets of the Declaration of Helsinki. Informed consent was obtained from each participant. An Institutional Review Board approval was not required by the authors' university of affiliation at the time this research was designed.

3.1.2. Material

The material included a set of static visual scenes (size: 800 × 600 pixels) displayed on a 15-inches computer screen (examples in Figure 3). Each of these scenes was composed of 9 or 25 creatures, according to the experimental condition, corresponding to one target of the shooting task and 8 or 24 several distractors. They were displayed within 3 × 3 or 5 × 5 arrays. These creatures were superimposed on a background of varying visual complexity. The creatures (target and distractors) and the backgrounds were exactly the same as in Experiment 1.

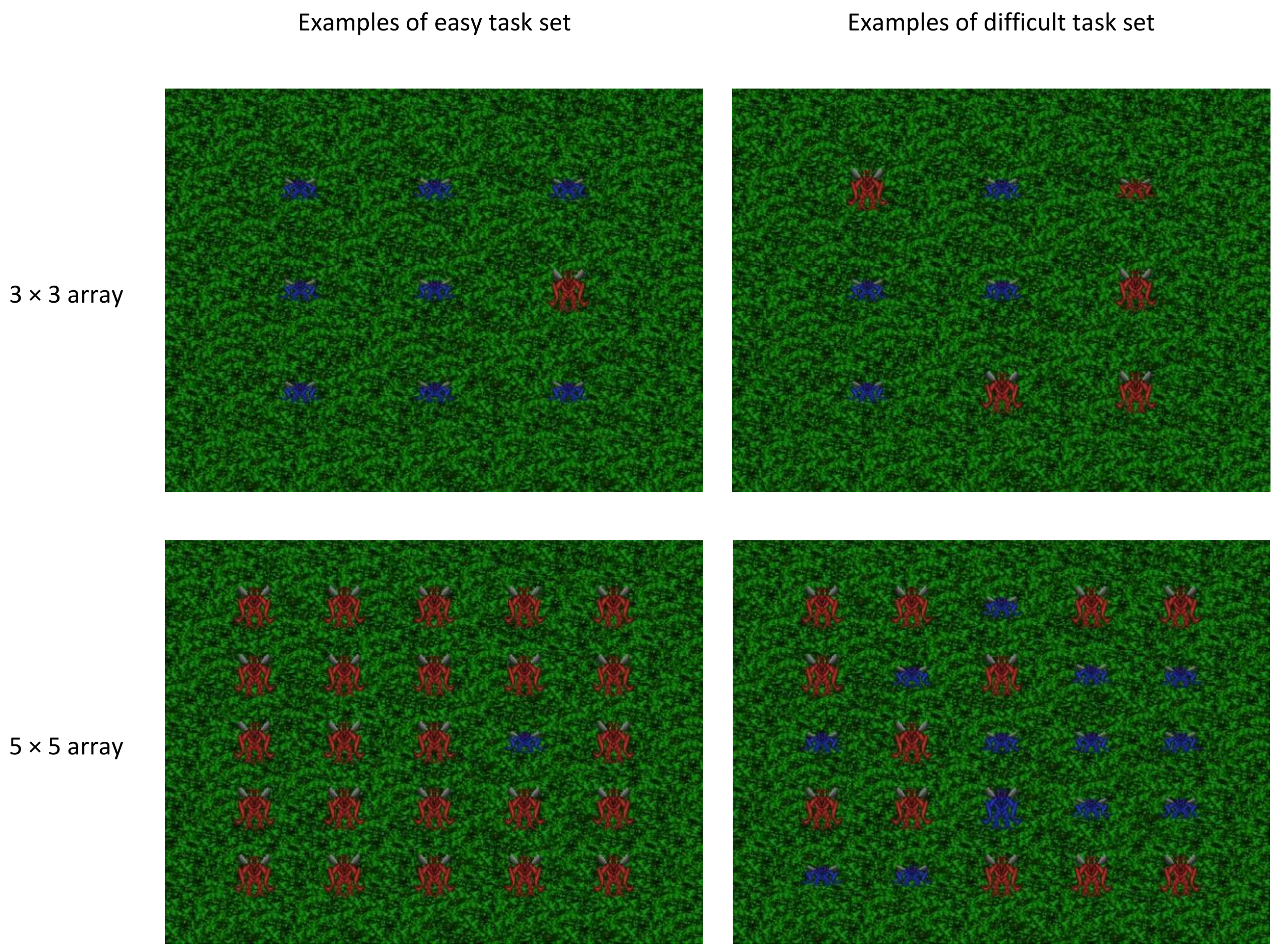

Figure 3. Examples of visual sets used in Experiment 2, according to set size. These examples show the target and distractors arrays superimposed to the low-complexity background. Examples of high-complexity backgrounds are shown in Figure 1.

3.1.3. Experimental design and procedure

Task difficulty (easy or difficult), set size (9 or 25) and background complexity (low or high) were manipulated within-participants. Action video game expertise (AVGP or NVGP) was studied between-participants.

The task was presented to participants as a simple video game. Participants were asked to shoot at the target as quickly as possible using a cursor. The pointing device used to control the cursor on the screen was a conventional computer mouse. Each participant completed 32 trials, divided into 4 blocks of 8 trials. Each block was associated with a single target, which combined a specific color (red or blue) and a specific size (small or large) such that each color × size combination was presented throughout the experiment. The target was the same for all 8 trials in a block (e.g., red, large target). The target was visually displayed once before the first trial of the block. There was no time limit on the presentation of the target. The participant was told to begin when ready. Each of the 8 trials in a block corresponded to a different experimental condition (search task × set size × background complexity). In the easy task, the target was displayed among distractors that shared no visual features