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Article

The Effects of Videogame Skills Across Diverse Genres on Verbal and Visuospatial Short-Term and Working Memory, Hand-Eye Coordination, and Empathy in Early Adulthood

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Abstract: The cognitive and affective impacts of video games are subjects of ongoing debate, with recent research recognizing their potential benefits. This study employs the Gaming Skill Questionnaire (GSQ) to evaluate participants' gaming skills across six genres and overall proficiency. Eighty-eight individuals aged 20-40 participated, completed assessments of empathy and six cognitive abilities: verbal short-term memory, verbal working memory, visuospatial short-term memory, visuospatial working memory, psychomotor speed (hand-eye coordination), and attention. Cognitive abilities were examined using the Digit Span Test, Corsi Block Test, and Deary-Liewald Reaction Time Task, while empathy was assessed using the Empathy Quotient Questionnaire. Findings indicate that high video game skill levels correlate with improvements in visuospatial short-term and working memory, psychomotor speed, and attention. Different genres enhanced specific skills: RPGs positively influenced verbal working and visuospatial short-term memory but negatively affected empathy; action games improved psychomotor speed and attention; and puzzle games benefited visuospatial working memory. These promising results contribute positively to ongoing research on the cognitive and affective effects of video games, highlighting the potential for video games to enhance certain cognitive functions while also underscoring the complexity of their impact on empathy. Future research should further investigate genre-specific effects and long-term outcomes.

Keywords: videogames; early adulthood; cognition; empathy; short-term memory; working memory; visuospatial memory; verbal memory; hand-eye coordination; attentional processing speed

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1. Introduction

Video games have become a significant form of entertainment, comparable to the film industry in profitability. In the United States, expenditure on game-related items has increased over 7 times, from $7.4 billion in 2006 to $57.2 billion in 2023 [1,2]. This expansive industry encompasses both hardware—such as video game consoles, personal computers, smartphones and virtual reality (VR) devices—and software- the games themselves. The development of gaming culture has led to the creation of a gamer identity, characterized by choices in gaming platforms, genres, specific games, and play styles. [3–5]. Additionally, electronic sports have emerged (eSports), where top players compete for substantial cash prizes, with audiences viewing these events similarly to traditional sports [6,7]. This trend emphasizes the importance of understanding the effects of video games on cognitive and affective aspects in early adulthood.

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Video games are designed in various genres to cater to different preferences and demands including adventure, action, sports, role-playing (RPG), racing, strategy, puzzles, martial arts, and first-person shooters (FPS). [8]. Each genre requires different skill sets and levels of engagement, being attractive to a wide audience. The difficulty levels of these games are carefully balanced to maintain player interest and satisfaction without overwhelming them. [9]. It is also important to note that many games now are designed to combine features from multiple genres, challenging traditional classifications [10–12].

Initially perceived as a predominantly male form of entertainment, gaming has seen a shift towards a more balanced representation of sexes, with an increased number of women identifying as gamers [13]. Furthermore, gaming is no longer perceived as a child's or adolescent's activity, a view which also changed with more and more adults playing videogames as a pastime. Studies indicate that 61% of U.S adults are playing videogames, with the average age of a gamers being 36 [2]. This is attributed to the fact that teenage gamers grow into videogame-playing adults. Early adulthood, defined as the period between 20 to 40 years of age, , is described as a period of cognitive stabilization and peak performance, making this age range critical for research on video game effects [14,15].

1.1. The Effects of Videogames on Cognitive and Affective Elements

The increased popularity and immersive nature of videogames have made them a significant topic in neuropsychological research. However, findings are not often inconclusive [16–18] and are often mediated by the game genre in question [19,20], independent from the platforms used [21].

A particular focus lies on the potential negative effects of violent video games on aggression, antisocial and externalized behavior, prosocial behavior, empathy, and desensitization to violence [22–26], with these effects being more prevalent in men [27]. However, this perspective is challenged by studies arguing that the deleterious effects of violent videogames are overstated, and result from less robust methodologies [28–33]. Additionally, some studies suggest that certain types of videogames, such as RPGs, social games, and cooperative games can enhance empathy [34–37], whereas cooperative violent videogames mitigate the empathy-reducing effects of violent content. [38–47]. There's an interesting finding regarding the age of the players and empathy, appearing to impact adolescents' empathy more than [48]. Finally, it should be noted that there are special videogames being developed for training empathy [49].

