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Effects of Gameplay Context on Visual Search Performance

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Abstract

Games of all modalities have been found to improve different cognitive skills. This experiment examined the cognitive skills of visual attention and search, and explored whether different modalities of one game would have different effects on visual search abilities. Specifically, we asked whether playing a game alone or with a partner, or playing an analog or digital version of this game would have measurable effects on visual attention and search. Participants (N = 30) completed a visual search task before and after playing the card game SET in three different experimental conditions. SET was chosen because of its focus on visual searching and matching. A three-way analysis of variance was conducted to analyze the data collected from the experiment. The findings indicate that playing the game may improve visual search performance regardless of the modality in which it is played. However, contrary to our hypothesis, there was no significant effect of modality. Limitations, practical implications, and future directions are further discussed.

Keywords: visual search, visual attention, cognition and gaming, cognitive effects of gaming, attentional control

Effects of Gameplay Context on Visual Search Performance

Games and game-based assessments have been used to learn about basic cognitive functions. The specific practice of comparing game-based assessments and psychometric assessments is quite new, with most game-based assessments used to evaluate cognitive skills in an employment context (c.f. van Lill et al., 2023). Games can be a more enjoyable form of cognitive assessment (Byusa et al., 2022; Chang et al., 2022; Chen et al., 2021), and the applicability of games could be relevant to a wide variety of situations.

Games are commonly divided into two categories: digital and analog (Sousa et al., 2023). Analog, or, more specifically, tabletop games are played with physical components, like cards and dice. Digital or video games are played using game consoles or computers. Some examples of tabletop games are chess, Settlers of Catan, UNO, and Monopoly, though most of these games can also be played digitally (Monopoly, 2014; Robbins, 1971; Teuber, 1995). Examples of digital/video games include World of Warcraft, Call of Duty, Animal Crossing, and the Halo franchise (Eguchi et al., 2001; Jones et al., 2001; Kern et al., 2004; Turner et al., 2003). Analog or digital games, as well as games played in social vs non-social contexts, have been found to activate and/or improve different cognitive skills depending on the kind of game being played. For example, analog board games can increase conceptual learning (Byusa et al, 2022; Chang et al., 2022), digital video games can improve visual attention (Belchior et al., 2013), and social cognition in children differs when playing analog vs digital games (von Steinkeller & Grosse, 2022).

The current study assessed whether social context or game format (analog vs digital) in a visual search game affects performance on a subsequent visual cognitive task. Previous psychological literature studies both cognitive and social aspects of gameplay and their effects, but they are studied separately. Because of this, we wondered whether there was an unexplored correlation between these two aspects of gameplay. The current experimental study aimed to answer the following research question: Does the context or modality in which a game is played affect the player's aptitude when performing a visual search task?

Games and Cognitive Performance

Games are used in a variety of settings to measure cognitive ability. Games and game-based assessments have been found to maintain and improve cognitive skills like knowledge retention, memory retrieval, and problem-solving (Chang et al., 2022; Chen et al., 2021; Taspinar et al., 2016; Varzani, 2013). They also improve the experience of taking assessments and studying (Byusa et al., 2022). We review the use of games and cognition in schools, in the workplace, and in other settings such as retirement homes and psychiatric facilities.

Cognitive Performance in Educational Settings

Schools at all levels use games, both digital and analog, to improve academic understanding and performance (Chang et al., 2022; Chen et al., 2021). Games have been found to improve knowledge retention (Taspinar et al., 2016; Varzani, 2013) among other cognitive improvements. In a meta-analysis about the effectiveness of 24 different chemistry-related games, played by students ranging in age from preschool to college age in several countries, researchers found that "students developed a positive opinion about using games in chemistry teaching and learning" and that students reported more confidence when faced with difficult questions (Byusa et al., 2022). Additionally, students reported spending more time studying, as the games made the process more enjoyable. Another study conducted in Taiwan by Chang and colleagues (2022) observed how nursing students retained more knowledge about medications when engaging in regular play of a bespoke board game. The researchers found that the students who played the game had higher levels of knowledge retention than those who studied in traditional ways. Additionally, adverse events related to medication administration in the hospital studied decreased, suggesting that the game resulted in students making fewer mistakes when giving medications to their patients (Chang et al., 2022).

Board games have also been found to improve creative problem-solving (CPS) skills in the educational environment. According to Chen and colleagues (2021), after playing a bespoke board game, high school chemistry students scored higher on a chemical concepts quiz. The students were also assessed for their aptitude in CPS, and students' performance on most components of CPS skills improved after gameplay (Chen et al., 2021).

Cognitive Performance in the Workplace

Companies and corporations often integrate cognitive assessments into their hiring and employee assessment practices, due to the apparent scientific and statistical soundness (Conway et al., 2002). According to a statistical analysis by Bertua and Anderson (2005), game-based training and assessments seem to be better predictors of job performance than individual cognitive ability tests. Traditional cognitive assessments typically resemble aptitude exams or surveys. These cognitive tests can be limiting because the skills employers want to observe are not being directly applied to any situation in which they are observable. As a result, it is becoming increasingly common for companies to specifically adapt or design games to assess their employees' performance and to measure the cognitive aptitude of potential new hires (Landers et al., 2022). Scores from these games may more accurately predict future job performance than specific cognitive ability tests.

In a 2023 experiment conducted by van Lill and colleagues, South African and Australian employees from two companies were given six digital mini games to play using a software called

Cognify. The minigames were designed to measure cognitive abilities, such as quantitative knowledge, fluid reasoning, and verbal comprehension (van Lill et al., 2023). Then, the participants were assessed on work-related performance factors within the context of their jobs. The Australian employees that participated in the study all held white-collar jobs, and the South African participants were mostly full-time employees, with some being part-time students. Due to privacy reasons, the participants' specific jobs were not published. Results showed that playing the games on *Cognify* improved employee performance scores on a variety of skills such as leadership, competence within and outside of job descriptions, and adaptability. The mini games also decreased scores in the *counterproductive performance* category, which measured employees' unproductive or harmful behaviors such as impoliteness between coworkers and lack of effort.

