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The Impact of Computer Games on Cognitive Performance in Pupils

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Abstract— This study investigated the effects of changing the computer game that adolescents play on their cognitive abilities, including concentration, memory, and problem-solving skills at a high level of thinking. The study included a group of 38 adolescents aged 12-13. The "source and imitation" game was employed to test concentration, the "Simon-flashing detection" game to assess memory, and mathematical tasks at an advanced level to evaluate problem-solving skills.

The findings of the study indicate that children who played Fortnite for 15 minutes experienced a significant increase in their concentration levels by approximately 43.4 % and by 74 % in memory levels after engaging in a session of Solitaire. Furthermore, the study also examined high-order learning skills in solving mathematical questions, particularly focusing on analysis and mathematical insight. The findings suggest that the time required to solve mathematical problems after playing Fortnite decreased by 41.5 % after engaging in a session of Solitaire, indicating enhanced efficiency in solving higher-order problems.

The results demonstrated a substantial improvement in cognitive abilities after playing a challenging computer game compared to a violent computer game. This suggests that engaging in thinking and challenging games significantly enhances the subjects' cognitive abilities. The increase in efficiency in solving higher-order mathematical problems may be attributed to the improvements in memory and concentration among children who played intellectually stimulating and challenging computer games. Therefore, it is recommended to reduce adolescents' exposure to violent computer games and increase their exposure to thinking and challenging games to create a balanced gaming experience.

Index Terms— cognitive abilities, Computer games, concentration, memory.

I. INTRODUCTION

Video games are usually associated mainly with entertainment, which may have negative meanings, and some people believe that they could threaten positive social behavior. However, this general perception is far from accurate. Like any other medium, video games can serve as effective teaching and education tools [7]. In fact, they offer many benefits beyond entertainment. Video games come in various forms and genres, each requiring specific skills of players. The impact of video games on cognitive abilities is an important focus area, including both positive improvements and negative consequences associated with games. Cognitive skills such as perception, attention control, and decision-making have been shown to improve when individuals participate in video game training. In addition, video games can be used as educational and training tools, particularly in the fields of medicine, military, and aviation, where decision-making skills are crucial [2].

In addition to these benefits, however, there are concerns about potential negative effects, including addiction, aggression and reduced social skills. In terms of game genres, Real-Time Strategy (RTS) players tend to outnumber First-person Shooter (FPS) players in cognitive flexibility, while FPS players often have lower change costs in their work. Psychological professionals suggest strategies for managing the risks associated with the use of video games, providing valuable insights to educators, parents, and policy makers to promote a balanced and constructive approach to video games [16]. Cognitive Challenge Games (CCGs) include logic, puzzle solving, and strategic games that require players to engage their minds in solving problems in a logical and successful way. These games can develop cognitive skills and stimulate critical thinking. Children exposed to CCGs can enhance their ability to perceive situations from different perspectives, to think analytically, and solve problems effectively [4, 8].

Guessing games can be divided into five types: thought puzzles, word games, geometry mechanics games, memory games and strategy games. All these games require high-level thinking and activate advanced cognitive abilities. Engaging in these digital games can improve students' cognitive and creative performance. The game process does not exhaust students, but rather offers them satisfaction and fun, while significantly improving their cognitive abilities after completing class-related problems [4, 8]. To evaluate the effectiveness of these games in influencing students' cognitive abilities, an electroencephalographic test (EEG) is required. This non-invasive method involves placing electrodes on the scalp to measure the activity of brain waves during cognitive tasks. To assess high-level thinking activity, including intense cognitive processes, it is necessary to focus on beta waves (13–30 Hz) that occur primarily in the front regions of the brain during concentration and learning [8].

In addition, Solitaire games can be used to assess and stimulate active cognitive functions, such as memory and concentration, without the need for players to practice.