There has also been extensive research on the effects of videogames on cognitive domains, including their potential for rehabilitating cognitive deficits. These cognitive domains commonly engaged during playing include visuospatial skills, short-term and working memory, attention, and psychomotor speed, which is also reported as hand-eye coordination

Most studies indicate that videogames have positive effects on the visuospatial skills of players [50–54]. Action video games, in particular, require players to track and identify multiple moving objects simultaneously, potentially enhancing visuospatial skills. This genre, along with FPS games, have shown improvements in visuospatial short-term and working memory. However, some studies suggest that videogames do not affect visuospatial memory, suggesting a need for further investigation [55]. Evidence also suggests a "dose-related" effect, with more videogame play leading to greater improvements in visuospatial skills [56].

Attention is another domain frequently investigated in the context of videogames. Videogames offer an interactive experience that often demands constant player attention and engagement, depending on the specific type of videogame [57–59]. Action videogames, in particular, seems to benefit attention, with a plethora of studies demonstrating a positive relationship [60–66]. Action video games exhibit an interesting, sex-related effect on attention, with women benefiting more from playing such games, than men [67]. Action games aren't the only genre that improves the attention of their players, RPGs appear to exhibit the same level of beneficial effects on player's attention as action videogames [68]. Furthermore, the advent of virtual reality (VR) games significantly improve the visuospatial skills compared to conventional ones [69]. However, some studies report no interaction between action games and attention [70,71], highlighting the need for more research.

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Videogames not only require attention and visuospatial skills, but they also demand fast player reactions to on-screen stimuli and psychomotor speed (hand-eye coordination). Both of these skills are reflected in the player's reaction time, an important metric, both for gamers and researchers alike. Research suggests that video games can improve psychomotor speed and reaction times, with FPS games exhibiting particular promise in psychomotor speed [72–78].

Verbal memory, both short-term and working, has not been extensively studied, with inconclusive results. Some research supports the notion that videogames provide benefits for one's verbal memory [53,79], while other studies indicate either a negative relation, with games being detrimental to one's verbal memory [80], or no relation at all [81]. Further investigation is needed to examine the effects of videogames on verbal skills.

Another significant area of research involves the impact of video games on cognitive functions and their potential use in neuropsychological rehabilitation to battle cognitive decline [82]. Various studies explored using videogames as a way to help older adults to reduce cognitive decline and retain cognitive levels [83–87]. Furthermore, there have been attempts to use videogames as training devices to bolster cognitive abilities of older people, including memory [88–91]. Real-Time Strategy games (RTS) and Puzzle games have been identified to improve both their short-term and working memory in older adults [92,93]. Interestingly older adults seem to benefit cognitively more than younger ones from playing videogames [94]. The general consensus is that more research is needed [95,96].

1.2. Aims of this Study

This study aims to contribute to the growing and mixed-result literature regarding the effects of videogames on various cognitive and affective domains. Specifically, the Gaming Skill Questionnaire (GSQ) was used to assess the skills of the adults in 6 different videogame genres as well as in gaming in general. The effects of these skills were then assessed on six cognitive and one affective domain. Cognitive domains included Verbal Short-term Memory and Verbal Working Memory, assessed by the Digit Span Test; Visuospatial Short-term Memory and Visuospatial Working Memory, assessed by the Corsi Block Test; Psychomotor skills and Attentional Processing Speed assessed by the Deary-Liewald Simple and Choice Reaction Time Tests, while the affective domain was investigated with Empathy using the EQ Questionnaire.

The research hypothesis posits that experience with video games will significantly affect the cognitive skills investigated, as well as empathy, either positively or negatively. Furthermore, this study aims to elucidate whether these forms of digital engagement can predict performance in cognitive assessments and empathy measures to better understand of the potential benefits and drawbacks of video game engagement. By integrating these findings, this research hopes to inform future studies and practical applications in cognitive training and mental health interventions.