Cognitive Performance in Other Settings

In addition to its applications in the educational and corporate worlds, regular engagement in games outside of school looks as though it could be beneficial for older adults. In a study by Estrada-Plana and colleagues (2022), it was found that regular engagement in modern social board and card games elicited cognitive improvements in residents of retirement homes not exhibiting symptoms of dementia. They were found to have increased inhibition scores when assessed, as well as improvements in impulse control. Participants in the gaming condition also maintained their levels of motor impulsivity control and improved their verbal fluency (Estrada-Plana et al., 2022).

Board games could also prove helpful as interventions for conditions such as depression, anxiety, dementia, schizophrenia, and ADHD. It has been found that chess improves general cognitive functioning in both adults and children based on test scores taken pre- and post-gameplay on a variety of cognitive measures (Noda et al., 2019). In addition, when observing older adults, researchers found that regular engagement with board games can improve working memory, attention, and executive functioning (Panphunpho, 2013). In older adults with Alzheimer's Disease, playing the game Go, in which players attempt to capture more territory than their opponent by barricading empty spaces on the board, regularly alleviated the symptoms of depression, anxiety, and Alzheimer's disease (Lin et al., 2015). In individuals with schizophrenia, board games were found to help participants with their ability to plan (Demily et al., 2009). Board games, specifically Go, helped individuals with ADHD because of their stimulating nature, allowing for improvements in executive functioning (Kim et al., 2014).

Games and Social Outcomes

Playing games in a social setting can have a positive impact on social outcomes such as belonging and bonding (Rogerson & Gibbs, 2016). As previously mentioned, games can have cognitive effects on students, in the workplace, and in aging populations. Playing games in a social setting can also have positive social effects (Kaufman et al., 2020; Li et al., 2018). A qualitative survey and interview-based study by Rogerson and Gibbs (2016) highlighted the importance of social board gaming, especially for parents. Regular gaming allows parents the opportunity not only to potentially bond with their children over a shared interest, but to get out of the house and socialize with other adults; specifically, other parents. Furthermore, it is an opportunity to rest and find enjoyment in a hobby, which in turn might provide them with more energy to parent (Rogerson & Gibbs, 2016).

A study by von Steinkeller and Grosse (2022) indicated the social importance of playing analog games instead of digital. The researchers observed ten-year-old children play either analog games together or digital games by themselves. They found that children who had played the analog games were more likely to help the researcher when they purposefully dropped something, were more likely to share with their fellow participants, and generally engaged in more prosocial behavior than their counterparts who had spent the study playing digital games (von Steinkeller & Grosse, 2022).

The Roles of Competition and Motivation

Competition is another important social factor in games. In fact, the mere presence of competition seems to change the way in which players, whether of sports or of games, are motivated. In a 1981 study by Deci and colleagues, participants solved puzzles in front of a confederate posing as a fellow participant. The researchers instructed half of the participants to compete with each other, and the other half were told to solve the puzzles as fast as they could in the amount of time they were given. In giving their results, the researchers stated that participants appear to view an activity as a means for winning instead of something to do for the reward of mastering it when they are instructed to compete against each other (Deci et al., 1981). This extrinsic motivation has also been found to potentially improve performance when playing competitive games or sports (Van de Pol & Kavussanu, 2012). Even outside of the context of games, Corell et al. (2018) found that competition increased motivation to learn and yielded higher scores on post-tests given to students after a competitive learning module. Games in general also seem to change the way in which players are motivated outside of the game. In educational contexts, games and game-based learning makes academic engagement more fun, which in turn motivates students to study more often (Byusa et al., 2022; Chang et al., 2022; Chen et al., 2021; Taspinar et al., 2016; Varzani, 2013).

Cognitive and social effects are generally studied as separate phenomena in research on the effects of games (Estrada-Plana et al., 2022). In the literature reviewed for the current manuscript, the studies considered seemed to be unintentionally presenting a dichotomy. According to the literature, games affect cognitive functioning, *or* they affect social functioning. Estrada-Plana et al. (2022) note that they did not consider sociality and cognition in conjunction, but most did not consider that the cognitive and social factors could go hand in hand. In the current study, the goal is to experimentally manipulate both factors (i.e., gameplay context (analog vs digital), and social context (solo or with a partner)) to determine if these factors have an effect on each other.

Games and visual attention

The current experiment focuses specifically on games and their links with visual attention and visual search abilities. Chesham and colleagues (2019) define visual search as “the ability to find target objects in complex scenes in everyday life” (page 2). In Treisman and Gelade (1980)’s paper, the authors claim that there are several different types of visual attention, in which they explain using their feature-integration theory of attention. According to the Treisman and Gelade (1980), attention must be serially focused on each stimulus in a display when the stimuli require the observer to separate one or more feature of the stimuli in order to distinguish between them. There are two main types of visual search: feature and conjunction. Feature (also known as disjunctive or efficient) search occurs when the searcher’s focus is on identifying a “previously requested target” from a field of distractors that differ significantly from the target by a unique feature like color or shape. Conjunction search (also known as inefficient or serial search) focuses on identifying a target from a field of distractors that are not distinct from the target itself (Treisman and Gelade, 1980).

Generally, when more distractors enter the field of vision, it becomes more difficult to find the target. However, some features are easier to distinguish from others. For example, with normal color vision, it’s easier to tell red and green apart than it is to tell blue and green apart. So, when participants in one of Treisman and Gelade (1980)’s experiments were asked to identify targets in easy (red vs. green) and difficult (blue vs. green) conditions, they found that participants in the easy condition were able to identify targets three times faster than the participants in the difficult condition.

Current literature about games is saturated with studies about video games and other digital games, despite studies indicating favor of analog games (von Steinkeller & Grosse, 2022). According to Chen et al. (2021), board games have an advantage over digital games because players interacting and discussing gameplay face to face aids in knowledge accommodation and the development of creative problem-solving skills. However, video games have been found to have some impact on the visual attention abilities of regular players (Chen et al. 2021).

Hubert-Wallander et al. (2010) wrote a literature review about the effects of heavy engagement in action video games on several aspects of visual attention. They were largely positive, with habitual gamers having faster reaction times while engaging in a visual task than non-gamers. Habitual gamers were also found to have better spatial awareness, selective attention, and a better ability to visually track multiple objects at once. When studying selective visual attention in older adults, Belchior and others (2013) found that regularly playing first person action games improved participants’ scores on visual attention assessments. They also found that regular gamers and non-gamers use different search patterns when exploring a visual scene (Belchior et al., 2013).

