Examining the influence of target-distractor similarity on difficulty in a working memory game

Abstract

Video games often feature complex game environments, with many elements irrelevant to the current task, which may distract from goal-relevant information. From a game design perspective, this increased difficulty factor may either be desired or lead to unwanted consequences and accessibility concerns. Evidence from cognitive science suggests that information processing is more susceptible to distracting items similar to the target. The current study therefore investigated the effects of target-distractor similarity on difficulty in a Working Memory (WM) game that requires participants to memorise a target path on a grid. Distractors with varying similarity to the path were presented either simultaneously with the path (encoding period), or after the path has disappeared (delay period). Results revealed that distractors generally led to poorer performance, and further that performance gradually declined with increasing target-distractor similarity during memory encoding. Exploratory analyses between performance and player experience suggest that higher success rates may be related to higher ratings of enjoyment. The present findings highlight the importance of considering the visual design of goal-relevant and task-irrelevant surrounding elements to provide an optimal challenge level and ensure positive player experiences in video games that place demand on WM capabilities.

Keywords: Video games, Working memory, Distraction, Target-distractor similarity, Player experience, Game design

1. Introduction

1.1. Visual complexity and cognitive demand

With the steadily increasing popularity of video games, there is a growing interest in better understanding player experience in order to design more enjoyable and engaging games. General user experience (UX) guidelines (such as Norman Nielsen's usability heuristics [1] or Ben Shneiderman's Eight Golden Rules of Interface Design [2]) often highlight the importance of reducing cognitive load and focusing on minimalist design. This encourages the prioritisation of information required to achieve the current goal and the elimination of elements irrelevant to the task at hand that might distract users. Such heuristics have their basis in cognitive research, which suggests highly limited short-term or Working Memory (WM) storage [3] and a strong disruptive influence of distraction on cognitive processes [4–6].

A different picture emerges when looking at video games: Visual environments in video games are often highly complex, with many elements that exist solely for aesthetic purposes and may not be directly relevant for the task at hand. Yet, considering the popularity of such visually rich games (e.g., 3D action games such as Fortnite or Overwatch), player experience or the accomplishment of in-game goals do not seem to suffer from this complexity. On the contrary, it has been suggested that removing all task-irrelevant elements can decrease engagement and immersion [7, 8]. Although an abundance of visual elements in the game world can increase cognitive demand and thus introduce a difficulty or challenge factor, this does not necessarily result in negative outcomes but may even enhance player experience [9, 10]. For instance, increasing challenge, specifically in the cognitive domain, has been shown to lead to higher levels of immersion [11]. Challenge is considered a core experience of gameplay, however it is crucial to balance the difficulty of the game to the player's skill level to avoid negative feelings such as frustration [12, 13]. The visual setup of the game world, specifically with regards to goal-relevant and -irrelevant elements, is thus an important factor to consider when attempting to balance skill and difficulty in video games and to elicit positive player experiences.

1.2. Attentional capture

While, as described, task-irrelevant game elements may enhance player experience, it is important to ensure that players can process all elements that are crucial to advance in the game. Task-irrelevant items should therefore not direct attention away from target elements to an extent that these cannot be processed anymore. What determines attentional capture has been researched widely in psychological experiments involving visual search. Visual search tasks require participants to search for a target stimulus among surrounding elements or distractors [14]. Generally, stimuli that stand out against their surroundings (i.e., salient stimuli) are more easily detected than non-salient stimuli [15–18]. Moreover, there is ample evidence that it is more difficult to find a target item among distractors when they share features, as compared to when the target can be easily differentiated by any feature from the distractors [19–21]. In addition to the mere saliency of a stimulus, Target-Distractor (TD) similarity has been shown to affect search performance [18, 22, 23]. For instance, in a study by Van Zoest and Donk [18], two sets of displays containing either a vertical target line or a tilted distractor line surrounded by a series of tilted non-target lines were presented to participants. Distractor lines varied in the extent to which their orientation differed from that of the target line and participants were asked to search for the vertical target line. Results showed that performance was not only better when the distractor was not salient, but also when the difference between the orientation of the target and the distractor was high, i.e., when they were not similar to each other. Some studies have investigated how TD similarity and saliency of task-irrelevant elements affect performance in video games [24–26]. For instance, Jie and Clark [26] positioned task-relevant items (enemies) in areas high or low in background complexity and found reduced performance in the former condition. Similarly, Caroux and colleagues were able to modulate difficulty in a simple shooting game by varying both background complexity and the visual features of targets and distractors [24, 25]. They found that the game was easier when background complexity was low, and also when the target was distinguishable in both colour and size from distractors, as compared to when distractors shared one of those visual features with the target.

Such saliency and TD similarity effects are of special relevance in video game design, considering the high visual complexity in many video games. To draw attention to goal-relevant objects or events, or to reinforce important game mechanics, visual features such as colour or animations are often used as highlighting cues to make important elements distinct from their surroundings [27]. Likewise, efforts to improve accessibility, especially with regards to visual impairments, often include the manipulation of visual features, such as enhancing contrast between elements or increasing the size of relevant items [28].

1.3. Saliency and similarity effects on WM

Besides requiring players to pay attention, many video games also ask players to encode and retain information in memory over a short period of time in order to advance in the game, thus placing a substantial demand on WM. This may be particularly relevant for games that involve a strategy component, since expertise in playing such games has been associated with superior Working Memory Capacity (WMC) and distractor resistance [29]. In such games, players may need to simultaneously process a variety of game elements and information, select adequate responses to game events, plan and coordinate their actions, and make meaningful decisions in order to reach in-game goals. The presence of distraction may disrupt this process, which can be a source of additional difficulty.

There is evidence that the saliency of visual stimuli, as well as TD similarity, not only influence the allocation of attention, but also WM [30–36], both of which are closely related [37]. Melcher and Piazza [33] for instance investigated WM in a task where participants had to memorise an array of items on a screen and later judge whether a presented item was the same or different compared to an item in the initial stimulus set. They increased the saliency of either the later probed item (target) or of a non-probed item (distractor) in terms of visual contrast or size and found that memory performance was better in the condition where targets were salient. In addition, it has been reported that memorising spatial frequencies is disrupted by the presence of distractors that differ in spatial frequency, but not in orientation [32, 34, 35], highlighting that TD similarity also influences WM performance. Nemes et al. [36] further found that variations along a single feature, the hue of the distractor, modulated memory for colours, with subtle differences in hue resulting in impaired memory performance but larger differences having no effect.

While there are plenty of studies reporting disruptive influences of distractors on WM, the timing of distraction seems to be an important factor as well. Task-irrelevant items can not only disrupt the encoding of information, but also contents already stored in memory [38]. Distractors similar to the memory representation can hereby have larger disruptive influences than more dissimilar distractors. For example, Yoon et al. [39] report decreased face recognition performance when face distractors as compared to scene distractors were presented during memory maintenance. Importantly, resisting distraction at encoding and during delay has been suggested to represent separate processes [38, 40]. Investigating the impact of TD similarity during both these periods can provide a more granular perspective as to when distractors of varying similarity to target items influence WM the most, which can in turn be useful from a game design perspective in order to control game difficulty or improve player experience.

1.4. The current study

To summarise, it has been demonstrated that visual manipulation of distractor stimuli in terms of their saliency or similarity to target items can increase cognitive demand and affect visual search performance and WM. Increased cognitive demand can be beneficial since it may improve immersion or engagement, however, excessive cognitive load might also lead to accessibility concerns and negative feelings such as frustration in players. It is therefore crucial for game designers to design game elements in a way that makes the game exciting and interesting but at the same time does not add excessive cognitive demand that prevents players from advancing in the game which may leave them frustrated. The current study thus places particular emphasis on how distraction through visual characteristics affects game difficulty, as well as how performance influences player experience.

Most studies that have looked at effects of saliency and TD similarity in video games have focused on the initial detection of elements [24–26], mirroring findings commonly found in cognitive-psychological experiments involving visual search. However, as described before, task-irrelevant stimuli can not only affect target detection, but also disrupt contents already stored in memory, providing further opportunity to increase cognitive demand. How the timing of distractors (i.e., during encoding versus during maintenance) affects target processing performance and player experience in a video game that places demand on WM has not yet been empirically investigated. Since many video games however not only require players to search for items but often also ask the player to remember certain information, such as locations or mechanics, a better understanding of how and when certain kinds of distractors affect WM can further inform the visual design of game elements, which may ultimately also help to improve PX. The current study thus examined how TD similarity influences memory for targets when distractors appear either during memory encoding or during memory retention. This can not only help better understand the situations in which certain visual features of task-irrelevant game elements may affect in-game performance, but also provide further cognitive-psychological evidence about the association between encoding and delay distractor filtering that has been interrogated previously [38]. In addition, associations between visual characteristics and player experience were explored to illuminate potential beneficial as well as harmful consequences of distraction. Investigating this can provide more clarity around the question of whether visual complexity in games positively influences player experience through an increased challenge level, as some scholars suggest [9–11], or whether it can also lead to negative experiences through the reduced performance that comes along with increased display complexity [see 41–43]. The relationship between visual features and player experience has been studied by only a few [44, 45], and a thorough search of the relevant literature revealed that the association between TD similarity, WM performance, and player experience has not yet been interrogated.

To investigate the current research questions, a custom-designed video game was utilised in which both the presence, the timing, and the visual appearance of distractors could be manipulated. Based on empirical evidence and theories of TD similarity, conditions with the smallest brightness difference between targets and distractors were expected to be the most difficult and conditions with the highest brightness difference to be the easiest, reflected in player performance. Since there is evidence of individual differences in WMC and the ability to ignore distraction [46, 47], which may influence players' feelings and attitudes towards the game, several aspects of player experience and their association with performance were further explored. Particular emphasis was placed on how performance was related to enjoyment as an overall indicator of positive player experience and key reason why people play video games [48]. Uncovering how task difficulty, induced by visual characteristics, and performance affect player experience can be relevant for a wide range of games that ask players to retain information in the presence of potentially distracting visual stimuli, such as open world games.