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Solitaire and similar games are accessible to researchers and players, providing an interesting and attractive platform for cognitive evaluation. In contrast to other large-scale cognitive practices, participation in these games does not cause fatigue or create a burden that could impede learning. Participants can improve their cognitive skills and academic performance while enjoying the process, as it feels more like leisure than a rigorous training [5, 6]. Children participate in various activities that contribute to the normal development of their brains, including reading, playing, sports and spending time with friends [1]. The brain plays an essential role in the regulation and control of all human functions and exhibits plasticity throughout life. During childhood and adolescence, the brain undergoes significant changes and growth, which makes children's activities and the environment influential factors in brain development and structure [17]. Repeated practice and experience lead to changes in the structure of the brain, including the connection and neural network, and promote learning and understanding [15].

However, contemporary children spend more and more time on screens and consume media, which can hinder earlier activities that have positive effects on brain activity and facilitate the pruning of brain pathways, thus strengthening the neural pathways associated with computer activities and games [1, 15]. Children's frequent use of computer games is often seen as a convenient solution to busy parents to engage their children when they are not available. These games provide entertainment and reduce boredom and fatigue, making them an effective leisure activity. However, computer games must be recognized that their frequency of use can affect brain function. Some games can enhance cognitive abilities, promote language learning, enrich vocabulary, and improve intelligence, but others have a negative impact on brain structures, lead to dependency, and reduce social and cognitive functions. Studies have shown that exposure to violent computer games for just one week can reduce brain activity in the prefrontal cortex, which is crucial to cognitive function [17].

First-person shooter games (FPS) are easy-to-use and pleasant video games, focused primarily on entertainment rather than educational purposes [3]. However, these games are associated with potential cognitive disadvantages, including addiction and its negative effects on intelligence and cognitive function. Research on students playing about 10 hours a day showed a reduction in grey matter in the prefrontal cortex, an important area for balanced thinking and cognitive performance. Short-term gaming sessions, i.e., 30 minutes, also resulted in a reduction in prefrontal cortex activity, causing anxiety and impairment of function in this critical brain region [15]. Furthermore, FPS users showed functional and structural changes in the neural reward mechanism, which affected impulse control and decision-making abilities. Recent studies have shown that a week of violent computer games results in a reduction in activity in the frontal area of the brain, which plays a crucial role in controlling emotions and aggressive behavior. Men who played violent video games for a week showed a decrease in activity in the left front lobe during emotional activation tasks and a decrease in activity in the anterior cortex during cognitive activity tasks. Changes in brain activity in this region decreased after participants stopped playing violent video games for a week [19].

The purpose of this study is to investigate the effects of computer games that challenge thinking and violent first-person computer games on cognitive abilities. Understanding the relationship between video games and skill development provides valuable insights into their educational potential and their effective use as tools for personal growth and development.

II. METHODOLOGY

Participants

63 middle school children all in grade 7 (32 females and 31 males). All participants came from middle class backgrounds as determined by the methodology of Hollingshead and Redlich (1958).

The research was conducted during the afternoon hours after the school day, outside the educational framework of the school. All students participated voluntarily, with the consent of their parents. The names of the subjects and their details were kept confidential, and their identities were not revealed.

The entire study population engages in playing computer games, including thought-challenging game such as Solitaire Spider with two packs and violent First-person shooter games like "Fortnite Battle Royale".

The purpose of this study is to investigate the effects of computer games that challenge thinking and violent first-person computer games on cognitive abilities.

Our assumption is that Cognitive performance will improve after changing the computer game you play from a violent game to a challenging thinking game.

Research Variables

Dependent Variables: Cognitive abilities - concentration, memory, and solving mathematical questions at higher-order thinking levels.

Independent Variables: Computer games - violent ("Fortnite Battle Royale") and challenging game (Solitaire Spider, two packs).