Wu and Spence (2013) found that regular video gaming was not the only factor associated with changes in visual search and attention abilities. The genre of game being played seemed to also have an effect. This study tested first person shooter games (FPS) and driving games. An FPS game is a type of video game in which the player shares the point of view of the game's protagonist, and also requires players to filter out distractions to keep an eye on their target(s). Participants were sorted into player (minimum of four hours per week in the last six months playing FPS games) and non-player (no experience playing FPS in the previous three years) groups. Further, it was found that players and nonplayers did not differ generally in accuracy in classic visual search tests, but they did differ in speed. Players were faster than non-players in general. Players were also quicker in conjunction search, but there was no difference in feature search. Participants who played driving games did not seem to improve in visual search when compared to the control group (Wu & Spence, 2013).

Chesham et al. (2019) specifically developed a Tile-matching match-3 (TMM3) puzzle video game which incorporated a digital search-and-match task and studied its effects on visual attention. Previous studies have shown that adults can improve visual search ability through digital videogame-based practice on conjunction and configuration tasks(Kramer & Fray, 2006; Oei & Patterson, 2013; Stroud & Whitbourne, 2015). Chesham and colleagues (2019) tested their visual search games on adults of different age groups. They found that while visual search performance differed by age (with younger adults playing the game faster than older adults, and older adults faster than the oldest adults), participants in each age group showed improved visual search ability after playing the TMM3 video game. This demonstrates that digital visual search games can improve visual cognition for adults across the lifespan, even across different baseline abilities.

The Current Study

We implemented a game-based intervention to improve a specific aspect of cognitive function—namely, visual attention and visual search—while manipulating the social context of gameplay. Participants either played the game alone or with a confederate (i.e., an individual that has been briefed on the experimental conditions and is posing as a participant). Additionally, building off of von Steinkeller and Grosse (2022), participants in the solo condition played either an analog or digital version of the game.

For the purposes of the current experiment, we used the card game SET (Falco, 1988), in which players must discriminate “sets” of cards from among a field of 12 (see Appendix A for full SET rules). We hypothesized that if manual experience with an analog card game engages attentional mechanisms more strongly than experience on a digital version of that card game, then we should see larger improvements in visual attention scores after the analog card game when compared to the digital card game. If the competition and increased motivation in social interaction further improves attentional mechanisms, we should see the largest improvement in visual attention for participants in the social analog condition.

Building off of Treisman and Gelade (1980), we can apply the concepts of visual attention to the card game SET. In a visual search task, it tends to be easier to tell the difference between Q and T than it is to tell the difference between letters like B and P. The same goes for discriminating between blue and green vs. green and red (for normal color vision). If you have to discriminate between similar objects, your reaction time is going to be a lot longer than it would be when you are differentiating between significantly different objects. In addition, the main sources of difficulty when engaging in visual search are going to be the number of items on display, and the perceptual dimensions (e.g., color and shape) of those items (Chesham et al., 2019). So, in SET, there are three significantly different colors on the cards, but confusability is still possible between amounts, symbols, and shapes, in certain conditions. A player might have a hard time differentiating between two opaque red diamonds next to two opaque red ovals but may have an easier time distinguishing between two opaque red ovals and two opaque *green* diamonds, to draw examples directly from the game itself.

Based upon the current literature within this field, games improve cognitive functions dependent upon the type of game being played, and upon whether the game is being physically played with other people. Therefore, the hypotheses for the current study are as follows: (H1) There will be a decrease in mean reaction time scores on the visual search task post-test for all conditions. (H2) The largest average decrease in mean RT scores will be for those who play the game in the social analog condition against a trained confederate, due to the player being motivated by the competitive element of playing against someone else. If players are paying more attention to the cards in the social analog game, then we should see improved attention in the visual search task. In addition, as an exploratory hypothesis, we expect to see a larger decrease in mean RT scores after the solo-analog condition than the solo-digital, because of the integration of multiple modalities (manual/tactile and visual) during analog game play.

Method

Participants

The sample consisted of 30 participants with an average age of 20.2 years (*SD* = 2.8). Twenty participants identified as female, nine identified as male, and one did not report their gender. Participants were recruited from students enrolled in General Psychology courses at Augustana University, as well as through flyers posted throughout the campus. Students taking the General Psychology course were compensated with research credit for the class, and no other compensation was provided.

Students had to be 18 years or older to participate. Other exclusion criteria included colorblindness or uncorrected vision conditions, such as astigmatism. No participants met the exclusion criteria, so the original 30 participants that were recruited were all included in the sample. The research was approved by Augustana University Institutional Review Board (IRB) and was conducted in accordance with the Declaration of Helsinki for research on human subjects. We collected information on participants' ages, genders, their dominant hands, their experience with board games, card games, and video games, how often they play each kind of game, and which games of each type they frequently play. One participant did not complete the game experience survey, so only their experimental task results are reported. Participants completed this survey before the experiment itself began.

Materials

The materials used for this experiment were as follows: a physical copy of the card game SET (Falco, 1988), a desktop computer, an online version of the game SET (Zhang & Du, 2020), and the digital implementation of the visual search task from psytoolkit.org (Stoet, 2010; Stoet, 2017) adapted from Triesman and Gelade (1980). Scripts for participants with instructions for the visual search task and how to play the game SET are included in Appendices A and B.

Procedure

Visual Search Task

The Visual Search Task implemented for this experiment was obtained from Psytoolkit.org's library of free experiments (Stoet 2010; Stoet 2017). On the screen, the participants were shown a field of inverted orange and/or upright blue letter Ts arranged in different formations with a black background. In each search display, there are 5, 10, 15, or 20 items displayed. Between each search display, a blue and orange checkered animation flashed on the screen to create a visual mask and sense of separation between stimulus displays. The task was conducted over two five-minute blocks, with 50 search displays in each block. Participants were asked to respond by keypress if the target stimulus, an upright orange T, was present. If the target stimulus was not present, participants were instructed not to respond. Our dependent measures were reaction time and accuracy. Our independent measures are the number of distractors in the visual search field and the presence or absence of the target. Participants were administered the visual search task both before and after their experimental condition so that pre and post score differences could be compared. For study participants assigned to the social condition (explained in more detail below), the confederate relocated to another room to give the illusion that they were also participating in the Visual Search Task. Participants completed the Visual Search Task before and after experimental intervention.