with the target (e.g., a red, large target among blue, small distractors). In the difficult task, the target was displayed among distractors that shared a visual feature of color or size with the target (e.g., a red, large target among some blue, large distractors and other red, small ones) (examples in Figure 3). Overall, each experimental condition was repeated 4 times for each participant. The order of presentation of blocks of trials, as well as the order of presentation of trials within blocks, was randomized.

3.1.4. Dependent measures

Participants' performance was assessed using the average time needed to hit the target as the dependent measure. The measure started when the visual scene appeared on the screen and stopped when the participant hit the target (by clicking on it). This variable was analyzed using a repeated measures ANOVA with task difficulty, set size and background complexity as within participants factors, and participants' action video game expertise as a between participants factor. As in Experiment 1, response time data were logarithmically transformed before ANOVAs were performed.

3.2. Results

All premature (response times shorter than 100 ms), late responses (response times greater than 5000 ms), as well as responses in which participants hit a distractor instead of the target were considered as errors and were excluded from analyses. The mean proportion of excluded trials per participant was 1.9%.

As in classical visual search studies, response times were longer for difficult tasks (*M* = 1710 ms, *SD* = 571) than for easy tasks (*M* = 1254 ms, *SD* = 404), $F(1,532) = 3155.5$, $p < .001$, $\eta^2_p = .86$. Also, response times were longer for the largest set size (*M* = 1598 ms, *SD* = 595) than for the smallest one (*M* = 1367 ms, *SD* = 462), $F(1,532) = 1094.2$, $p < .001$, $\eta^2_p = .63$. The interaction between task difficulty and set size was significant, $F(1,532) = 742.9$, $p < .001$, $\eta^2_p = .58$. As shown in Figure 4, response times with the largest set size were more extended in the difficult task (*M* = 1492 ms, *SD* = 482 in the smallest set size condition; *M* = 1928 ms, *SD* = 571 in the largest set size condition), than in the easy task (*M* = 1242 ms, *SD* = 404 in the smallest set size condition; *M* = 1267 ms, *SD* = 405 in the largest set size condition).