Procedure

All 63 participants were asked to play two types of games: the first being a thought-challenging game, and the second a violent game. Each game lasted for 15 minutes. Subsequently, all participants were immediately asked to perform cognitive tasks for 10 minutes which included:

A) Memory game- sequential memory task consisting of a Simon-type multisensory memory game [14].

B) Concentration game - feature-detection task

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consisting of presentations of famous paintings twice, once with the complete painting and later with a minor feature of the painting missing. The task of each participant was to find the missing feature [14].

C) A mathematical task for solving higher-order problems. The questions were taken from the textbook approved by minister of education in Israel.

Each participant served as a control group for himself to obtain paired data.

The research was conducted over a span of two weeks, following the schedule as outlined below:

During the first week, the research activities were carried out on three specific days: Monday, Wednesday, and Friday. At 5 pm on these days, the participants were asked to play the thought-challenging game for 15 minutes. Immediately after completing the game, they were instructed to perform one of the cognitive tasks for 10 minutes and record their scores. Each day, after playing the computer game, one specific task was performed. On Monday, they completed the memory task on the computer, recording their scores after 10 minutes under the supervision of an observer. On Wednesday, they performed the concentration task on the computer and recorded their scores after 10 minutes under the observer's supervision. Finally, on Friday, they engaged in a math task on the computer, involving high-order problem-solving, and recorded the time it took to solve the task under the supervision of an observer.

In the second week, the same schedule was repeated, but this time the participants played the violent game. Notably, the memory, concentration, and math tasks remained at the same level each week, but different tasks were assigned for each week.

Statistical Analysis

Paired t-test comparisons were conducted between the thought-challenging computer game and the violent First-person shooter computer game tasks, with each participant serving as their own control for the three dependent variables: Memory, Concentration, and mathematical task.

III. FINDINGS

The current research aimed to investigate the impact of different types of computer games on the cognitive abilities of children. The study's findings revealed that the type of game significantly influences children's ability to concentrate, as indicated in Table 1 and chart 1.

Specifically, children who played Fortnite for 15 minutes demonstrated a concentration level of 80.16 ± 20.8, as rated by the game's 'source and imitation' assessment. Notably, this value increased significantly by approximately 43.4%, with an average concentration level of 114.98 ± 23.73 observed during the Solitaire game ($P < 0.0001$)

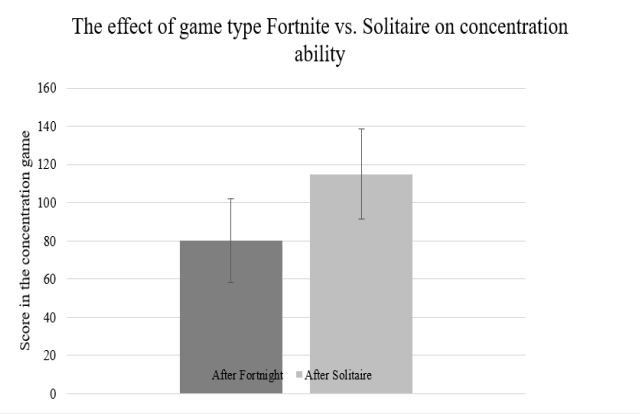

Chart 1: Score in a concentration game (sum of points in increments of 10) after playing Fortnite and after playing solitaire.

Table No. 1 - The effect of game type Fortnite vs. Solitaire on concentration ability

Subject number	Performing in a concentration game after Fortnight	Performing in a concentration game after Solitaire	% of change
Mean	80.6±21.8	114.98±23.73	43.4%
Statistical significance	t= 20.39 P<0.0001 n=63		

It is important to highlight that the study also investigated the memory abilities of children impacted by different types of computer games. The results from the study demonstrate that altering the type of game influences this cognitive ability, as depicted in Table 2 and chart 2.

Specifically, children who played Fortnite for 15 minutes exhibited a memory level of 64.76 ± 12.42, as rated by the 'Simon' game. Remarkably, this value increased by approximately 74%, with an average memory level of 111.27 ± 20.91 observed after playing Solitaire ($P < 0.001$).