Experimental Conditions

In the game play portion of the experiment, participants were randomly assigned to one of three separate conditions- solo-digital, solo-analog, and social-analog- and played SET for a total of 20 minutes. Before playing, participants were given instructions and time to ask questions.

In the solo-digital condition, participants played the game SET by themselves on a computer using the game Set with Friends (Zhang & Du, 2020; see Figure 1). Participants in this condition were given verbal instructions on how to play the game, along with a visual demonstration. The researcher loosely followed a script, which is in the supplemental materials section. The participants were given several opportunities to ask questions before their 20 minutes started. It was also made clear that participants were allowed to ask the researcher questions if they needed to, and that a hint button would be present just in case. The game was then started over once questions were cleared up, and participants proceeded to play.

In the solo-analog condition, participants played SET by themselves with a physical deck of cards. Participants sat at the lab table with the game of SET already out on the table. Verbal instructions were given by the researcher, which were based on a script that will be in the supplementary materials section. A visual demonstration was also given as the researcher set the game up for the participant. It was made explicitly clear to participants that they were allowed to ask the researcher questions if they needed to during their gameplay session. The participants were given several opportunities to ask questions before their 20 minutes started. They were also told that they were allowed to look at the game box and the rule booklet whenever they wanted over the course of their 20-minute gameplay.

In the social-analog condition, participants played SET with a confederate using physical cards. The confederate was instructed to arrive before the participants and hid their personal belongings in a smaller room attached to the lab. When the participant arrived, the researcher introduced them to the confederate, stating that the confederate would also be participating in the study. The researcher then had the participant fill out their pre-experiment surveys and told the participant that the confederate had already done this. As the participant completed the visual search task, the researcher relocated the confederate to the small lab room to give the illusion that they were also completing the task. Once the participant finished, the researcher signaled to the confederate that it was time for them to leave the room. After sitting the confederate and the participant at the lab table, the researcher gave verbal instructions for the game of SET, stating that each is allowed to ask questions, and that they are allowed to refer to the game box and rule booklet at any time. Players were given the opportunity to ask clarifying questions before their time started. After the game session began, the confederate found a SET and showed it to the researcher for confirmation that it is a SET in order to further demonstrate what a valid SET is.

The confederate was also previously instructed to keep the ratio of SETs they found in comparison to the participant at as close to 1:1 as possible.

In each condition, participants played the game for 20 minutes at a time, trying to achieve as many "sets" as possible within that time frame. Participants played the game only once.

Design

A between-subjects design was utilized for this experiment. The dependent variables were mean reaction time and variability in mean reaction time on the Visual Search Task pre- and post-experimental intervention. The independent variable (gameplay modality) consisted of three different levels: solo-digital condition, solo-analog condition, and social-analog condition (more detail on conditions in the experimental conditions section below).

Analysis

We adapted psytoolkit's code to filter data to include only present and correct trials. "Present" trials indicated that the target stimulus was actually present on the screen, and a "correct" trial indicated that the participant correctly identified it. We recorded mean reaction times and variability in reaction times in each block (pre and post), for each number of items present on the screen (5, 10, 15, and 20), in each experimental condition (solo-digital, solo-analog, and social-analog). Game play experience survey responses were not included as a factor – results of the gameplay experience survey are reported in Appendix C. A three-way repeated-measures ANOVA was performed to evaluate the effects of number of items, order, and condition on mean reaction time and variability in mean reaction time as follows:

1. $\text{meanRT} \sim \text{items}_{(5,\ 10,\ 15,\ 20)} * \text{order}_{(\text{pre, post})} * \text{condition}_{(\text{solo-digital, solo-analog, social-analog})}$
2. $\text{variabilityRT} \sim \text{items}_{(5,\ 10,\ 15,\ 20)} * \text{order}_{(\text{pre, post})} * \text{condition}_{(\text{solo-digital, solo-analog, social-analog})}$

Results

Mean Reaction Time

A three-way repeated-measures ANOVA was performed to evaluate the effects of number of items, order, and condition on mean reaction time. The means for reaction time are presented in Table 1, and in Figures 2 and 3.

The results indicated a significant main effect for items, $F(1) = 179.41$ $p = < .001$ significant main effect for order, $F(1) = 23.21$, $p < .001$; and no significant main effect for condition, $F(2) = 1.53$, $p = 0.218$. There was no significant interaction between items and order $F(1) = 1.08$, $p = 0.301$; no significant interaction between items and condition $F(1) = 0.71$, $p = 0.49$; no significant interaction between order and condition, $F(2) = 0.16$, $p = 856$; and no significant interaction between items, order, and condition, $F(2) = 0.90$, $p = 0.407$.

Variability in Reaction time

A three-way repeated measures ANOVA was performed to evaluate the effects of number of items, order, and condition on variability in reaction time. The variability for reaction time is presented in Table 1.

The results indicated a significant main effect for items, $F(1) = 116.27$, $p = < .001$; a significant main effect for order, $F(1) =9.42$, $p = 0.002$); no significant main effect for condition, $F(2) = 1.46$, $p = 0.233$. There was no significant interaction between items and order, $F(2) =0.21$, $p =0.645$; a significant interaction between items and condition, $F(2) = 3.77$, $p = 0.025$; no significant interaction between order and condition $F(2) = 0.04$, $p = 0.964$; and no significant interaction between items, order, and condition $F(2) = 1.84$, $p = 0.162$.

Discussion

For the current experiment, we investigated whether the social context in which a game was played had a significant effect on a participant's performance on a Visual Search Task. It was hypothesized that the different experimental conditions would yield different levels of performance on the Visual Search Task post-experiment.

The results of this study indicate that, in line with our hypotheses, participants had faster reaction times with fewer items on the screen. Also in line with our hypothesis, participants exhibited significantly faster mean reaction times and less variability after playing the game SET.

Participants did have lower mean reaction times when performing the Visual Search Task after playing SET in any of the experimental conditions, which is to say that they got faster regardless of game play modality. Interestingly, there was a significant interaction between the number of items on the screen and the experimental conditions when it came to both mean and variability in reaction time on the Visual Search Task, both pre- and post-experiment. One may expect that participants would have faster mean reaction times just by completing the visual search task multiple times. However, we observed no learning effects between blocks one and two in the pretest, and blocks three and four in the posttest – suggesting that the observed changes were, in fact, due to the experimental intervention. It appears as though playing SET – a game advertised as a game of visual perception – was what had the effect on performance.