2. Methods

The study was approved by the Ethics Committee of the Department of Psychology at the authors' university. The design and procedure, study hypotheses, as well as a data analysis plan were preregistered using the Open Science Framework repository. Deviations from the preregistration are described at the end of this section.

2.1. Participants

An *a priori* power analysis using G*Power (version 3.1.9.6) [49] was calculated to determine the minimum required sample size. With expected medium effect sizes, a power of 0.80 and an alpha error probability of $\alpha = 0.05$, the required sample size was $N = 28$ for a repeated-measures ANOVA. To allow for potential missing or faulty data, the final sample consisted of 36 participants (32 female, 1 male, 2 other) aged between 18 and 20 years ($M = 19.2$, $SD = 0.77$). Participants were recruited online via the University participant pool system SONA and received course credit for their participation. No participants were excluded from the main analysis as specified in the preregistration. All participants gave informed consent ahead of the experiment and were debriefed after the study.

2.2. The working memory game

A digital game was developed that requires players to memorise a path consisting of grey circles presented for a short time on a rectangular grid. After a brief delay, players were asked to navigate their player character on the empty grid along the memorised path. Three conditions were implemented in which either no distractors were presented, distractors were presented simultaneously with the to-be-remembered path, or in the delay period after the path had disappeared. For distractor conditions, the similarity between the distractors and the target path was further manipulated. Since contrast is often utilised to highlight game objects and at the same time offers the possibility to gradually alter similarity by increasing or decreasing brightness, this visual feature was used to manipulate TD similarity. Three brightness conditions were implemented, with distractors differing either to a large, medium, or small extent from the target path circles. The game was developed in Unity. Figure A.1 in Appendix A displays the gameplay loop of a successfully completed level without any distractor circles, and Figure A.2 in Appendix A shows the gameplay loop of a successfully completed level with distractor circles appearing simultaneously with the path.

2.3. Experimental design and task

The experiment was uploaded and accessed by participants on the website itch.io. The memory game consisted of three phases. The first phase served to identify players' individual Working Memory Capacity (WMC) in the absence of distraction. Evidence in cognitive research suggests that processing irrelevant items only affects performance when the limited capacity Working Memory (WM) system is exceeded and distractors are processed in place of targets, and not when there is enough storage to process both the target and distractor items [50]. Since the present study sought to examine how different types of distractors affect memory performance, it was necessary to ensure that participants did not have spare capacity to also remember distractors in addition to the target. Ensuring that each player played the game at a level where their baseline WMC was fully occupied made it possible to investigate the sole influence of distraction on performance. On top of that, there is substantial individual variance in the amount of information that can be stored in WM [51] as well as in the ability to ignore distraction [38, 46]. Thus, the adaptation procedure also made it possible to investigate distraction effects irrespective of inter-individual variance in WMC.

Before participants started with phase 1, a calibration screen was provided to ensure all participants were able to clearly differentiate between circles in all experimentally used shades of grey. On this screen, participants were asked to adjust the brightness and contrast settings of their device to ensure they could clearly see the difference between the shades. The circles that were presented differed 10% in brightness from each other, which was the highest degree of similarity that could occur in the main part of the experiment.

After the calibration, participants proceeded with the adaptation (phase 1) as follows: they were asked to remember a path consisting of grey circles presented on a grid with the top left cell as starting point and bottom right cell as end point. The grey circles had a brightness value of 50% (HSB value of H=0, S=0, B=50). After the path had disappeared, participants were asked to follow the memorised path with a red player character presented in the top left cell, which represented the beginning of the path in every trial. The first trial started with a grid size of 3x3. If participants got at least 2 out of 3 trials correct, the grid size increased by 1 column and 1 row on the next trial (i.e., the player had moved to the next level). If only 1 out of 3 trials were solved correctly, the grid size decreased by 1 column and 1 row (i.e., the player moved down a level). The maximum grid size that could be reached was 7x7. In total, each participant completed 18 trials in this phase. The individual grid size that was used in phase 2 was determined as the largest grid size at which the participant successfully completed at least 2 out of 3 trials. The procedure for phase 1 can be seen in Figure 1.

The procedure in the second phase of the experiment was similar to phase 1, and participants were asked to memorise a path on a grid, and after the path has disappeared, follow the memorised path with their player character. However, this time the grid size was fixed to each player's individual level that was determined in phase 1. In addition, distractor trials

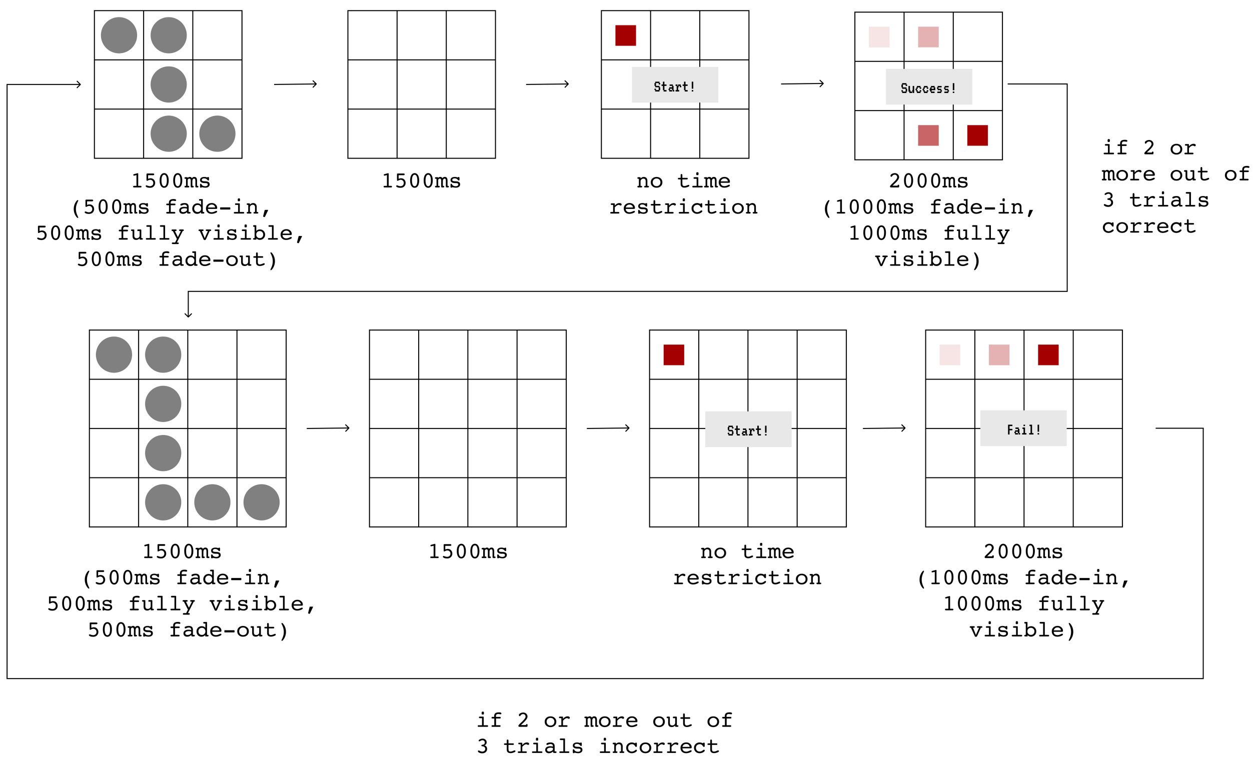

Figure 1: Phase 1 of the game. The game started with a grid size of 3x3. If at least two out of three trials were correct, grid size increased by 1 cell size in width and 1 cell size in height. If two or more out of three trials within that grid size were incorrect, grid size decreased by 1 cell size in width and height, respectively. Maximum reachable grid size was 7x7. Where fade effects were used, game elements changed their appearance in a linear manner between fully opaque and fully transparent.

were introduced in this phase, and 5 distractor circles appeared either simultaneously with the target path (Encoding Distractor (ED) condition), or in a delay period (Delay Distractor (DD) condition). Where participants reached a grid size of only 3x3, only 4 distractors could be presented as the path already occupied 5 of the 9 possible grid positions. Distractors were grey and had brightness values of 20% (H=0, S=0, B=20), 30% (H=0, S=0, B=30), 40% (H=0, S=0, B=40), 60% (H=0, S=0, B=60), 70% (H=0, S=0, B=70), and 80% (H=0, S=0, B=80), resulting in Target-Distractor (TD) difference values of 10%, 20%, and 30% (hereafter referred to as Diff10, Diff20, and Diff30). Distractors were thus either brighter or darker than the target path circles (which had a brightness value of 50%), in order to account for potential confounds due to stimulus brightness per se and not the relative difference to the target. The results of the analysis comparing brighter and darker distractors compared to target brightness can be viewed in section 3.2. A point system was further implemented to keep players engaged throughout the experiment. For each successful level, 100 points were gained, and for each failed level, 50 points were deducted. Figure 2 illustrates the experimental procedure in phase 2.