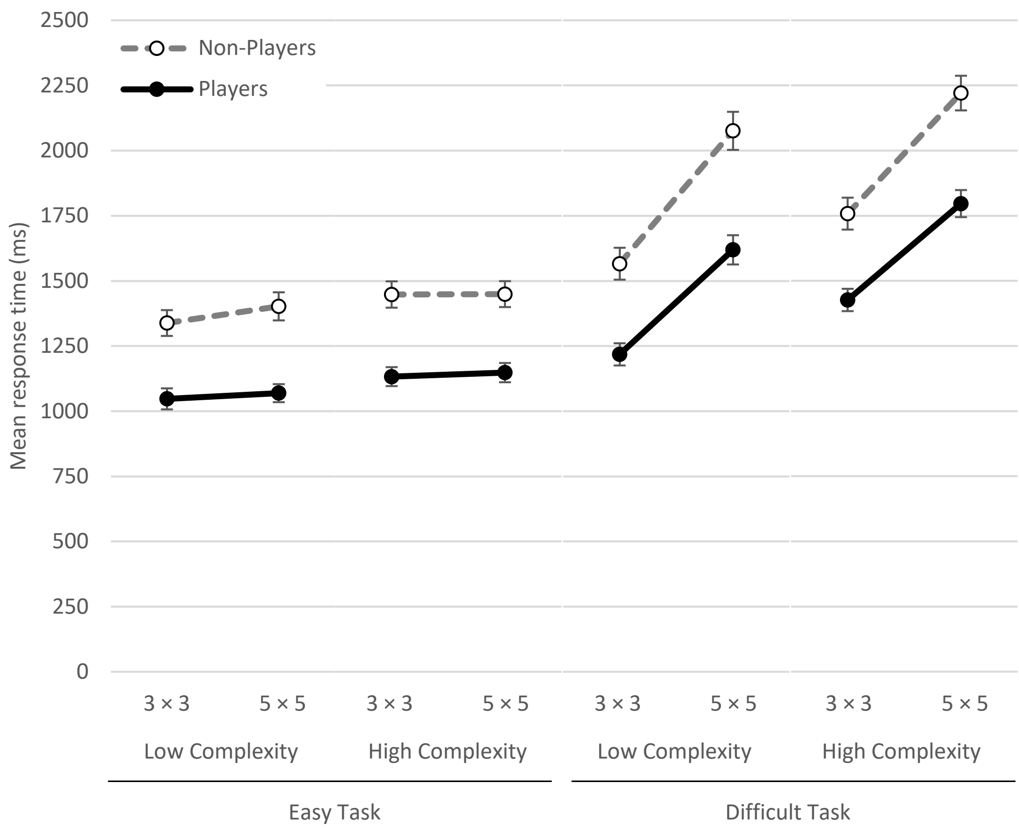

Figure 4. Mean response time (in ms) needed to hit each target in each condition of task difficulty, background complexity, set size and action video game expertise in Experiment 2. The error bars represent 95% confidence intervals.

As it was expected in hypothesis 1, response times were shorter for AVGPs (M = 1307 ms, SD = 444) than for NVGPs (M = 1694 ms, SD = 579), $F(1,532) = 127.1$, $p < .001$, $\eta^2_p = .19$. However, there was no interaction between action video game expertise and task difficulty, $F(1,532) = 3.1$, $p = .077$, nor between expertise and set size, $F(1,532) < 1$. The interaction between these three factors did not reach significance either, $F(1,532) < 1$.

As it was expected in hypothesis 2, response times were longer when the background was of high complexity (*M* = 1547 ms, *SD* = 541) than when it was of low complexity (*M* = 1417 ms, *SD* = 541), *F*(1,532) = 432.0, $p < .001$, $\eta^2_p = .45$. The interaction between background complexity and action video game expertise was significant, *F*(1,532) = 11.6, $p < .001$, $\eta^2_p = .02$. However, contrary to what was expected in hypothesis 2, response times were more extended by the high-complexity background for AVGPs (*M* = 1238 ms, *SD* = 433 in the low complexity condition; *M* = 1376 ms, *SD* = 445 in the high complexity condition), than for NVGPs (*M* = 1596 ms, *SD* = 578 in the low complexity condition; *M* = 1719 ms, *SD* = 573 in the high complexity condition), as shown in Figure 4.