However, in contrast with the original hypothesis, there were no significant differences between experimental conditions on participants' performance of the Visual Search Task. The modality in which the game SET was played had little to no effect on performance differences.

On average, participants in the Solo Digital condition reacted more quickly to the target stimulus when more items were on the screen during the post-test. There was more variability in the Solo Analog condition's reaction times on the posttest compared to the other conditions, with the Solo Digital condition having the least variation between reaction times. Variability in reaction times generally increased as more items appeared on the screen during the posttest. In addition, variability in reaction times seemed even between pretest and posttest data as well. These results support the idea that there were no learning effects occurring between the pretest and the posttest, and that the change in performance on the Visual Search Task may have been caused by playing SET.

Limitations and Future Directions

There were a few aspects of the experiment that we were unable to control, resulting in some limitations to this study. First, we were unable to track how many times participants used the "Hint" button in the Solo Digital condition. We were also unable to find a digital version of SET where we could turn off or hide the timer that is shown on the screen when playing the game. It is unknown how the timer would possibly change motivation or performance on the Visual Search Task.

In addition, in the analog conditions, the rules of SET stipulate that players are allowed to add cards to the playing field if they feel there is not a SET present. This was not a feature in the digital condition, as there was always a SET on the playing field. It is unknown whether this discrepancy had an effect between conditions and the number of items on variability in reaction time on the Visual Search Task. The researcher did not correct participants if they laid out too many cards on the table to keep experiment conditions as uniform as possible.

The level of understanding of the rules may also have varied between participants, despite the researcher giving ample opportunities for questions, which most participants in the analog conditions took more frequently than those in the digital condition. In fact, the majority of participants in the solo digital condition asked no questions. If participants disregarded the rules in the solo digital condition (i.e. pressing “hint” to reveal every SET), we were unaware of it.

Future researchers could require the experimenters to include a specific block of time for thoroughly training participants to play SET, in which the participants demonstrate finding a correct SET to the experimenter(s) in order to make sure that the participants understand the rules. Perhaps future researchers could also deliberately encourage participants to have the instructions for playing SET in front of them in the analog conditions. Additionally, it may be beneficial for researchers to pay more attention to gaze cues among participants in the Social Analog condition.

In addition, if this experiment is replicated, future researchers may want to incorporate a non-visual attention control condition (e.g., participants reading a book). Although reading a book does require the use of visual attention, it is not the same kind of visual attention that would be used to play SET, or to participate in the Visual Search Task. When reading a book, there are no target stimuli for the reader to find. Rather, they are simply absorbing the information on the page. Alternatively, when playing SET, the player is required to actively look for cards that match with each other. The same goes for participation in the Visual Search Task. The player must scan the computer screen for the target stimulus.

There are several potential practical applications for the results of this study. Although scores on the visual search task were not influenced by game play condition or social context, there was a significant effect of playing the visual search game of SET on reaction times in the visual search task. A simple, low-cost intervention like the game of SET has potential to improve visual attention skills in jobs that rely on visual tasks. For example, future research might investigate whether nursing students or pharmacists benefit from a low-cost visual attention game like SET in improving their visual attention skills to decrease adverse events when administering medications. Research with older adults might investigate whether a game like SET improves their visual attention skills as a way to ward off age-related cognitive decline, and whether a social version of game play will have a greater effect in this population compared to the younger demographic of this study.

Conclusion

As hypothesized, we observed a decrease in reaction times in a visual search task after playing the visual perception game of SET. However, this improvement in reaction time did not differ based on the social or gaming context of the experimental conditions (Social Analog, Solo Analog, or Solo Digital). In every condition, visual search was improved after gameplay.

Further research may indicate that social context matters for other visual cognitive functions. Social context may not have an effect on visual search for any number of reasons. Generally, social context and visual attention have an effect on each other (Capozzi & Kingstone, 2023); however, our results suggest that they may not affect each other in regard to the specific cognitive function of *visual search.*

This study supports the existing literature stating that gameplay positively affects cognitive performance, specifically in visual attention, despite there being no significant differences between the experimental conditions. Previous research has shown that when assessed before and after playing a game, participants in several experiments showed improvement in cognitive performance areas such as attention & speed in identifying target stimuli (Wu & Spence, 2013), and knowledge retention (Chang et. al, 2022; Taspinar et al., 2016; Varzani, 2013). Estrada-Plana (2022) showed that regular engagement in games in a social setting can improve cognitive functioning in residents of retirement homes not exhibiting symptoms of dementia. Our work shows that, in healthy college-aged individuals, even the minimal context of playing one game for twenty minutes can have an effect on cognition.

Our study expands the recent literature because we examined a largely untapped area of study – the influence of both social and game-play conditions on cognitive function. Games and game-based assessments are generally studied in order to discern their effects on cognition, and we have shed light on the social aspects of gaming in *conjunction* with its effects on cognition.

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Table 1

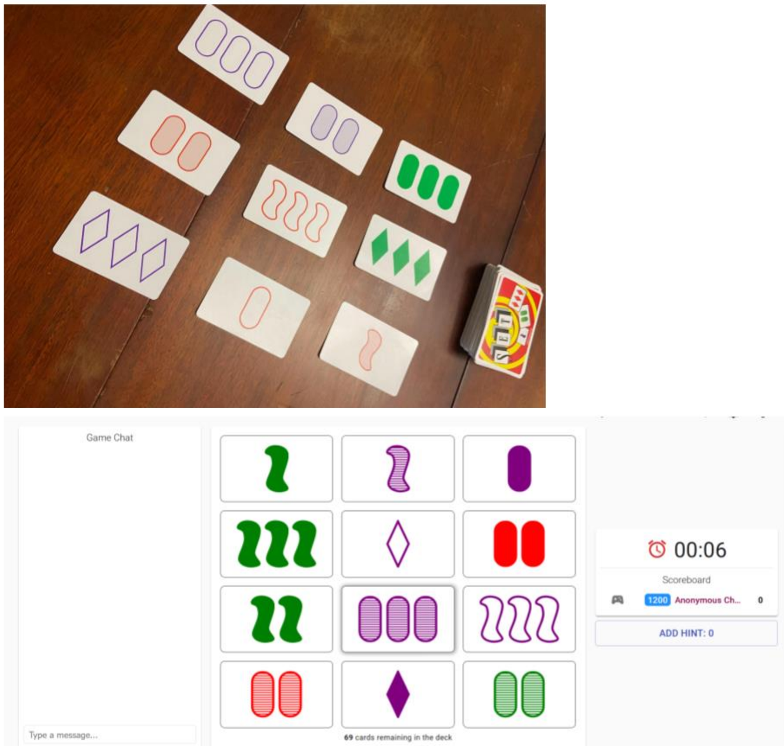
Mean reaction times and Variability in mean reaction times by items, time, and condition