2. Materials and Methods

2.1. Participants

The present study's sample consisted of 88 adults, aged 20 to 40, 45 female and 43 male participants. Apart from age and sex, demographic data also included the education level of the participants, measured in years, ranging from 12 to 25 years. Their recruitment was conducted using a convenience sampling method. Participation was voluntary and each participant signed a consent form before taking part in the study. Inclusion criteria required the absence of neurological and psychiatric diseases/disorders, any form of addiction, drug/alcohol abuse, and learning difficulties.

2.2. Materials

Demographic data for this study were collected using a custom questionnaire that incorporated questions relating to the participants' age, sex, years of education, and exclusion criteria as described above.

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2.2.1. Gaming Skill Questionnaire (GSQ)

This questionnaire was used to quantify the skills of the participants in six different gaming genres and overall gaming skills [97]. GSQ includes sections, for each of the six gaming genre: Sports Games, First Person Shooter (FPS) Games, Role Playing Games (RPG), Action-Adventure Games, Strategy Games, and Puzzle Games. Each section is comprised of two questions, one on the frequency of play, ranging from 1 (Never) to 6 (Everyday), and one on the self-perceived expertise on said genre, ranging from 1 (No skill) to 6 (Expert). Scoring on each genre's gaming skills consists of the sum of the scores of the two questions. Total Gaming Skill score is the sum of the gaming skills of each of the six sections. Thus, the test provides seven scores, Sports Games Skill (SpGS), FPS Games Skill (FPSGS), Role-Playing Games Skill (RPGS), Action-Adventure Games Skill (AGS), Strategy Games Skill (StGS), Puzzle Games Skill (PGS), and Total Gaming Skill (TGS) [97].

GSQ has high reliability and validity, with a high Cronbach's alpha (varying from .8 to .91 in the different sections) , strong convergent validity (with item loadings at .69 at minimum and 1 at maximum) and excellent divergent validity (with low associations between the sections, ranging from .092 to just .002), thus proving its inclusion in the present experiment [97]. The GSQ (English version) can be accessed here: http://dx.doi.org/10.13140/RG.2.2.27257.24160

2.2.2. Digit Span Test (DST)

The Digit Span Test measures verbal memory by presenting sequences of digits for participants to verbal recall [98]. The sequences of digits progressively increase in length. There are two iterations of DST, DST Forward and DST Backward. In DST Forward the participants recall the sequences of digits in the same order that they were presented, while in the DST Backward, the participant has to recall them in the inverse order. Performance is calculated based on the longest correctly recalled sequence and the number of correct trials. DST Forward specifically is used to assess one's verbal short-term memory, while DST Backward is used to assess one's verbal working memory [99]. This difference warrants the inclusion of both iterations of DST in this experiment.

2.2.3. Corsi Block Test (CBT)

The Corsi Block Test assesses visuospatial memory [100]. Participants are shown blocks on the screen, which sequentially light up, and must recall the sequence. The sequence of blocks lighting up progressively increases in length. There are two iterations, CBT Forward, and CBT Backward. In CBT Forward the participants have to recall the sequence in the same order and in the CBT Backward the participant has to recall it in the inverse order [101]. Performance is calculated based on the longest sequence successfully recalled and the number of correct trials. CBT Forward assesses visuospatial short-term memory, while CBT Backward assesses visuospatial working memory [102–104].

2.2.4. Deary-Liewald Reaction Time Task (DLRTT)

This task is implemented in order to assess the reaction time and the information processing speed of the participants. There were two iterations of DLRTT implemented in the present study. the Deary-Liewald Simple Reaction Time Task (DLSRTT) where participants press a key as fast as possible when a visual stimulus (a cross is presented [105] and the Deary-Liewald Choice Reaction Time Task (DLCRTT), where participants press one of two buttons, depending on whether a left or right arrow appears on the screen [105]. Reaction time measured in milliseconds is the score for each task. DLSRTT measures psychomotor skill, while DLCRTT measures attentional speed [105].