After this phase, participants' experience playing the game was assessed with the PXI

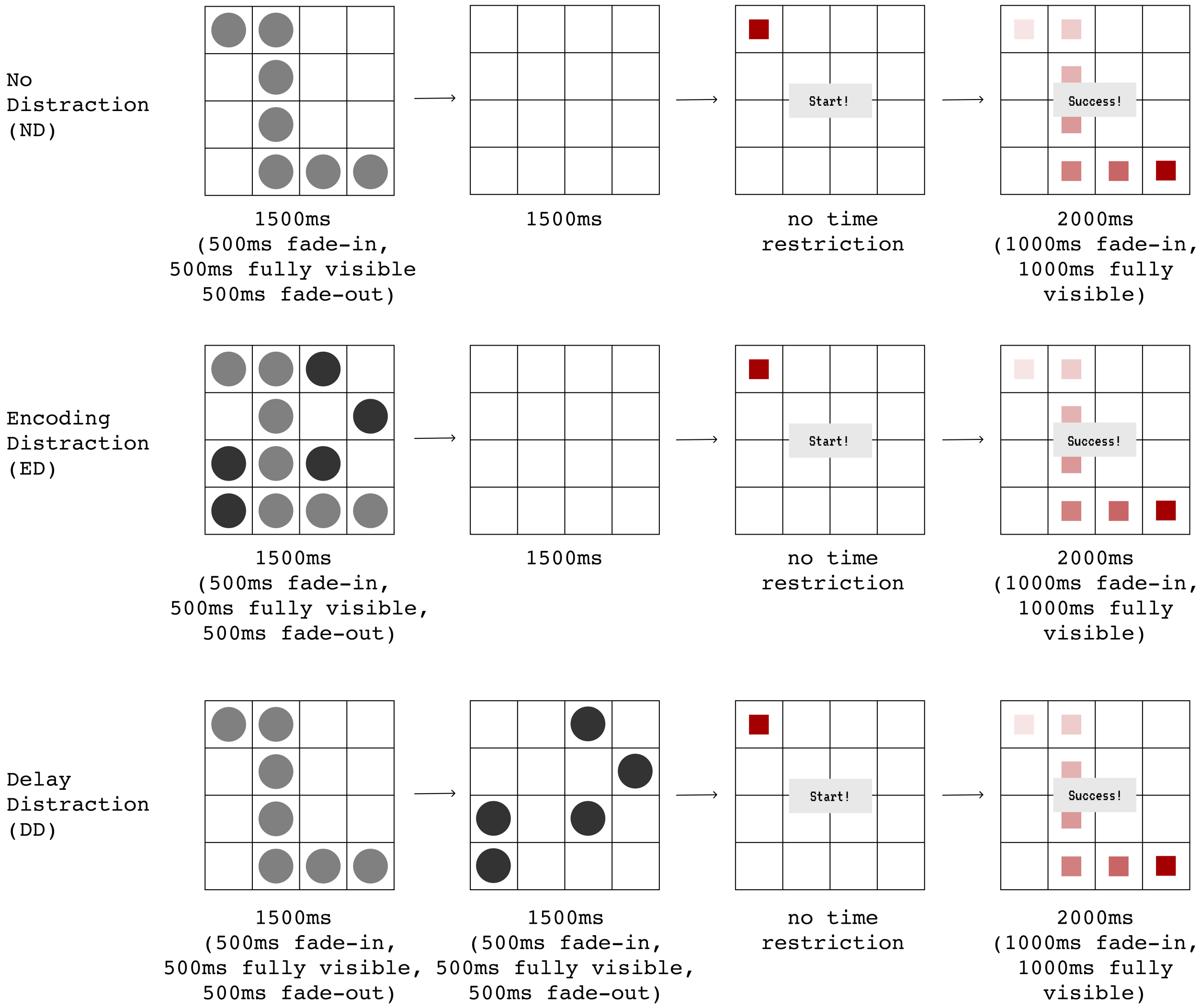

Figure 2: Phase 2 of the game. In ND conditions, the path was presented alone. Players responded by following the memorised path after a delay period of 1500ms. In ED conditions, distractors (here: 20% grey) were presented with the path. After a delay of 1500ms, players responded. In DD conditions, the path was first presented alone, and in the delay period, distractors appeared. Then, players responded. Grid size stayed constant for each participant in this phase. Where fade effects were used, game elements changed their appearance in a linear manner between fully opaque and fully transparent.

questionnaire [52]. The PXI was chosen since it is an open-access and well validated player experience instrument that is widely used in video gaming research as it covers a broad range of player experience facets. It consists of 30 questions on a 7-point Likert scale (-3: strongly disagree to +3: strongly agree) and includes the scales meaning, curiosity, mastery, autonomy, immersion, progress feedback, audiovisual appeal, challenge, ease of control, and clarity of goals, enabling the exploration of a variety of potential associations between game difficulty, performance, and player experience. As the study also aimed to assess the extent to which players enjoyed the game overall, the three questions for enjoyment were included, which are provided with the inventory but are not a construct of the PXI per se. Finally, two questions about participants' expertise playing video games (years playing digital games, hours per week spent playing digital games) were asked. Total duration of the experiment was around 25 minutes.

2.3.1. Experimental Conditions

In total, there were 7 within-subject conditions: a no distractor (ND) condition, which served as the baseline, an ED condition with Diff10 (ED10), an ED condition with Diff20 (ED20), an ED condition with Diff30 (ED30), a DD condition with Diff10 (DD10), a DD condition with Diff20 (DD20), and a DD condition with Diff30 (DD30). There were 10 trials in each distractor condition (5 with the distractors darker than the target and 5 with the distractors brighter than the target), resulting in 30 ED trials and 30 DD trials. The number of ND trials was 60 to ensure an equal number of trials with and without distractors. Trials were further presented in a random order to limit expectation effects. Each participant completed all 7 conditions, in addition to the first phase to identify each player's individual WMC, and the PXI at the end of the experiment.

2.4. Data analysis

The main outcome variable in the current study was performance in phase 2, which was measured in two different ways: success rate and progression. The success rate refers to the overall win-to-lose ratio (a trial is won when players successfully follow the entire path, a trial is lost when players move to a cell that was not occupied by the path), whereas progression refers to the average number of moves a participant made before failing or succeeding. The number of moves was averaged over the number of trials in each condition. For instance, the progression value for the encoding condition represents an average of a player's number of moves in the 30 encoding trials. Since the presented paths always started in the top left cell and ended in the bottom right cell, all paths within a given grid size were of the same length. The average number of moves thus takes into account the individual grid size, and serves as a more fine-grained measure of performance that also considers a person's WMC. Success rate instead made it possible to investigate distraction effects irrespective of participants' baseline WMC, and may furthermore be more relevant for player experience than absolute performance, since it is directly related to the in-game feedback players receive (gained or deducted points).

For both outcome measures, a one-factorial ANOVA with the three levels ND, ED, and DD was calculated in order to uncover how the presence of distractors at different stages of the WM task affects performance compared to no-distractor trials. Again for both outcome measures, a further 2x3 repeated measures ANOVAs with the factors Condition (ED, DD) and TD difference (Diff10, Diff20, Diff30) was calculated to directly compare the effects of the two different types of distraction, as well as TD similarity on performance. Follow-up comparisons were calculated where appropriate and corrected using Bonferroni-Holm.

For the measurement of player experience, which formed part of the exploratory analysis, sum scores were created for every scale of the PXI, including enjoyment. Each scale consisted of 3 questions and since possible answers on each item ranged from -3 to +3, possible sum scores for each scale reached from -9 to +9. Those scores were correlated with averaged performance for ND, ED, and DD, and with performance in each ED10, ED20, ED30, DD10, DD20, DD30 conditions.

While the correlation analysis provided insights about how ND, ED, and DD performance are related to each other, these performance measures may also involve combined skills that were required in each ND, ED, and DD conditions, such as overall WMC, or the ability to follow instructions or handle game controls. To control for such factors and see how ED resistance and DD resistance specifically and uniquely predict enjoyment, a hierarchical regression analysis was performed. Two hierarchical regressions were conducted using either success rates (regression 1) or progression (regression 2) in the ND, ED and DD conditions to predict enjoyment. The regression hierarchy was set up so that at stage 1, ND performance alone, at stage 2, ND and ED performance, and at stage 3, ND, ED and DD performance were used to predict enjoyment. Having seen how performance is affected by TD difference, a follow-up analysis investigated how TD similarity predicts enjoyment, which could provide further support for the importance of considering TD similarity in game design. Thus, where significant associations were found regarding distractor presentation period (ED or DD), further hierarchical regressions were calculated with enjoyment predicted from performance in the ND and each of the three TD difference conditions (Diff10, Diff20, Diff30) of the respective distractor presentation period. Again, this regression was calculated for both success rates and progression. The regression hierarchy was set up so that enjoyment was predicted from ND alone at stage 1, then Diff10 was added at stage 2, then Diff20 was added at stage 3, and finally, Diff30 was added at stage 4. It should be noted that these analyses were exploratory in nature, as no specific hypotheses were established regarding such associations.

2.5. Deviation from preregistration

A deviation from the preregistration was made in one aspect: for the secondary performance measure (progression), the number of moves a participant made was used instead of the ratio between target path length and reached path length. This alteration was made since the initial measure would eliminate any baseline WMC differences, which may be an important factor in the relationship between TD similarity, performance, and player experience. For instance, the ratio between target path length and reached path length of a participant reaching 3 steps on a grid size of 5 x 5 (target path length = 9) would be the same as for a participant reaching 5 steps on a grid size of 8 x 8 (target path length = 15), although the latter memorised a higher absolute number of target positions, indicating a higher WMC. Utilising the number of moves a participant makes, averaged across trials, takes into account the person's baseline WMC and may thus be more relevant for addressing the present research questions.

3. Results

3.1. Descriptive statistics

Participants spent on average 4.67 hours per week playing video games ($SD = 8.31$, min: 0, max: 48). Participants have been playing video games for 10 years on average (min: 4 years, max: 15 years). Maximum reached grid size was 7 (7x7), and the smallest reached grid size was 3 (3x3), with a median of 6 ($IQR = 1$). Only 1 person (2.78% of participants) was at the bottom end, and 2 participants (5.56% of participants) reached the upper end of 7, so no floor or ceiling effects were present.