Items	**Condition**	**Mean RT**		**Variability in Mean RT**	
		Pre	**Post**	**Pre**	**Post**
5	**Social Analog**	789.595	703.568	219.4823	165.9585
5	**Solo Analog**	740.4173	681.4472	148.6451	162.0471
5	**Solo Digital**	782.675	733.2213	192.6345	198.553
10	**Social Analog**	930.4957	821.5528	268.1165	196.189
10	**Solo Analog**	927.7422	814.6311	361.7231	230.8887
10	**Solo Digital**	954.6694	888.2893	268.3357	235.8466
15	**Social Analog**	1135.9508	1052.4567	335.776	364.6472
15	**Solo Analog**	1066.6803	979.2205	387.4194	278.1957
15	**Solo Digital**	1126.6202	1028.6429	383.4998	309.5269
20	**Social Analog**	1152.1349	1063.8871	485.215	463.5278
20	**Solo Analog**	1104.1545	1033.6748	430.3852	464.3112
20	**Solo Digital**	1155.7317	952.697	412.6217	261.513

Note. Mean Reaction Times and Variability in Mean Reaction Times in each experimental condition, separated by number of items on the screen during the Visual Search Task and when in the experiment the task was performed.

Figure 1

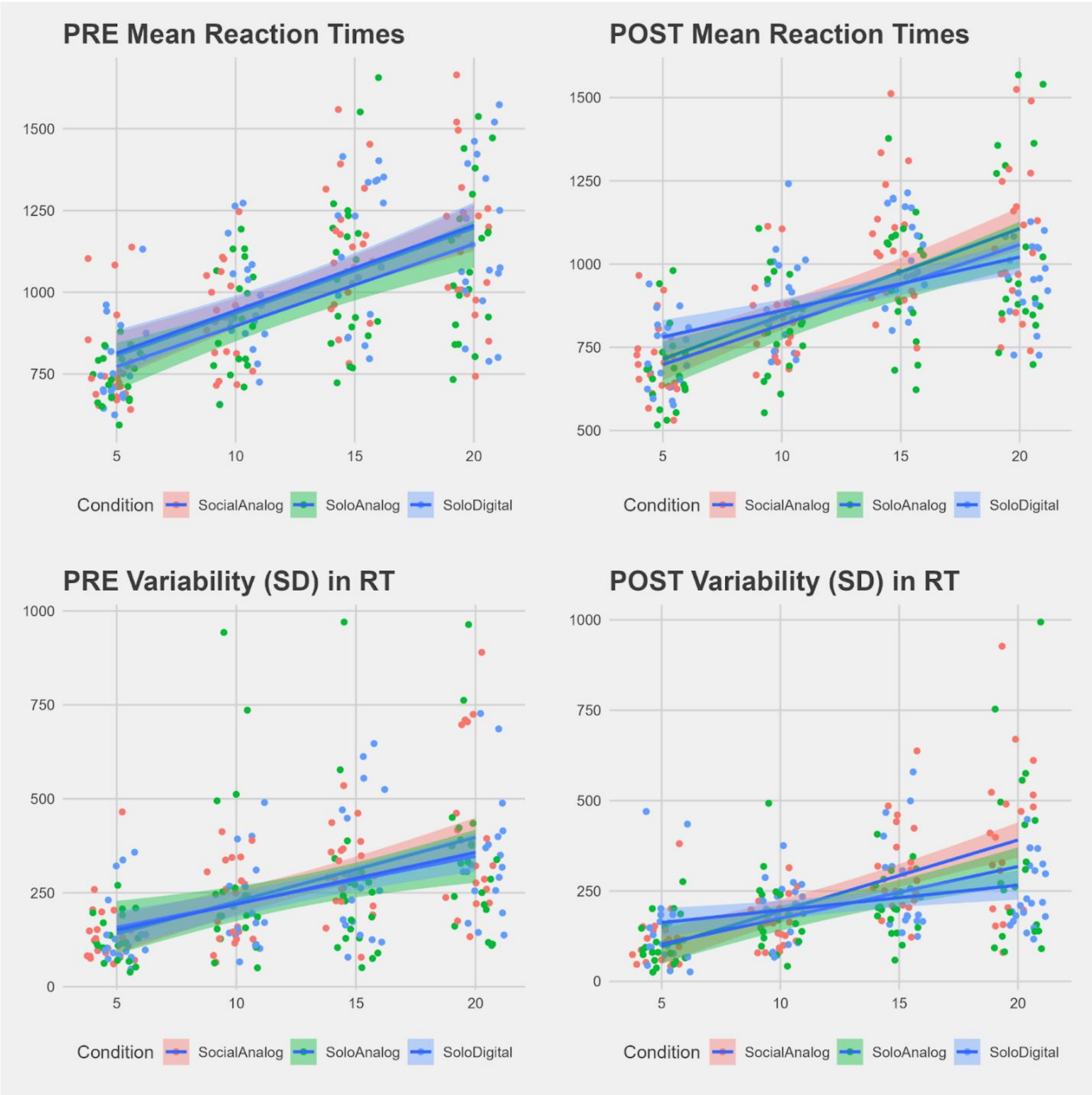
Game play set up for SET



Note. Game play set up for Analog and Digital versions of SET (http://setwithfriends.com)