2.2.5. Empathy Quotient Questionnaire (EQ)

The EQ questionnaire is a tool designed to evaluate the empathy of adults. It includes 60 questions, 40 of which are designed to assess the perception of and the influence of the emotions of others, and 20 are filler items [106]. The participant is presented with each question and has to choose the best-suited reply from four available, ranging from totally agree, somewhat agree, somewhat disagree, and totally disagree. It is designed to be completed within 5 to 10 minutes, with scores

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ranging from 0 to 80 [107]. The questionnaire appears to be both highly reliable and valid , which holds true also for the Greek version of the EQ Questionnaire that was used, with a Cronbach's alpha of .902, an Intraclass Correlation Coefficient of .928, and a good fit in the Confirmatory Factor Analysis [108].

2.3. Procedure

The study was conducted in a controlled laboratory setting. Each participant was alone with the researcher during data collection. Participants received a detailed briefing on the procedure, tests, type of data collected, and the confidentiality as well as the adherence to GDPR laws. Informed consent was obtained prior to participation.

Initially, participants had to fill in the demographic questionnaire, followed by the completion of the GSQ. Extra care was taken to ensure that the participants provided accurate information.

Subsequently, the three tasks were administered, namely DST, CBT, and DLRTT, as they were described in the Materials section. In each type of test, the sequence was maintained as proposed in the literature, with the Forward iteration being administered first, followed by the Backward one, in the cases of DST and CBT, while for DLRTT, the Simple iteration was administered first, followed by the Choice one [98,105,109]. The order of the three tests was randomized using a Latin square design to avoid primacy effects.

After the administration of all three tests, the participants completed the EQ questionnaire, striving to capture thoughtful and accurate answers, by reminding them the importance of truthfully replying. Finally, the participants were debriefed, reminded of their rights regarding their participation in the study and their personal data.

2.4. Statistical Analysis

Statistical analyses for this study were performed using the R programming language (version 4.3.3) [110] within the RStudio environment (version AGPL v3) [111]. Essential R packages were utilized, including psych [112] for correlation, regression, ANOVA, and post hoc comparison analyses, and ggplot2 [113] for generating visual plots. The analysis began with descriptive statistics to provide a comprehensive overview of the sample demographics and test scores. Pearson's correlations were performed to identify potential correlations between variables.

2.4.1. Regression Analysis Process

Linear Simple regressions were performed with the goal to uncover the predictive values of all individual predictor variables on the criterion variables. For the Linear Multiple Regression models, the variables considered included demographic data (namely Age, Sex, and years of education), gaming skill levels (namely Sports Gaming Skills, First Person Shooter Gaming Skills, Role Playing Gaming Skills, Action-Adventure Gaming Skills, Strategy Gaming Skills, Puzzle Gaming Skills, and Total Gaming Skills), cognitive test scores (DST Forward, DST Backward, CBT Forward, CBT Backward, DLSRTT, and DLCRTT), as well as the EQ questionnaire score. The incremental approach was chosen, which consisted of initial Single-Predictor models, one for each predictor, being created. These allowed the identification of the most effective variable. These were followed by Dyadic Predictor Models, including two predictors, with the inclusion of the most effective variables from the Single-Predictor Models. The performances of Dyadic Predictor Models and of the Single Predictor Models were compared to identify the most effective combinations. Finally, an Incremental Model Development process was conducted, whereby predictors were added in each phase, with the resulting model being compared to the previous one. This leads to progressively more complex models, with the process being halted when the addition of a new predictor lead to no significant improvement in the model's performance. The optimal model was chosen as the simplest possible model with superior performance compared to more complex ones. This allowed the selection of a robust and accurate representation of the most influential variables in the chosen models.