3.2. Direction of TD difference

In order to rule out potential effects of stimulus brightness per se rather than the relative distance to the target, two three-way ANOVAs with the factors direction (darker, brighter), TD difference (Diff10, Diff20, Diff30), and distractor condition (ED, DD) for both success and progression outcome variables were calculated. There were no significant main effects for direction regarding success rates ($F(1, 35) = 2.61$, $p = 0.115$) or progression ($F(1, 35) = 1.26$, $p = 0.269$), and no significant interactions between direction and TD difference (success rates: $F(2, 70) = 0.35$, $p = 0.706$; progression: $F(2, 70) = 0.01$, $p = 0.987$) or distractor condition (success rates: $F(1, 35) = 0.23$, $p = 0.638$; progression: $F(1, 35) = 2.02$, $p = 0.165$). The three-way interaction between direction, TD difference and distractor condition also remained non-significant for both success rates ($F(2, 70) = 0.397$, $p = 0.674$) and progression ($F(2, 70) = 0.26$, $p = 0.773$). These results do not suggest that the effects of TD difference on performance are specific to distractors that are brighter or darker than the targets. Subsequent analyses therefore focused on TD difference, irrespective of the direction of this difference.

3.3. Main effects for distractor condition

Descriptive statistics for success and progression values in each condition are presented in Table 1.

3.3.1. Success rate

A one-factorial ANOVA with success rate as the dependent performance variable and distractor condition (ED, DD, ND) as the independent factor revealed a significant main effect ($F(2, 70) = 29.60$, $p < 0.001$, $\eta_p^2 = 0.46$). Follow-up pairwise comparisons revealed a higher ND performance than both ED performance ($t(70) = 7.41$, $p < 0.001$) and DD performance ($t(70) = 3.71$, $p < 0.001$), and a significantly higher DD performance than ED performance ($t(70) = 4.05$, $p < 0.001$).

Outcome	Success	Progression
ND	0.71 (± 0.15)	7.97 (± 1.36)
ED	0.55 (± 0.17)	7.20 (± 1.54)
DD	0.64 (± 0.18)	7.59 (± 1.46)
ED10	0.46 (± 0.21)	6.71 (± 1.90)
ED20	0.56 (± 0.22)	7.31 (± 1.59)
ED30	0.64 (± 0.18)	7.57 (± 1.46)
DD10	0.63 (± 0.22)	7.53 (± 1.61)
DD20	0.64 (± 0.21)	7.67 (± 1.57)
DD30	0.64 (± 0.23)	7.57 (± 1.47)

Table 1: Means and Standard Deviations for each condition for the outcome variables success and progression. ED and DD are averaged over the three TD difference conditions (e.g., ED includes ED10, ED20, and ED30)

3.3.2. Progression

Consistent with the analysis for success, a one-factorial ANOVA with progression as the dependent performance variable and distractor condition (ED, DD, ND) as the independent factor revealed a significant main effect ($F(2,\ 70) = 18.12$, $p < 0.001$, $\eta_p^2 = 0.34$), with pairwise comparisons revealing a better ND performance than both ED performance ($t(70) = 6.16$, $p < 0.001$) and DD performance ($t(70) = 2.88$, $p = 0.008$), and a significantly better DD performance than ED performance ($t(70) = 3.06$, $p = 0.008$).

3.4. Interaction effects between condition and TD difference

3.4.1. Success rate

A 2x3 ANOVA with the factors condition (ED, DD) and TD difference (Diff10, Diff20, Diff30) and the dependent variable success rate revealed a main effect for condition ($F(1,\ 35) = 16.76$, $p < 0.001$, $\eta_p^2 = 0.32$), a main effect for TD difference ($F(2,\ 70) = 5.96$, $p = 0.004$, $\eta_p^2 = 0.15$), as well as an interaction between the two factors ($F(2,\ 70) = 6.96$, $p = 0.002$, $\eta_p^2 = 0.17$) (see Figure 3). Table 2 displays the results of the follow-up pairwise comparisons. Adjusting for multiple comparisons, there were significant differences between ED10 and ED20, between ED10 and ED30, and between ED20 and ED30 while no significant differences were observed between TD difference conditions in the delay period.

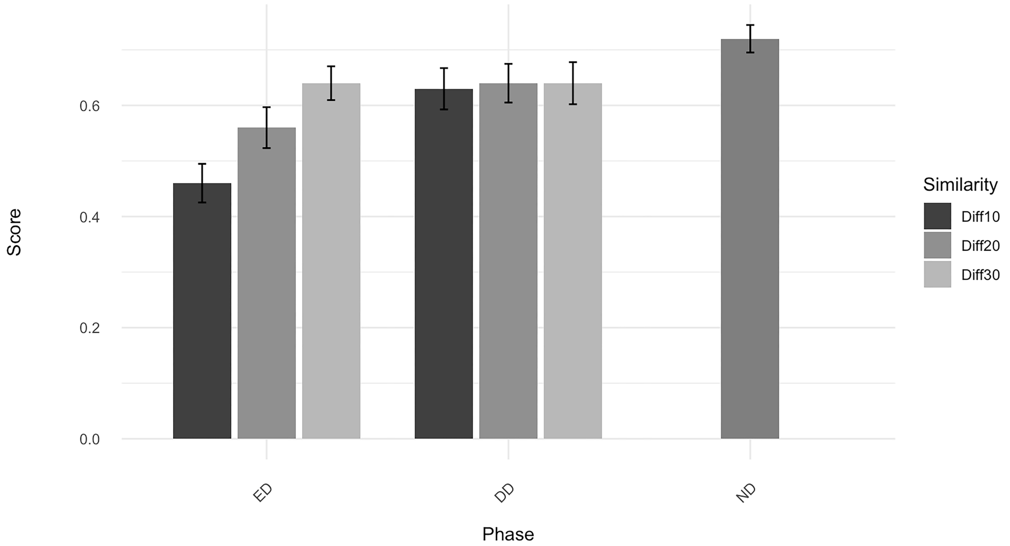

Figure 3: Interaction between TD similarity (Diff10, Diff20, Diff30) and distractor condition (ED, DD) for the outcome measure success rate (defined as the ratio of correct trials to total trials). The ND score is displayed for reference. Error bars represent +/- 1 standard error.

Pair	t	df	p-value (Bonferroni-Holm-adjusted)
ED10 - ED20	-3.30	70	0.004**
ED10 - ED30	-4.53	70	$<$ 0.001***
ED20 - ED30	-2.48	70	0.018*
DD10 - DD20	-0.31	70	$>$ 0.999
DD10 - DD30	-0.16	70	$>$ 0.999
DD20 - DD30	0.15	70	$>$ 0.999

Table 2: Paired t-test results for success rate. **** p < .001; ** p < .01; * p < .05*

3.4.2. Progression

For the dependent variable progression, results revealed a similar pattern: A 2x3 ANOVA with the factors condition (ED, DD) and TD difference (Diff10, Diff20, Diff30) revealed a main effect for condition ($F(1,\ 35) = 9.35$, $p = 0.004$, $\eta_p^2 = 0.21$), a main effect for TD difference ($F(2,\ 70) = 7.72$, $p = 0.001$, $\eta_p^2 = 0.18$), as well as a significant interaction between the two factors ($F(2,\ 70) = 6.29$, $p = 0.003$, $\eta_p^2 = 0.15$) (see Figure 4). Table 3 displays the results of the follow-up pairwise comparisons. As for success rates, there were significant differences between ED10 and ED20, and between ED10 and ED30, and no

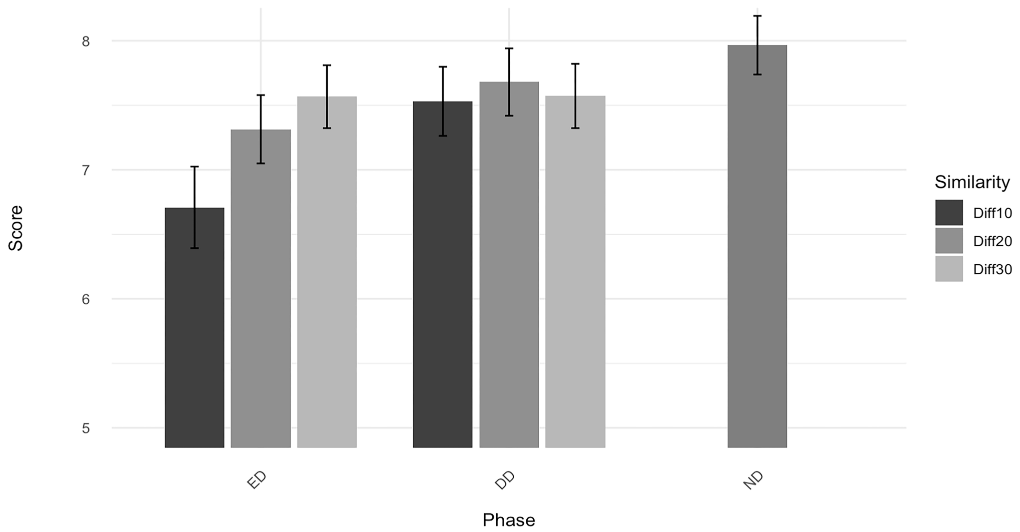

Figure 4: Interaction between TD similarity (Diff10, Diff20, Diff30) and distractor condition (ED, DD) for the outcome measure progression. The ND score is displayed for reference. Error bars represent +/- 1 standard error.

significant TD differences were observed between the different DD conditions.

Pair	t	df	p-value (Bonferroni-Holm-adjusted)
ED10 - ED20	-3.49	70	0.002**
ED10 - ED30	-4.15	70	0.001**
ED20 - ED30	-1.61	70	0.117
DD10 - DD20	-1.08	70	0.864
DD10 - DD30	-0.28	70	> 0.999
DD20 - DD30	0.62	70	> 0.999

Table 3: Paired t-test results for progression values. **** $p < .001$; ** $p < .01$; * $p < .05$*

3.5. Player experience and correlation analyses

Two-tailed Pearson correlations were calculated for the sum scores of the PXI, the individual grid size, the performance metrics in the ND, ED10, ED20, ED30, DD10, DD20, DD30 conditions, as well as performance in the averaged ED and DD conditions for success rate and progression respectively. All Pearson values can be viewed in the correlation matrices for success in Table A1 and for progression in Table A2 in Appendix B.