Figure 2

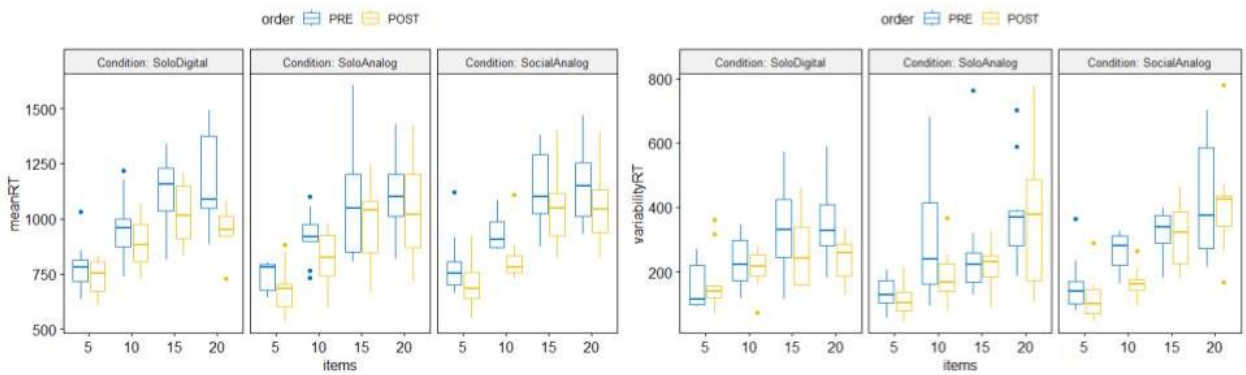
Mean reaction times and variability in reaction times



Note. *Mean reaction times (top) and variability in reaction times (bottom) in each condition, pre and post experimental intervention.*

Figure 3

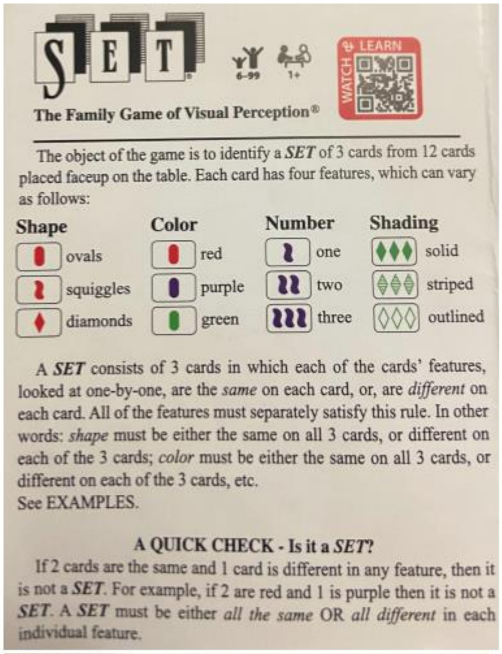
Mean reaction times and variability in reaction times (Boxplot)



Note. *Mean reaction times (left) and variability in reaction times (right) in each condition, pre and post experimental intervention. (Boxplot)*

Appendix A

Instructions for the Game SET



SET

The Family Game of Visual Perception®

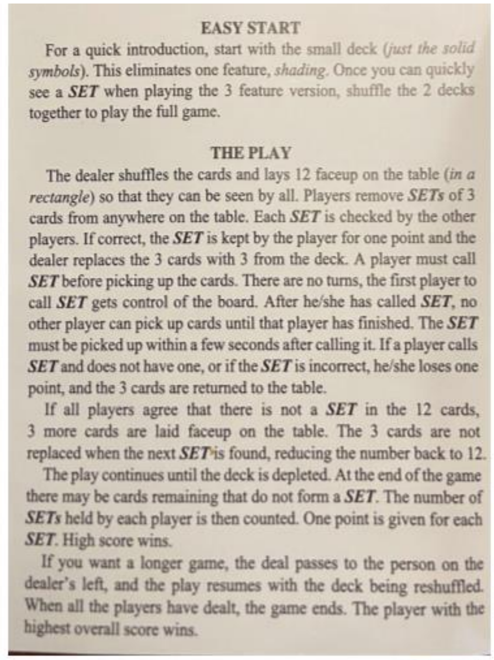
The object of the game is to identify a *SET* of 3 cards from 12 cards placed faceup on the table. Each card has four features, which can vary as follows:

Shape	Color	Number	Shading
ovals	red	one	solid
squiggles	purple	two	striped
diamonds	green	three	outlined

A *SET* consists of 3 cards in which each of the cards' features, looked at one-by-one, are the *same* on each card, or, are *different* on each card. All of the features must separately satisfy this rule. In other words: *shape* must be either the same on all 3 cards, or different on each of the 3 cards; *color* must be either the same on all 3 cards, or different on each of the 3 cards, etc.
See EXAMPLES.

A QUICK CHECK - Is it a *SET*?

If 2 cards are the same and 1 card is different in any feature, then it is not a *SET*. For example, if 2 are red and 1 is purple then it is not a *SET*. A *SET* must be either *all the same* OR *all different* in each individual feature.



EASY START

For a quick introduction, start with the small deck (*just the solid symbols*). This eliminates one feature, *shading*. Once you can quickly see a *SET* when playing the 3 feature version, shuffle the 2 decks together to play the full game.

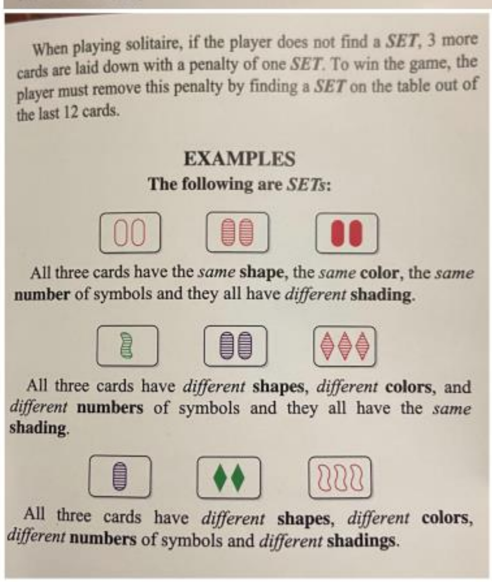
THE PLAY

The dealer shuffles the cards and lays 12 faceup on the table (*in a rectangle*) so that they can be seen by all. Players remove *SETs* of 3 cards from anywhere on the table. Each *SET* is checked by the other players. If correct, the *SET* is kept by the player for one point and the dealer replaces the 3 cards with 3 from the deck. A player must call *SET* before picking up the cards. There are no turns, the first player to call *SET* gets control of the board. After he/she has called *SET*, no other player can pick up cards until that player has finished. The *SET* must be picked up within a few seconds after calling it. If a player calls *SET* and does not have one, or if the *SET* is incorrect, he/she loses one point, and the 3 cards are returned to the table.