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The regression analysis commenced with verifying data normality using the Shapiro-Wilk Normality test (shapiro.test function from the stats package [110]) and confirming homoscedasticity with the Non-Constant Error Variance test (ncvTest function from the car package [114]). Multicollinearity was assessed by calculating the variance inflation factor (VIF) for each predictor within the models using the vif function from the car package [114]. Linear regression analyses were employed to explore various predictors of cognitive functions and behaviors, utilizing the lm function from the stats package [110]. Models were compared using the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), F statistic significance level, and the proportion of explained variance (R^2).For the multiple linear regression analyses, variables considered included demographic factors (age, sex, years of education), gaming skill levels (Sports Gaming Skills, First Person Shooter Gaming Skills, Role Playing Gaming Skills, Action-Adventure Gaming Skills, Strategy Gaming Skills, Puzzle Gaming Skills, and Total Gaming Skills), cognitive test scores (DST Forward, DST Backward, CBT Forward, CBT Backward, DLSRTT, and DLCRTT), and the EQ questionnaire score. An incremental approach was adopted for the analytical process:

1. Single-Predictor Models: Initially, separate models were developed for each predictor to identify the most effective variable based on performance.
2. Dyadic Predictor Models: Subsequently, models incorporating two predictors were constructed, consistently including the most effective variable from the single-predictor models. The performance of these dyadic models was then evaluated and compared to the single-predictor models to ascertain the most effective combination.
3. Incremental Model Development: This iterative approach involved adding a predictor in each phase and comparing the performance of increasingly complex models. The process continued until the inclusion of new variables no longer significantly improved the models' performance. The optimal model was determined when a simpler model from an earlier phase demonstrated superior performance compared to a more complex model from a later phase. This ensured the final model was robust and accurately reflected the most influential variables identified in the study.

2.4.2. One-Way ANOVA Analyses

One-way ANOVA analyses were performed on the data set using the aov function from the stats package [110], with participants divided into Low, Medium, and High Gaming Skill Levels based on their GSQ scores. This division was used to examine differences in cognitive performance on the three tests and empathy across different levels of gaming skills in individual genres and overall gaming proficiency. Post-hoc Bonferroni corrected comparisons were conducted using the pairwise.t.test function to uncover specific differences between gaming skill levels. This comprehensive approach ensured a detailed understanding of how different gaming skill levels impact cognitive and affective functions.

3. Results

The sample (N=88) included 45 female and 43 male adults, aged 20 to 40. Table 1 presents the descriptive statistics, which include the demographics, namely age and years of education, their gaming skills in all 6 genres inquired in the GSQ, as well as the total gaming skill. Furthermore, it also includes the descriptive statistics of the 3 cognitive tests, specifically the DST Forward and Backward, the CBT Forward and Backward, and the DLRTT Simple and Choice, as well as for the EQ questionnaire. Table 1 includes the total values but also the values based on the gaming skills of the participants, when divided into Low, Medium, and High based on their Gaming Skills Score.

Table 1. Descriptive Statistics of Demographics, Gaming Skills per Genre and Total, Cognitive Performance, and Empathy per Gaming Skill Level and Overall.

	Gaming Skill	Mean	SD	Range
Age	Low	26.93	4.274	20-38
	Medium	29.00	5.359	21-40

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	High	29.28	4.122	21-38
	Total	28.39	4.680	20-40
Education	Low	16.40	2.343	12-21
	Medium	17.24	3.055	12-25
	High	15.93	2.298	12-20
	Total	16.52	2.610	12-25
Sport Games Skill	Low	2.27	0.450	2-3
	Medium	3.17	0.928	2-6
	High	3.69	1.228	2-6
	Total	3.03	1.090	2-6
FPS Games Skill	Low	2.13	0.346	2-3
	Medium	2.72	0.797	2-5
	High	4.41	1.615	2-9
	Total	3.08	1.420	2-9
RPG Games Skill	Low	2.10	0.305	2-3
	Medium	3.03	1.239	2-7
	High	6.86	2.656	2-11
	Total	3.98	2.660	2-11
Action Games Skill	Low	2.27	0.640	2-4
	Medium	3.62	1.898	2-10
	High	6.31	2.140	2-11
	Total	4.05	2.370	2-11
Strategy Games Skill	Low	2.07	0.365	2-4
	Medium	2.76	0.988	2-5
	High	4.86	2.532	2-12
	Total	3.22	1.960	2-12
Puzzle Games Skill	Low	2.43	0.626	2-4
	Medium	3.52	1.326	2-6
	High	5.52	2.309	2-11
	Total	3.81	2.02	2-11
Total Gaming Skill	Low	13.27	1.143	12-15
	Medium	18.83	2.633	16-24
	High	31.66	5.627	25-43
	Total	21.16	8.540	12-43
Digit Span Forward Recall	Low	16.13	2.849	8-20
	Medium	16.07	2.685	9-20
	High	16.79	2.411	11-20
	Total	16.33	2.650	8-20
Digit Span Backward Recall	Low	13.97	3.429	9-19
	Medium	15.00	3.082	8-20
	High	15.69	3.486	3-20
	Total	14.88	3.380	3-20
Corsi Block Forward Recall	Low	7.23	2.687	3-13
	Medium	7.86	3.020	2-14
	High	9.90	3.745	2-17
	Total	8.32	3.340	2-17
Corsi Block Backward Recall	Low	6.97	2.632	3-11
	Medium	7.90	3.457	3-13
	High	9.55	3.709	2-16
	Total	8.13	3.430	2-16
Deary-Liewald Single Reaction Time	Low	282.60	46.154	231-462
	Medium	286.07	57.681	207-462