As expected, all measures of WM were positively correlated, although some correlations did not reach statistical significance: There were significant and strong positive correlations between ND, ED, and DD performance (all p values < 0.001). Correlations were also significant and positive between most TD difference conditions regarding success rates ($p < 0.05$), with the exception of ED30 and ED10, and ED20 and DD10, which were not significantly correlated. Regarding progression, all TD difference conditions were highly correlated (all p values < 0.001).

No *a priori* hypotheses had been established for relations between performance and player experience metrics, so the following analyses were exploratory in nature. Figure 5 displays a boxplot of the sum scores for each of the PXI scales including enjoyment.

Enjoyment correlated with the averaged success rates for ED conditions, and also with success rates in each of the ED conditions. Enjoyment did not correlate with success rate in the ND condition (see Table A1). Regarding progression, enjoyment correlated with none of the performance metrics (see Table A2).

Similar outcomes were obtained for audiovisual appeal, which correlated moderately to strongly with averaged success rates for both ED and DD, and also with success rates in each of the ED conditions. Audiovisual appeal also correlated with success rate in the DD30 condition (see Table A1). Like for enjoyment, regarding progression, audiovisual appeal did not correlate with any performance metric (see Table A2).

There were further significant positive correlations between each ND, ED, and DD success rate and mastery, progress feedback, and ease of control. Regarding progression, the only measure to show a significant positive correlation with performance in the ND condition and the averaged performance in ED and DD conditions was clarity of goals. Ease of control further correlated significantly and positively with progression for ED and DD.

3.6. Regression analysis

Having seen positive correlations between enjoyment and success rate for the WM task with each type of distraction (ED and DD), but no significant correlation for ND success, it was further explored how WMC and distractor resistance may contribute to overall game enjoyment. To that end, a hierarchical regression analysis was performed for each outcome measure: success rate and performance. Detailed results and standardised β coefficients can be found in Appendix C in Table B1 for success rate and Table B2 for progression. At stage 1, ND performance was used to predict enjoyment (model 1), then ED performance was entered at stage 2 (model 2), and finally, DD performance was added at stage 3 (model 3). Regarding success rates, the model with ND predicting enjoyment alone was not significant, however adding ED to the model accounted for an additional 19% of variation in enjoyment. ED success significantly and uniquely contributed to enjoyment when also taking into account ND success. Adding DD performance to the model at stage 3 did not explain any additional variance and ED success was still found to make a significant and unique contribution to predicting enjoyment.

Regarding progression, model 1 with only ND as a predictor was not significant, consistent with the results for success. Adding ED to the model at stage 2 explained an additional 20% of variation in enjoyment. Here, both ND and ED significantly and uniquely predicted

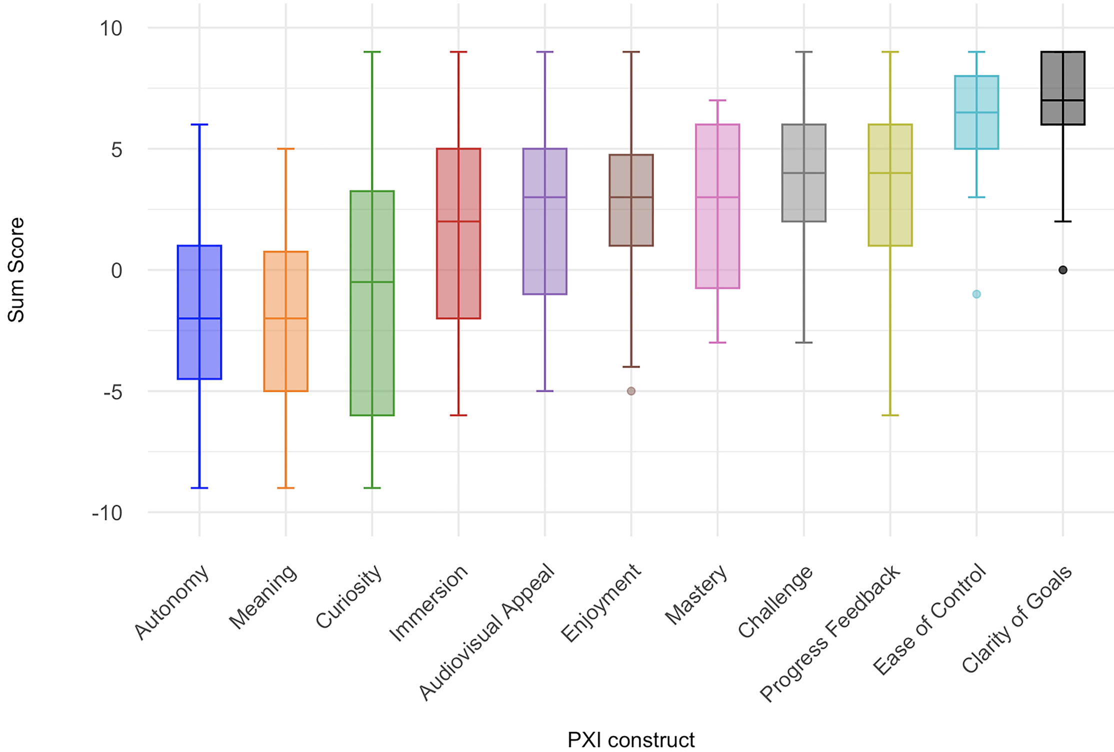

Figure 5: Boxplot for each of the scales of the PXI including enjoyment. Boxes represent the interquartile range between the third and first quartile (IQR = Q3-Q1). Lower whiskers extend to Q1 - 1.5IQR; upper whiskers extend to Q3 + 1.5IQR. Horizontal lines within each box represent the median.

enjoyment, with a negative coefficient for ND and a positive coefficient for ED. The addition of DD performance to the model again did not explain any additional variance and both ND and ED continued to significantly and uniquely predict enjoyment.

Since ED performance seems to contribute uniquely to enjoyment and TD similarity at the stage of encoding seems to affect performance, this association was further explored by calculating a hierarchical regression with each TD difference level (ED10, ED20, ED30) predicting enjoyment, controlling for ND. Detailed outcomes and standardised β coefficients can be found in Appendix C in Table B3 for success rate and Table B4 for progression. At stage 1, ND was used to predict enjoyment (model 1), at stage 2, ED10 was entered (model 2), at stage 3, ED20 was entered (model 3), and at stage 4, ED30 was entered (model 4). For success rates, the first model was not significant. Adding ED10 at stage 2 did not significantly explain additional variance, and neither did adding ED20 at stage 3, and ED30 at stage 4.

For progression, again model 1 remained non-significant. Adding ED10 at stage 2 did not significantly explain additional variance, however adding ED20 at stage 3 explained an additional 15% of variation in enjoyment. In addition, at this stage, ND performance uniquely and negatively contributed to enjoyment. Adding ED30 at stage 4 did not explain additional variance, and neither ND nor ED20 performance remained significant.

4. Discussion

4.1. Distractors and game performance

The present experiment examined how Target-Distractor (TD) similarity affects game difficulty and memory performance when distractors were presented during periods of memory encoding and maintenance utilising a custom-designed video game. Associations between difficulty, performance, and player experience metrics were further explored. Overall, results revealed that all distractors, irrespective of their visual characteristics and presentation period (encoding, delay), had a debilitating effect on performance when compared to trials without any distractors, suggesting that game difficulty can be increased when irrelevant items are present in the game world. This finding is in line with evidence from cognitive research reporting impaired Working Memory (WM) performance in the presence of distraction [4–6]. Performance in Delay Distractor (DD) conditions was overall better than in Encoding Distractor (ED) conditions, which suggests that ignoring distractors during encoding of the target path was more difficult than ignoring distractors that appear after the path has already been encoded, providing further cognitive-psychological evidence for separate mechanisms involved with encoding and delay distractor filtering [38]. Contrary to the present findings, the majority of studies looking at ED and DD resistance report better memory performance in the presence of encoding distractors as opposed to delay distractors [40, 53, 54]. A reason for this may be the nature of the task and stimuli in the current experiment compared to previous studies. In the present experiment, the to-be-remembered stimuli formed a coherent object (the path), which may be more resistant to delay distraction than individual elements, since it may be represented in memory as one object. In the encoding period, such an object representation might not have been fully formed, and could have further been disrupted by the presence of distractors that diverted attention away from the path. Nonetheless, these results highlight the importance of visual design considerations during periods of memory encoding in particular. There are many situations in video games where players are asked to retain certain pieces of information (e.g., quest targets, pathways, enemy attack patterns) and the present results suggest that stimuli presented during these periods may add (unwanted) difficulty to the task by distracting from the main goal. Acknowledging these potential consequences could be especially relevant in games where the baseline difficulty of memory retention is high, such as in open world games, which are prone to have many different moment-to-moment gameplay aims and a variety of visual stimuli competing with player attention [55, 56]. Future studies could research the impact of delayed versus simultaneous distraction in these more complex games to further inform how different types of games could be designed in a way that reduces unwanted challenge during or after memory encoding. It is also worth considering that individuals show differences in their ability to ignore distractors at encoding versus at maintenance [57] and may therefore be impacted differently by distraction during or immediately after memory encoding, which has implications for providing a consistent player experience.