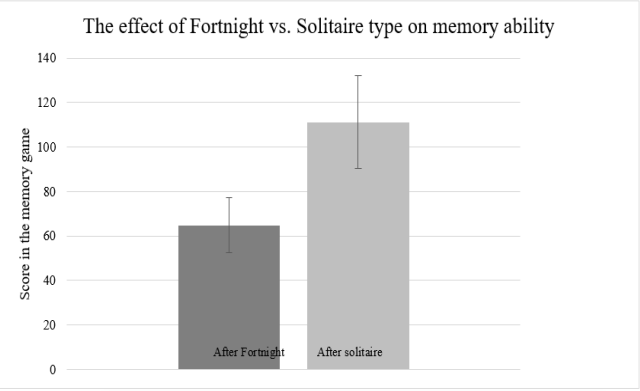

Chart 2: Score in a memory game (sum of points in increments of 10) after playing Fortnite and after playing solitaire.

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Table 2 - Effect of Fortnight vs. Solitaire type on memory ability

Subject number	Performing in a memory game after Fortnight	Performing in a memory game after solitaire	% of change
Mean	64.76+12.42	111.27+20.91	74%
Statistical significance	t= 16.24 P<0.0001 n=63		

The research aimed to explore the relationship between memory and concentration in different types of computer games. The study's results revealed that Solitaire showed a significant level of correlation, as tested by the Pearson correlation test.

Furthermore, this investigation examined high-order learning skills in solving mathematical questions, particularly in analysis and mathematical insight questions (Table 3). The study findings indicate that the time taken to handle mathematical problems after playing Fortnite was 9.73 ± 2.94. Notably, these values decreased by 41.5%, with the time taken to handle mathematical problems after playing Solitaire reaching 5.69 ± 1.69.

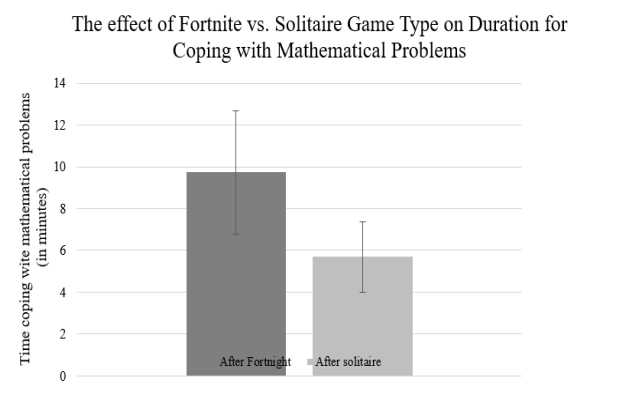

Chart 3: Time coping with mathematical problems (in minutes) after playing Fortnite and after playing solitaire.

Table 3 - Effect of Fortnite vs. Solitaire Game Type on Duration for Coping with Mathematical Problems

Subject number	Duration of coping with math problems after Fortnight (in minutes)	Duration of coping with math problems after Solitaire (in minutes)	% of change
Mean	9.73+2.94	5.69+1.69	-41.5%
Statistical Significance	t = 13.255 P<0.0001 n=63		

IV. CONCLUSION

The present research explores the impact of changing the type of game on the cognitive abilities of adolescents. The study found that the type of computer game in which adolescents participate causes a significant change in their cognitive abilities. Specifically, after playing Solitaire compared to Fortnite, adolescents showed an increase of approximately 43.4%, in their ability to concentrate. This indicates changes in the brain's neural network and the optimization of the neural connection, which leads to significant improvements in concentration. Furthermore, the study suggests that changing the type of Fortnite computer game to a thought-provoking and challenging game such as Solitaire has a similar effect to the combination of music during the learning process. Previous studies have shown that music can improve gamma waves associated with thinking and alpha waves associated with calmness and reward systems [13]. Thinking and challenging games may stimulate and increase the activity of gamma waves responsible for thinking processes, focus, and problem solving. As mentioned above, alpha waves are characteristic of a state of calm and relaxation. During calm moments, such as meditation, the alpha waves play a role in reducing stress. However, the activity of waves in the brain may not allow full concentration on a single task [10].