If all players agree that there is not a *SET* in the 12 cards, 3 more cards are laid faceup on the table. The 3 cards are not replaced when the next *SET* is found, reducing the number back to 12.

The play continues until the deck is depleted. At the end of the game there may be cards remaining that do not form a *SET*. The number of *SETs* held by each player is then counted. One point is given for each *SET*. High score wins.

If you want a longer game, the deal passes to the person on the dealer's left, and the play resumes with the deck being reshuffled. When all the players have dealt, the game ends. The player with the highest overall score wins.



When playing solitaire, if the player does not find a *SET*, 3 more cards are laid down with a penalty of one *SET*. To win the game, the player must remove this penalty by finding a *SET* on the table out of the last 12 cards.

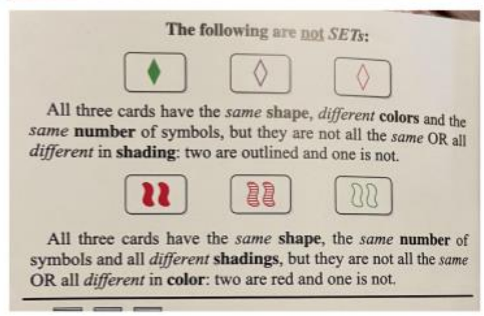
EXAMPLES

The following are *SETs*:

All three cards have the *same* **shape**, the *same* **color**, the *same* **number** of symbols and they all have *different* **shading**.

All three cards have *different* **shapes**, *different* **colors**, and *different* **numbers** of symbols and they all have the *same* **shading**.

All three cards have *different* **shapes**, *different* **colors**, *different* **numbers** of symbols and *different* **shadings**.



The following are not *SETs*:

All three cards have the *same* shape, *different* **colors** and the *same* **number** of symbols, but they are not all the *same* OR all *different* in **shading**: two are outlined and one is not.

All three cards have the *same* **shape**, the *same* **number** of symbols and all *different* **shadings**, but they are not all the *same* OR all *different* in **color**: two are red and one is not.

Instructions included in
SET The Family Game of Visual Perception ®

Appendix B

Scripts for Participant Tasks

Script for Visual Search Task

- The instructions will be on the computer screen, but I'll give you some as well, just to make sure everything is clear.
- There's going to be upside down Ts on the screen. Your goal is to find an upright orange T, if there is one there.
- If you see the upright orange T, press the spacebar as soon as you do. If you don't see the upright orange T, just wait for the next screen to load. If you press the spacebar in error, the computer will tell you. If that happens, no worries! On to the next one!

Script for SET Instructions (analog)

- Draw a field of 12 cards.
- Your goal is to find a set of 3 cards based on number, shape, shading, and color.
- For example, a set would be one opaque purple squiggle, two shaded purple squiggle, three outlined purple squiggle, or three outlined green ovals, three outlined red squiggles, and three outlined purple diamonds. (it would be better to use the examples on the instructions in the box.)
- A set would NOT be one opaque purple squiggle, two opaque green squiggle, and three red outline squiggle, because two of them are opaque.
- When you find a set, take it off of the playing field and draw back up to 12.
- If you absolutely do not think there's a set in the playing field, add 3 cards for a total of 15, but don't draw back up to 15. Let it go back down to 12.
- When the timer goes off after 20 minutes, we'll switch back to the computer task.

- Leave the cards the way they are when it's time to go do the task on the computer again.

Script for SET Instructions (digital)

- There will be a field of 12 cards on the screen. Your goal is to find a set of cards by number, symbol, shape, or shade.
- For example, a set would be one opaque purple squiggle, two shaded purple squiggle, three outlined purple squiggle, or three outlined green ovals, three outlined red squiggles, and three outlined purple diamonds. (it would be better to use the examples on the instructions in the box.)
- A set would NOT be one opaque purple squiggle, two opaque green squiggle, and three red outline squiggle, because two of them are opaque.
- When you find a set, click on each card in the set. The computer will tell you if you're right or not.
- If you do not think there's a set in the playing field, you can add 3 cards.
- When the timer goes off, we'll switch back to the computer task.

Appendix C

Results of the Game Experience Survey

Participants were given a pre-experiment survey to measure their level of experience with different types of games and the frequency of game play. One participant did not fill out the game experience survey, so the results of twenty-nine participants are reported below.

Experience with game types

Participants were asked to rate the level of experience they have with board games, card games, and video games on a five-point scale, with one being little to no experience, and five being a lot of experience. One (3.4%) participant rated their experience with board games one, six participants (20.7%) answered two, thirteen participants (44.8%) answered three, nine (31%) answered four, and no participants answered five.

Two (6.9%) participants rated their experience with card games one, four (13.8%) answered two, ten (34.5%) answered three, twelve (41.4%) answered four, and one (3.4%) answered five.

Five (17.2%) participants rated their experience with video games one, seven (24.1%) answered two, six (20.7%) answered three, eight (27.6%) answered four, and three (10.3%) answered five.

Frequency of game play

Next, participants rated the frequency at which they play board games, card games, and video games on a five-point scale, and chose their answers from the following list: very rarely or never, once or twice a year, once or twice a month, once or twice a week, and almost daily or daily.

Five (17.2%) participants stated that they play board games very rarely or never. Eighteen (62.1%) said that they play board games once or twice a year. Three (10.3%) said that they play once or twice a month, two (6.9%) said that they play once or twice a week, and one (3.4%) said that they play almost daily or daily.

Four (13.8%) participants stated that they play card games very rarely or never. Thirteen (44.8%) said that they play card games once or twice a year, and twelve (41.4%) participants said that they play card games once or twice a month.

Twelve participants (41.4%) stated that they play video games very rarely or never. Two (6.9%) said they play once or twice a year, seven (24.1%) said they play once or twice a month, seven (24.1%) said they play once or twice a week, and one (3.4%) said they play almost daily or daily.