As can be seen in Figures 3 and 4, the present results further reveal a gradual pattern of decreased performance as TD similarity increased when distractors were presented in the encoding period, suggesting that the more similar task-relevant and task-irrelevant items are, the more difficult the game becomes. This result is in line with the stated hypotheses and consistent with findings reported in a recent study by Duan et al. [53], who reported a decreased efficiency in ignoring distractors when targets and distractors could only be distinguished by a pre-cue indicating target locations but were otherwise identical in appearance. However, in the present study, this pattern was not observed for distractors presented during the delay period, where participants performed similarly well irrespective of the distractors' visual setup (see Fig 3 and 4), suggesting that maintaining information in memory is more robust to interference from similar distractors than encoding information. These results further illustrate the importance of considering potential distraction through visual elements during memory encoding periods in video games. Non-goal-related game elements, and particularly those that are visually similar to goal-related elements could present a source of additional challenge for players. This can cause accessibility problems, not only for players with visual or cognitive impairments, but also more generally when games are played in suboptimal viewing conditions such as in bright sunlight or on small screens. To combat such issues, game accessibility guidelines recommend options to hide potentially distracting background movement or to adjust contrast to highlight essential game elements or information [e.g., 58]. El-Nasr and Yan [59] illustrate such a highlighting effect in an action-adventure game, where players' attention was drawn to a health object only once it changed its appearance from being very similar to the background to a bright red colour. The present results indicate that highlighting methods such as increasing contrast between target elements and distractors can not only aid the initial identification of relevant elements, but also further benefit the retention of such information in memory. However, since distraction has to be interpreted with player aims in mind, such bottom-up stimulus characteristics are not the only relevant aspects. As El-Nasr and Yan also emphasise, attention is highly dependent on top-down influences such as where players expect certain items to appear [59]. Therefore, it can be argued that the current aim of the player influences whether or not a stimulus is considered relevant or potentially distracting. Given the present results, game design efforts might consider the visual similarity of stimuli unrelated to the current player goal in gameplay situations that demand attention and memory encoding capabilities.

4.2. Associations between performance metrics and player experience

Correlation analyses revealed that the performance metrics for ND, ED, and DD trials were highly intercorrelated, indicating that individuals who were more successful in trials without distraction were also better in trials with distractors. In addition, individuals who were better in trials where distractors were presented together with the target were also better in trials where distractors were presented during memory retention. This was expected since all conditions required shared abilities such as WM or the ability to follow task instructions.

Analysis of the PXI scales and performance measures revealed that enjoyment correlated with success rate in all conditions except the ND condition, indicating that a better performance in conditions with distractors was associated with higher enjoyment ratings. The absence of a correlation between enjoyment and performance in ND trials in the present study suggests that enjoyment is particularly related to distraction and not WM in general. The aim of the utilised game was specifically linked to memory retention, so any additional challenge associated with distractors was related to the player goal. It could therefore have been the case that distractors made the game more interesting and challenging, and players may have been particularly satisfied when they succeeded in these levels compared to levels without distractors. Consequently, this may have led to the higher ratings of enjoyment that were observed. Additionally, since grid size was calibrated to individual performance in the absence of distraction, ND success rates were similar in all players, while distractor success rates were also based on the individual abilities of the players to handle distraction, which were found to be associated with enjoyment. These findings provide some clarity around the question of whether and how visual complexity impacts player experience. While the current work demonstrates that distractors generally led to reduced performance, which mirrors findings of poorer performance with increased display clutter in tasks requiring visual search, attention, or WM [41–43], the results also suggest that the presence of distractors can have a positive influence on player experience. This appears to be particularly the case when participants are able to overcome the heightened challenge level that comes along with the increased display complexity. While this is in line with reports of enhanced player experience through challenge in games [9–11], the present findings suggest that the challenge level still needs to be aligned with players' skills in order to evoke positive experiences. With regards to the design of digital applications such as video games, the effects of visual complexity on performance as well as the effects of performance on player experience should thus not be considered in isolation. Instead, these factors should be viewed as part of a complex interplay that involves the individual skills of the player, and potentially also further player characteristics such as game difficulty preferences or play styles.

Notably, no correlations were found between enjoyment and the number of moves participants were able to progress (see Table A2), indicating that enjoyment is not a result of participants' skill per se, but particularly of the successful completion of levels. Likewise, mastery was found to be associated with success rate but not progression, which also suggests that (objective) skill in terms of how far players proceeded did not necessarily elicit feelings of achievement when they did not complete the level successfully. Thus, more skillful players - irrespective of whether this skill is related to WMC, their ability to follow instructions or to handle game controls - did not necessarily feel that they did particularly well, especially when they did not successfully complete the level, and consequently may not have enjoyed the game as much as players who were less skillful objectively but had higher success rates. This is in line with previous studies reporting associations between player performance and enjoyment [60–62]. It has been suggested that such associations are mediated by feelings like self-efficacy [62] or by the satisfaction of intrinsic needs of competence [63], which is closely related to the PXI scale of mastery that was assessed in the current study [64]. Since results revealed that both enjoyment and mastery were associated with success rate but not progression, and further that enjoyment and mastery were correlated, players who actually succeeded and thus were rewarded with positive feedback and points may have attained a higher sense of mastery or competence and consequently enjoyed the game more. From a game design perspective, this can have important implications regarding the length of levels or when players are rewarded, since even though players might do well, positive player experiences may only arise from recognising the successful completion of a task. Rewards are indeed thought to bear a central role in driving video game motivation [65], and in addition, the timing and frequency of rewards is crucial: breaking down complex tasks into smaller steps that allow for immediate feedback is considered much more effective in eliciting positive player experiences than providing a single reward for accomplishing a long-term goal [66].

A similar pattern was found for the relationship between success rate and audiovisual appeal, with positive associations in all but the ND condition. There were no correlations between progression and audiovisual appeal, suggesting that high ratings of audiovisual appeal specifically depend on whether players actually succeed, and not how far they proceed within levels. This finding is in line with a study by Wiley et al. [67], who report a relationship between game performance and audiovisual appeal when success was rewarded with points, indicating that the visual feedback in form of points after succeeding led to higher ratings of audiovisual appeal. The present game also featured a point system to reward successful completion of levels, but also to punish failures (albeit players were awarded twice as many points for succeeding as were deducted for not succeeding). Yet, correlation results showed that higher success rates were associated with experienced progress feedback, suggesting that players were more aware of positive feedback after success than negative feedback after failure, which may have led to the observed higher ratings of audiovisual appeal. Audiovisual appeal further correlated very highly with enjoyment, indicating that games that are perceived as more appealing are enjoyed more, a relationship that has been proposed before [68, 69]. Audiovisual design can thus be a powerful way to increase enjoyment in video games. It has to be noted that the game that was created for the present study was very minimalist in order to eliminate noise in examining subtle contrast differences and their effects on game performance. There were further no audio effects, thus providing very little opportunity for audiovisual appeal. Further studies are needed that directly manipulate visual and auditory features of games in addition to their difficulty and examine the relationship between players' success rate, progress feedback, perceived audiovisual appeal, and enjoyment in order to make more meaningful conclusions.

Regression analyses revealed that the success rate in the ED condition uniquely predicted enjoyment, suggesting that higher ED resistance abilities lead to higher ratings of enjoyment. Notably, this was similar for progression, with a significant unique contribution of ED performance to enjoyment when added to the regression model. Thus, it seems that when accounting for the shared variance between ND and ED performance, not only the experience of success, but the number of grid positions participants were able to remember in presence of distractors predicted enjoyment. The ND and ED condition differed merely in the presence of distractors in the ED condition, wherefore the unique part of ED progression may be specifically related to resisting distractors. DD performance did not significantly explain more variance in enjoyment when added to the model, suggesting that the ability to resist distraction during memory maintenance did not affect enjoyment. The regression analysis for progression also revealed a unique contribution of ND performance to enjoyment, yet only when ED was added to the model and thus the shared variance between ND and ED scores was effectively removed. Notably, the coefficient for ND was negative, whereas ED performance positively predicted enjoyment as mentioned beforehand. This may seem counterintuitive at first, however it could again indicate that individuals who perform well in the absence of distraction may find the task less engaging or challenging, which could have led to lower ratings of enjoyment. Hence, a high performance per se does not necessarily enhance player experience, but may only do so when the task is interesting or challenging, again highlighting the importance of providing an adequate challenge level for each player. Overall, the finding that ED performance explained significant variance in enjoyment for both success and progression suggests that ED resistance abilities may be an important predecessor of enjoyment in games that require players to retain information in the presence of distracting elements. Follow-up analyses looking at whether this effect was specific to ignoring very similar or dissimilar distractors hinted at a contributing unique effect of ignoring encoding distractors with a 20% TD difference (ED20), when accounting for shared variance with performance in ND trials and trials with very similar distractors (ED10). Since it was found that trials with a 30% TD difference were the easiest, and trials with a 10% TD difference were the most difficult, this indicates that a good performance only in trials with medium difficulty leads to enjoyment. In players who performed well in easy or difficult trials it is possible that feelings of frustration or boredom dampened a sense of achievement and thus limited enjoyment. Yet, it has to be noted that the unique contribution of ED20 became non-significant when performance in ED30 trials was added to the model, and was further only observed for progression and not success rate. To yield more conclusive outcomes, future studies are needed that investigate more closely the unique effects of performance in different game difficulty modes on enjoyment. Still, the present results further support the notion of separable mechanisms involved in ignoring distraction at the time of memory encoding or during delay periods, as has been suggested in cognitive-psychological research [38]. The current work extends this view by demonstrating that the effects of distraction at different times of processing go beyond mere performance, but can also impact experiential qualities like enjoyment, which is particularly important in areas such as game design or gamification.

4.3. Limitations and future directions

In order to eliminate differences in baseline ability (i.e., performance in the ND condition), an adaptation phase was implemented that should determine the optimal grid size for each individual. This procedure allowed individuals with a high WMC to play at a level where they would less likely feel bored and reduced the likelihood of frustration in individuals with a lower WMC. Yet, the adaptation phase might have not eliminated all individual differences in baseline performance. As it was quite short and only two out of three trials needed to be correct for the grid size to increase, chance could have influenced the grid size players reached. Since there was a 50 percent likelihood of guessing the right grid position for every move (possible moving directions were right and down), there was still a 25 percent chance to guess the last two moves correctly, and a 12.5 percent chance to guess the last three moves correctly.