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	High	255.59	27.800	195-303
	Total	274.84	47.070	195-462
Deary-Liewald Choice Reaction Time	Low	470.03	119.097	331-804
	Medium	433.55	69.300	296-641
	High	395.21	48.565	310-521
	Total	433.35	89.340	296-804
Empathy Quotient	Low	44.57	9.134	18-62
	Medium	42.86	12.397	18-66
	High	40.55	12.126	22-63
	Total	42.68	11.280	18-66

FPS = First-Person Shooting; RPG = Role Playing Games.

Comparing the three levels of gaming skill, namely Low, Medium, and High, it is evident that higher gaming skill individuals tend to be older, with the mean age of the participants increasing along with the increase in gaming skill. Regarding education level, those with medium gaming skills exhibited the highest, followed by those with low and finally those with high gaming skills. In all genres of games, specific skills increased together with the general gaming skill level increase. In both Forward and Backward iterations in both DST and CBT, the higher the gaming skill level, the better the score. In DLSRT, the reaction time was the lowest in the high gaming level group but worst in the medium gaming level group. In DLCRT, the higher the gaming level, the lower the reaction time. Finally, in the EQ, the higher the gaming level, the lower the EQ score.

3.1. Correlations

Pearson's correlations are reported in Table 2. Starting with the demographic factors, Age seems to be significantly but weakly positively correlated with the scores in both CBT forward and backward as well as significantly weakly negatively correlated with the EQ score. Education on the other hand, resulted in no significant correlations with any of the 7 tests.

Regarding Gaming Skills, the Sports one was significantly weakly positively correlated only with the DST Backward. FPS gaming skill was significantly weakly positively correlated with both CBT forward and backward, and significantly weakly negatively correlated with both Simple and Choice iterations of the DLRTT. RPGS too was significantly weakly positively correlated with both Forward and Backward iterations of the CBT, but also significantly weakly negatively correlated with the scores of the EQ Questionnaire. AGS was significantly weakly positively correlated with the scores of DLSRT and DLCRT tasks. StGS only resulted in a significantly weak positive correlation with the Forward variant of the CBT. PGS was significantly weakly positively correlated only with the two iterations of the CBT, forward and backward. Finally, TGS was significantly weakly positively correlated with almost all of the tests, specifically DST Forward, CBT Forward and Backward, DLSRT, and DLCRT, with only the Forward variant of DST and the EQ Questionnaire not achieving significance.

Table 2. Pearson's r Correlations: Cognitive Performance, Empathy, Demographics, and Gaming Skills.

	DST-FR	**DST-BR**	**CBT-FR**	**CBT-BR**	**DLSRT**	**DLCRT**	**EQ**
Age	.08	.20	.30**	-.27*	.14	.13	-.24*
Education	-.06	-.03	-.18	-.14	.09	.16	-.07
SpGS	.04	.25*	.13	.18	-.17	-.18	-.08
FPSGS	-.02	.11	.25*	.23*	-.27*	-.23*	-.21
RPGS	.17	.35*	.35*	.27*	-.10	-.16	-.26*
AGS	.07	.13	.10	.12	-.39***	-.32**	-.12
StGS	.03	-.01	.34*	.18	-.12	-.03	-.21
PGS	.20	.10	.25*	.28**	-.18	-.21	-.08
TGS	.13	.22*	.29**	.27*	-.26*	-.24*	-.20