The concentration processes primarily take place in the region of the limbic system, particularly the hippocampus. Any changes in the quality and organization of neural connections within this region can significantly impact the order of networks in the prefrontal area. Consequently, thinking, and challenging computer games are likely to be associated with the limbic system, influencing the reward area, and ultimately leading to increased effectiveness and optimization in processes related to a person's level and degree of concentration.

For an intellectually active individual, the brain's concentration processes are closely linked to how effectively the brain manages memory. The study's findings strongly suggest that the improvement in the ability to concentrate is probably correlated with enhancements in memory levels. Specifically, when adolescents played thinking and challenging computer games, the study recorded a remarkable 74% increase in memory levels. Moreover, it was observed that such games appear to enhance brain flexibility while inhibiting emotional connections. This inhibition can prevent any impairment or dysfunction in the prefrontal area.

Different ways of studying the construction of belief flexibility are presented, highlighting a recent approach to other well-established theoretical areas; in particular, the models of “dual-process” reasoning popularized by Daniel Kahneman as “fast and slow thinking” [9].

Thus, we assume that there is a week-long connection between the prefrontal region and the limbic system, indicating a unique phenomenon that has not been reported in the existing literature. This also supports the assertion that

when the prefrontal region can handle tasks without interrupting the limbic system, which is a sensitive part of the brain, the development of thinking processes and problem-solving abilities depends significantly on the activity of the prefrontal region.

The findings of the present study demonstrate that exposing students to computer games that challenge thinking, as opposed to violent games, results in a significant increase in the efficiency of higher-order thinking, specifically in the context of solving mathematical problems. The notable 47% decrease in the time required to solve math tasks that demand critical thinking indicates improved cognitive efficiency and potential optimization of connections within the cerebral cortex and the frontal area responsible for complex thinking and problem-solving [12].

The "fast brain" is equivalent to the prefrontal cortex, and is responsible for conscious and complex cognitive processes, including working memory, attention, concentration, and decision-making. These processes are indispensable in learning, concentration, and memory. Interestingly, the prefrontal cortex works at higher cognitive functions when the brain is sensitive to learning, even in emotional contexts. As a result, the brain is emotionally prepared for learning, and this region becomes active and plays a vital role in improving cognitive performance [11, 18]. On the contrary, the slow brain refers to the limbic system, which functions as a system of survival and evolutionary remains in our minds. It performs fundamental actions and supervises emotions, action motivation (including hormones such as dopamine), memory and learning, all with the aim of ensuring the best survival opportunities for the individual. The actions of the limbic system are immediate and require minimal energy and mental effort. Within this system there is the hippocampus, which is responsible for the memory processes in which short-term memory is assimilate and consolidated into long-term memory. All these functions are vital to learning, but the "low brain" takes priority and hampers the best learning process when our brain is overwhelmed with emotions. In such situations of pain, the "slow brain" gives priority to survival rather than learning, which prevents effective cognitive functioning [18]. Understanding the complex interaction between the "fast brain" and the "slow brain" is essential to understanding the cognitive functioning and its implications in various learning environments.

We recommend that future research should focus on investigating the long-term effects of video gaming on cognitive abilities, brain function, and electrophysiology. Additionally, exploring the potential negative effects of video gaming on brain function is crucial. Furthermore, we propose that thought-provoking and challenging games like Solitaire can serve as therapeutic tools for individuals with cognitive impairments or neurological disorders, as they have shown positive effects on the brain and cognitive abilities. However, further research is necessary to comprehensively comprehend the potential benefits and risks of video gaming.

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