Another limitation related to the design of the game is that the spatial proximity between targets and distractors was not controlled. This was due to the varying grid sizes which made it impossible to ensure a consistent spatial distance between path and distractors. Consequently, on larger grids, the likelihood was higher that distractors were further away from the target since a fixed number of distractors was used for all grid sizes (except for grid size 3x3, where there was space for only 4 distractors, which all touched the path). This increased spatial distance could have reduced interference with memorising the target path. There is evidence that spatial proximity between targets and distractors can interfere with visual search speed and accuracy [70–72], and also with visual WM [73], so subsequent studies may further investigate how spatial proximity between goal-relevant and irrelevant items affect difficulty in video games.

Furthermore, the present sample consisted of participants aged 18-20 years old. Since there is evidence of limited WMC and also a reduced ability to ignore distraction with increasing age [54, 74], it may be the case that the present results are not applicable to older individuals, who may be affected to a larger extent by the visual complexity in digital applications, leading to potentially negative user experiences. Gaming is increasingly popular across all age groups [75], therefore it is important to also consider different age groups when looking at the effects of distraction and TD similarity on performance and player experience. Future studies should take this into consideration.

It also has to be noted that the present correlation and regression analyses were exploratory in nature and thus need to be interpreted with caution. Since many associations were examined, there is an increased likelihood of seeing Type I errors. Some of the observed results could thus be false positives and not represent actual associations. Future studies should attempt to replicate the relationships suggested by this exploratory approach. Moreover, the sample size was specifically aimed at the main hypotheses regarding associations between TD similarity and game performance, so it may well be the case that for these additional exploratory analyses, more participants are needed to avoid Type II errors. Again, future studies could take the preliminary findings in this study as a starting point to formulate specific hypotheses surrounding associations between game difficulty and enjoyment, and select adequate sample sizes based on an *a priori* power analysis.

In the current study, only a single visual variable was considered: brightness. While this can be reliably used to alter the similarity between target and distractor stimuli, other visual variables may have separable effects to the ones observed in this study. Variables such as size, colour, orientation, or shape may be utilised for further investigations to uncover potential effects on game difficulty and player experience. It is important to note that some of these variables may also increase stimulus saliency, which can have separable effects from similarity on cognitive performance [18]. Investigating saliency as a second difficulty factor could yield further insights that can inform the design of goal-relevant and -irrelevant game elements.

Finally, to broaden the applicability of the findings, further studies should look at more complex games such as 3D action games or open world games in which players are faced with multiple in-game goals in a highly saturated visual environment. The relationship between performance and enjoyment and the influence of distraction may in these contexts be more complex than in the currently examined very simple game, which deliberately limited possible visual complexity (see screenshots in Appendix Appendix A) and linked gameplay with a visual working memory task.

5. Conclusion

The current study demonstrates that the presence of distractors can impact memory for task-relevant items and hence difficulty in video games that require players to retain information over short periods of time. More precisely, it was found that performance was most impaired when distractors were presented simultaneously with the to-be-remembered stimulus, and in these conditions, performance gradually declined with increasing TD similarity, adding to existing evidence of greater distractor interference on visual search and memory performance with increased TD similarity. With regards to player experience, exploratory analyses revealed positive correlations between enjoyment and success rate, which fits within the extensive body of literature associating enjoyment with game performance. Notably, no correlations were found between enjoyment and progression as an objective measure of player skill, indicating that performance per se does not suffice to elicit enjoyment, but that rewarding players' performance is crucial. Above that, results revealed that enjoyment was uniquely predicted by performance in trials where distractors were presented simultaneously with the to-be-remembered path, indicating that enjoyment particularly arises from the ability to resist distraction at the time of encoding. Whether the mere presence of encoding distraction could increase enjoyment for some players and decrease enjoyment for others needs to be investigated in more detail in future studies. It is important to note that the current study utilised a very simple memory game and only considered a single visual variable (brightness). Further studies are necessary that investigate such effects with different visual variables, and also within more complex game environments. Nevertheless, the present results highlight the importance of taking into consideration the visual design of both task-relevant and task-irrelevant game elements during cognitively demanding tasks and may be used to inform practices to reduce unwanted challenges or accessibility barriers for different kinds of players, but also to enhance enjoyment.

Appendix A. The Working Memory Game

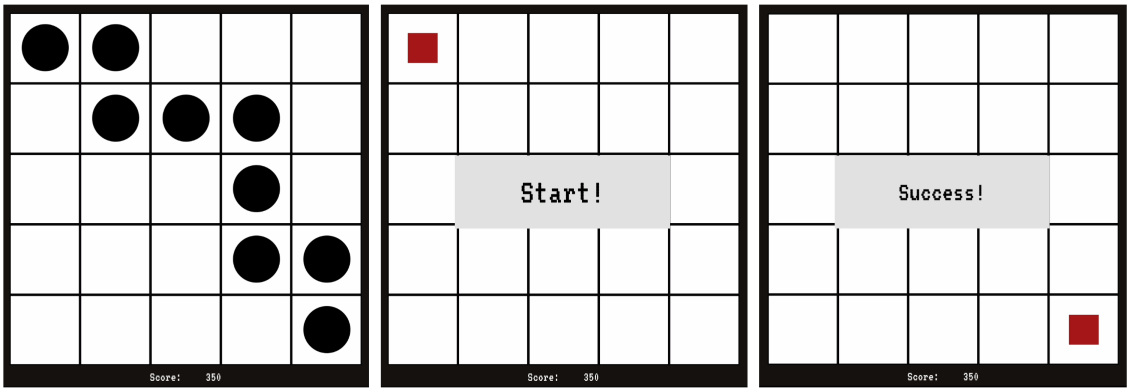

Figure A.1: Example level of the game without distractor circles. First, a path is presented that players need to memorise (left). The path disappears and a player character appears in the top left cell (centre). After navigating correctly along the memorised path, a success message is displayed (right). Points are added once the next level starts.

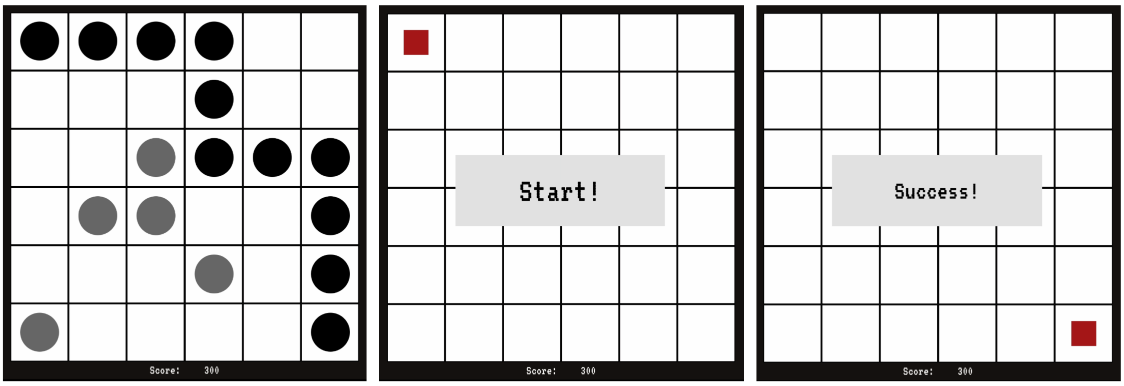

Figure A.2: Example level of the game with distractor circles. First, a path is presented that players need to memorise, ignoring any other circles that may be presented (left). The path disappears and a player character appears in the top left cell (centre). After having navigated correctly along the memorised path, a success message is displayed (right). Points are added at the beginning of the next level.

Appendix B. Correlation matrices

	ND	ED	DD	ED10	ED20	ED30	DD10	DD20	DD30	Enjoy-ment	Mea-ning	Curio-sity	Mas-tery	Auto-nomy	Immer-sion	Progress Feed-back	Audiovis. Appeal	Chall-enge	Ease of Control	Clarity of Goals
ND	1	.661**	.716**	.459**	.574**	.600**	.627**	.447**	.672**	.262	.278	.142	.426*	.014	.133	.347*	.226	.284	.371*	.322
ED	.661**	1	.742**	.797**	.916**	.735**	.509**	.656**	.660**	.499**	.436**	.359*	.471**	.174	.254	.485**	.529**	.306	.602**	.435*
DD	.716**	.742**	1	.525**	.592**	.726**	.839**	.782**	.825**	.357*	.263	.139	.495**	.106	.013	.381*	.382*	.242	.441**	.285
ED10	.459**	.797**	.525**	1	.642**	.281	.385*	.421*	.479**	.366*	.436*	.345*	.263	.227	.264	.415*	.424*	.182	.513**	.294
ED20	.574**	.916**	.592**	.642**	1	.578**	.323	.627**	.515**	.486**	.438**	.339*	.491**	.134	.262	.417*	.506**	.347*	.572**	.404*
ED30	.600**	.735**	.726**	.281	.578**	1	.571**	.560**	.645**	.400*	.176	.197	.400*	.064	.098	.356*	.378*	.216	.394*	.359*
DD10	.627**	.509**	.839**	.385*	.323	.571**	1	.495**	.549**	.324	.235	.205	.527**	.212	.025	.316	.236	.175	.383*	.190
DD20	.447**	.656**	.782**	.421*	.627**	.560**	.495**	1	.450**	.253	.261	.123	.306	.071	-.050	.274	.325	.335*	.441**	.223
DD30	.672**	.660**	.825**	.479**	.515**	.645**	.549**	.450**	1	.273	.165	.022	.368*	-.023	.055	.320	.377*	.098	.261	.296
Enjoy	.262	.499**	.357*	.366*	.486**	.400*	.324	.253	.273	1	.697**	.721**	.540**	.523**	.716**	.231	.795**	.457**	.332	.371*
Mean	.278	.436**	.263	.436*	.438**	.176	.235	.261	.165	.697**	1	.700**	.473**	.631**	.725**	.411*	.548**	.277	.185	.197
Curio	.142	.359*	.139	.345*	.339*	.197	.205	.123	.022	.721**	.700**	1	.368*	.610**	.660**	.379*	.645**	.259	.144	.225
Mast	.426*	.471**	.495**	.263	.491**	.400*	.527**	.306	.368*	.540**	.473**	.368*	1	.401*	.373*	.411*	.528**	.454**	.332	.520**
Auto	.014	.174	.106	.227	.134	.064	.212	.071	-.023	.523**	.631**	.610**	.401*	1	.612**	.369*	.385*	.333	.138	.070
Imm	.133	.254	.013	.264	.262	.098	.025	-.050	.055	.716**	.725**	.660**	.373*	.612**	1	.364*	.585**	.193	.148	.211
Feedb	.347*	.485**	.381*	.415*	.417*	.356*	.316	.274	.320	.231	.411*	.379*	.411*	.369*	.364*	1	.339	.215	.467**	.551**
Audio	.226	.529**	.382*	.424*	.506**	.378*	.236	.325	.377*	.795**	.548**	.645**	.528**	.385*	.585**	.339	1	.230	.438*	.521**
Chall	.284	.306	.242	.182	.347*	.216	.175	.335*	.098	.457**	.277	.259	.454**	.333	.193	.215	.230	1	.279	.297
Ease	.371*	.602**	.441**	.513**	.572**	.394*	.383*	.441**	.261	.332	.185	.144	.332	.138	.148	.467**	.438*	.279	1	.646**
Clar	.322	.435*	.285	.294	.404*	.359*	.190	.223	.296	.371*	.197	.225	.520**	.070	.211	.551**	.521**	.297	.646**	1