Otherwise, the interaction between background complexity and task difficulty was significant *F*(1, 532) = 34.0, $p < .001$, $\eta^2_p = .06$. As shown in Figure 4, response times were more extended by the high-complexity background in the difficult task (*M* = 1620 ms, *SD* = 580 in the low complexity condition; *M* = 1800 ms, *SD* = 548 in the high complexity condition), than in the easy task (*M* = 1214 ms, *SD* = 408 in the low complexity condition; *M* = 1294 ms, *SD* = 397 in the high complexity condition). The interaction between background complexity and set size was also significant, *F*(1, 532) = 22.8, $p < .001$, $\eta^2_p = .04$. As shown in Figure 4, response times were more extended by the high-complexity background with the smallest set size (*M* = 1292 ms, *SD* = 450 in the low-complexity condition; *M* = 1441 ms, *SD* = 462 in the high-complexity condition), than with the largest set size (*M* = 1542 ms, *SD* = 593 in the low-complexity condition; *M* = 1654 ms, *SD* = 592 in the high complexity condition). Other interactions between these factors did not reach significance, *Fs*(1,532) < 2.

4. General discussion

Hypothesis 1 was that performance is impaired by task difficulty, but that this impairment is attenuated for AVGPs. It was not confirmed. In both experiments, participants' performance was impaired by task difficulty. In addition, AVGPs performed better on the shooting tasks than NVGPs, which is consistent with previous studies [41,47]. However, the results of both experiments failed to show that there would be a greater difference in performance between AVGPs and NVGPs when the task was more difficult. The results of Experiment 2 did not show a significant interaction between expertise and task difficulty. The results of Experiment 1 showed the opposite of what was expected. The difference in performance between AVGPs and NVGPs was smaller when the task was difficult. One explanation for the difference in results between these experiments could be related to the sample size of each experiment. The sample size of Experiment 1 was relatively small. Consequently, the interaction that was revealed could be a false positive result (type I error). Experiment 2, which had a much larger sample size, did not reveal this type of interaction. Moreover, this can be reasonably supported by the fact that the result of Experiment 1 is not at all in agreement with the results of previous studies.

In sum, these results showed an effect of task difficulty on task performance. There was also a simple effect of action video game expertise on task performance, which is the consequence of the enhanced top-down attentional control of expert players. However, even if the enhanced attentional abilities of expert players allowed them to perform the tasks better, this effect would not be amplified as the difficulty of the task increased, in terms of integration of visual features of the items.

Hypothesis 2 was that performance is impaired by the complexity of the visual scene, but that this impairment is attenuated for AVGPs. It was not confirmed. In Experiment 2, the results showed that the level of background complexity had an influence on task performance. High complexity impaired performance, which is in line with previous studies [10,25,29,30]. However, Experiment 1 failed to show this effect. The explanation could be again the small sample size that could have led here to a false negative result (type II error). Again, this can be reasonably supported by the fact that this result is not in agreement with the results of previous studies.

Beyond of this simple effect, the results of both experiments failed to show that there would be a greater difference of performance between AVGPs and NVGPs when the background was of high complexity. In fact, the results of Experiment 2 showed the opposite of what was expected. The difference in performance was smaller when the complexity was high. Nevertheless, the effect size of the latter result was very small and should lead to careful consideration.