Table A1: Correlation matrix with Pearson values for all performance, game, and player experience variables. The first nine rows and columns (ND to DD30) represent correlations between success rates. ** denotes a significant correlation at the 0.01 level, * denotes a significant correlation at the 0.05 level.

	ND	ED	DD	ED10	ED20	ED30	DD10	DD20	DD30	Enjoy-ment	Mea-ning	Curio-sity	Mas-tery	Auto-nomy	Immer-sion	Progress Feed-back	Audiovis. Appeal	Chall-enge	Ease of Control	Clarity of Goals
ND	1	.873**	.852**	.829**	.757**	.857**	.801**	.847**	.749**	-.046	-.063	-.144	-.170	.080	-.062	.125	-.149	.005	.280	.437*
ED	.873**	1	.866**	.939**	.946**	.908**	.782**	.873**	.780**	.175	.140	.064	-.027	.180	.036	.249	.089	.125	.426*	.451**
DD	.852**	.866**	1	.767**	.782**	.886**	.958**	.935**	.920**	.103	.036	-.083	-.003	.121	-.122	.182	.035	.080	.355*	.452**
ED10	.829**	.939**	.767**	1	.836**	.756**	.701**	.778**	.676**	.113	.130	.088	-.118	.146	.051	.220	.060	.073	.383*	.326
ED20	.757**	.946**	.782**	.836**	1	.812**	.694**	.796**	.710**	.264	.246	.118	.076	.214	.074	.214	.143	.182	.451**	.416*
ED30	.857**	.908**	.886**	.756**	.812**	1	.803**	.879**	.811**	.122	-.005	-.042	-.023	.145	-.034	.261	.046	.102	.342*	.512**
DD10	.801**	.782**	.958**	.701**	.694**	.803**	1	.862**	.830**	.099	.046	-.060	.095	.144	-.148	.179	.005	.080	.397*	.438*
DD20	.847**	.873**	.935**	.778**	.796**	.879**	.862**	1	.765**	.096	.070	-.032	-.043	.131	-.091	.130	.058	.124	.314	.422*
DD30	.749**	.780**	.920**	.676**	.710**	.811**	.830**	.765**	1	.091	-.013	-.146	-.060	.063	-.102	.201	.035	.018	.285	.407*
Enjoy	-.046	.175	.103	.113	.264	.122	.099	.096	.091	1	.697**	.721**	.540**	.523**	.716**	.231	.795**	.457**	.332	.371*
Mean	-.063	.140	.036	.130	.246	-.005	.046	.070	-.013	.697**	1	.700**	.473**	.631**	.725**	.411*	.548**	.277	.185	.197
Curio	-.144	.064	-.083	.088	.118	-.042	-.060	-.032	-.146	.721**	.700**	1	.368*	.610**	.660**	.379*	.645**	.259	.144	.225
Mast	-.170	-.027	-.003	-.118	.076	-.023	.095	-.043	-.060	.540**	.473**	.368*	1	.401*	.373*	.411*	.528**	.454**	.332	.520**
Auto	.080	.180	.121	.146	.214	.145	.144	.131	.063	.523**	.631**	.610**	.401*	1	.612**	.369*	.385*	.333	.138	.070
Imm	-.062	.036	-.122	.051	.074	-.034	-.148	-.091	-.102	.716**	.725**	.660**	.373*	.612**	1	.364*	.585**	.193	.148	.211
Feedb	.125	.249	.182	.220	.214	.261	.179	.130	.201	.231	.411*	.379*	.411*	.369*	.364*	1	.339	.215	.467**	.551**
Audio	-.149	.089	.035	.060	.143	.046	.005	.058	.035	.795**	.548**	.645**	.528**	.385*	.585**	.339	1	.230	.438*	.521**
Chall	.005	.125	.080	.073	.182	.102	.080	.124	.018	.457**	.277	.259	.454**	.333	.193	.215	.230	1	.279	.297
Ease	.280	.426*	.355*	.383*	.451**	.342*	.397*	.314	.285	.332	.185	.144	.332	.138	.148	.467**	.438*	.279	1	.646**
Clarity	.437*	.451**	.452**	.326	.416*	.512**	.438*	.422*	.407*	.371*	.197	.225	.520**	.070	.211	.551**	.521**	.297	.646**	1

Table A2: Correlation matrix with Pearson values for all performance, game, and player experience variables. The first nine rows and columns (ND to DD30) represent correlations between progression measures. ** denotes a significant correlation at the 0.01 level, * denotes a significant correlation at the 0.05 level.

Appendix C. Regression Tables

Model	Predictor	ΔR^2	β	p value	Partial correlation
1	ND	0.07	0.26	0.135	0.26
2	ND	0.19**	-0.12	0.553	-0.11
	ED		0.58	0.008**	0.45
3	ND	0.00	-0.13	0.597	-0.10
	ED		0.58	0.029*	0.39
	DD		0.01	0.985	0.00

Table B1: Hierarchical regression results predicting enjoyment from success rates in each distractor condition. Model 1 predicts enjoyment from ND performance, Model 2 predicts performance from ND and ED performance, and Model 3 predicts enjoyment from ND, ED, and DD performance. Partial correlations for each predictor while controlling for the other predictor variables are displayed. **** $p < .001$; ** $p < .01$; * $p < .05$*

Model	Predictor	ΔR^2	β	p value	Partial correlation
1	ND	0.00	-0.05	0.796	-0.05
2	ND	0.20**	-0.86	0.015*	-0.42
	ED		0.92	0.009**	0.45
3	ND	0.01	-0.93	0.018*	-0.42
	ED		0.84	0.040*	0.37
	DD		0.17	0.650	0.08

Table B2: Hierarchical regression results predicting enjoyment from progression in each distractor condition. Model 1 predicts enjoyment from ND performance, Model 2 predicts performance from ND and ED performance, and Model 3 predicts enjoyment from ND, ED, and DD performance. Partial correlations for each predictor while controlling for the other predictor variables are displayed. **** $p < .001$; ** $p < .01$; * $p < .05$*

Model	Predictor	ΔR^2	β	p value	Partial correlation
1	ND	0.07	0.26	0.135	0.26
2	ND	0.08	0.12	0.532	0.11
	ED10		0.31	0.106	0.29
3	ND	0.10	-0.06	0.765	-0.06
	ED10		0.12	0.561	0.11
	ED20		0.45	0.055	0.34
4	ND	0.02	-0.14	0.539	-0.12
	ED10		0.15	0.467	0.14
	ED20		0.33	0.205	0.23
	ED30		0.21	0.373	0.17

Table B3: Hierarchical regression results predicting enjoyment from ED success rates in each TD similarity condition. Model 1 predicts enjoyment from ND performance, Model 2 predicts performance from ND and ED10 performance, and Model 3 predicts enjoyment from ND, ED10, and ED20 performance. Model 4 predicts enjoyment from ND, ED10, ED20, and ED30 performance. Partial correlations for each predictor while controlling for the other predictor variables are displayed. *** $p < .001$; ** $p < .01$; * $p < .05$

Model	Predictor	ΔR^2	β	p value	Partial correlation
1	ND	0.00	-0.05	0.796	-0.05
2	ND	0.07	-0.45	0.158	-0.25
	ED10		0.48	0.128	0.27
3	ND	0.15	-0.63	0.043*	-0.36
	ED10		0.03	0.935	0.02
	ED20		0.73	0.023*	0.40
4	ND	0.01	-0.72	0.065	-0.34
	ED10		0.06	0.878	0.03
	ED20		0.64	0.092	0.31
	ED30		0.16	0.684	0.08

Table B4: Hierarchical regression results predicting enjoyment from ED progression in each TD similarity condition. Model 1 predicts enjoyment from ND performance, Model 2 predicts performance from ND and ED10 performance, and Model 3 predicts enjoyment from ND, ED10, and ED20 performance. Model 4 predicts enjoyment from ND, ED10, ED20, and ED30 performance. Partial correlations for each predictor while controlling for the other predictor variables are displayed. **** $p < .001$; ** $p < .01$; * $p < .05$*

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