In sum, these results would show that the level of background complexity has an influence on task performance. Visual search theories argue that a highly complex visual background attracts more attention than a low-complexity background [49], meaning that bottom-up guidance is particularly engaged [48]. At the same time, participants had to control their attention to the search task items to perform their task, which solicits top-down guidance of attention [48]. Therefore, information-dense backgrounds would be more likely to trigger bottom-up (uncontrolled) attentional guidance and, therefore, disrupt top-down (controlled) guidance. However, attentional control was not directly assessed in the present research. Further studies should collect eye-tracking data to empirically support this claim. Also, there was no difference in performance impairment as a function of background complexity between AVGPs and NVGPs. This result would imply that bottom-up attentional guidance would not function differently based on action video game expertise.

Another explanation for the lack of interaction between visual background complexity and player expertise could be that high visual complexity is not necessarily related to frequent action video game play. This explanation would be based on the fact that the nature of the increased attentional abilities of action video game players is based on the nature of the elements of games they play. There are at least two things that would argue against this explanation. The first is that the intrinsic nature of action video games is based on the complexity and dynamic nature of the virtual environment included in the game. The complexity of the visual scene is one of the main characteristics of these games. Therefore, players of action video games are naturally used to play with this type of visual scene complexity and are widely exposed to it. The second is that, according to previous studies on action video game players [15], the improvement in their attentional abilities is not directly related to the material they use to see or play. Rather, it is related to the cognitive processes that are involved during play. For example, in action video games, there are many other elements besides background complexity that might involve bottom-up guidance, such as directing attention to salient elements of the scene (e.g., reacting to the sudden appearance of an enemy or obstacle). Although visual complexity was not thought to be a frequent feature of action video games, bottom-up guidance is actually frequently solicited in other ways.

4.1. Application to video game design

The results obtained in the present study can be used to propose recommendations to video game designers. In addition to other characteristics that game designers can use to modulate challenge, the visual features of game interfaces, and in particular the features of visual backgrounds, can be manipulated.

The low-level features of interfaces can be manipulated to vary the difficulty level of action video games. Increasing the visual complexity of the task increases the difficulty of the game. Increasing the visual complexity of the background also increases the difficulty of the game.

It would not be necessary to change the visual characteristics of objects related to the game task (e.g., target, distractors) or not (e.g., elements embedded in backgrounds) to a higher degree if the game is intended for more expert players.

4.2. Conclusion and perspectives

The study presented in this article showed that manipulating low-level visual features of game interfaces may influence player performance. More precisely, performance on shooting tasks can be impaired by the visual complexity of backgrounds, in accordance with previous studies that investigated the influence of visual background features on human performance. However, although the enhanced attentional abilities of AVGPs lead to better task performance, this effect would not be amplified when the task is more difficult or the background is visually more complex. The present findings add to previous research that has shown the influence of visual features of interfaces on player performance and that video game designers can modify these features to tailor the game challenge.

Nonetheless, further studies are needed to investigate these research questions with visual environments closer to those used in more complex commercial games. The material used in the present study was purposely very simple in order to study as precisely as possible phenomena related to attentional guidance in environments that may exist in video games. Further experiments should use a wider range of visual environments, such as 3D environments, and a wider range of tasks. In particular, there is a wide range of visual complexity that can be designed into video games. We chose in the present research to study the design of the visual background, but other studies on visual scene complexity have focused on the complexity of different scene elements, such as the nature of the objects in the scene, their number in the scene (e.g., virtual characters in a crowd) and their similarity, but also the spatial layout or the occlusion of objects (e.g., the shape of the crowd and the superimposition of objects) [50]. These different elements could be the subject of further studies on video game-like displays. In addition, the complexity of the graphics and the visual style of the virtual environment are important elements in video games [51]. Their influence on player performance and experience should be further investigated.

Finally, the present study focused only on player performance. A specificity of player-video game interaction is that the overall goal of players is often related to entertainment and enjoyment [1,6]. Further studies should examine the influence of low-level visual features on subjective player experience, in addition to player performance. Similarly, other studies should also examine the effect of visual (background) complexity as a function of player diversity. Although we studied player expertise in the present research, other individual characteristics, such as age or visual disabilities for example, may be of interest for such a display manipulation [52].

5. References

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