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DST = Digit Span Test; CBT = Corsi Blocks Test; FR = Forward Recall; BR = Backward Recall; DL = Deary-Liewald; SRT = Single Reaction Time; CRT = Choice Reaction Time; EQ = Empathy Quotient; SpGS = Sport Games Skill; FPSGS = First-Person Shooting Games Skill; RPGS = Role Playing Games Skill; AGS = Action-Adventure Games Skill; StGS = Strategy Games Skill; PGS = Puzzle Games Skill; TGS = Total Gaming Skills. * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

3.2. Regressions

Table 3 depicts the Best Regression Models for each of the 7 tests that were performed. Digit Span Test Forward has a null model indicated as best, ergo no factor was predictive of the DST Forward performance.

The best regression model for Digit Span Test Backward had an R^2 of .12, indicating a weak relationship between the Verbal Working Memory of the participants and the sole predictor of the model, namely RPGS. Specifically, the latter has a beta coefficient of .35, postulating that an increase in RPGS leads to a moderate improvement of Verbal Working Memory.

Corsi Blocks Test Forward's model achieved an R^2 of .20, indicating a moderate relation of Visuospatial Short-Term Memory and the predictors of the model, which are Age and RPGS. RPGS was the strongest predictor with a beta coefficient of .32, which indicates that an increase in RPGS leads to a moderate improvement in Visuospatial Short-Term Memory. Age had a beta coefficient of .24, and thus increased age leads to moderately better results in CBT Forward.

The best regression model of CBT Backward achieved an R^2 of .19, which means that Visuospatial Working Memory is weakly related to the Age and PGS, the predictors of the model. PGS is the strongest predictive factor of the two, with a beta coefficient of .25, indicating that an increase in PGS leads to a moderately better CBT Backward score. Age resulted in a beta coefficient of .23, pointing to the fact that older age leads to moderately better visuospatial working memory.

DLSRT's best regression model had an R^2 of .16, indicating that Psychomotor speed and AGS, the predictor, are weakly related. The sole predictor of the model, AGS, had a beta coefficient of -.39. Keeping in mind that the Deary-Liewald test scores are in the form of reaction times, and thus a lower score is deemed better, an increase in AGS leads to a moderate decrease of the DLSRT.

The best regression model for the DLCRT, like the one of DLSRT, had AGS as its sole predictor. Its R^2 equaled .10 and thus indicates that DLCRT and AGS are weakly related. The beta coefficient of AGS in this regression model was -.32, which indicates that an increase in AGS leads to a moderate decrease of the DLCRT, and thus a moderate increase in attention speed.

EQ's best regression model achieved an R^2 of .07, postulating a weak relationship between Empathy and RPGS, the sole predictor of the model. The beta coefficient of RPGS was -.26, which indicates that an increase in RPGS leads to a moderate decrease in Empathy.

Table 3. Best Regression Models for Predicting Cognitive Performance and Empathy.

Predicted	Predictors	β coefficient	p-value(β)	R^2
Digit Span Forward Recall	Null Model	-	-	-
Digit Span Backward Recall	Role-Playing Games Skills	.35	.004*	.12
Corsi Blocks Forward Recall	Age	.24	.022*	.20
	Role-Playing Games Skills	.32	.003**	
Corsi Blocks Backward Recall	Age	.23	.028*	.19
	Puzzle Games Skills	.25	.018*	
Deary-Liewald Single Reaction Time	Action Games Skills	-.39	.001***	.16
Deary-Liewald Choice Reaction Time	Action Games Skills	-.32	.008**	.10
Empathy Quotient	Role-Playing Games Skills	-.26	.014*	.07

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

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3.3. ANOVA

The ANOVA analyses were performed to examine the differences among the levels of gaming skills in terms of cognitive performance in 6 different domains and empathy. For this reason, participants were divided into three groups, based on their gaming skills. The low group included 30 participants, the middle group and the high group included 29 participants each. The descriptive statistics are presented in Table 1.

The ANOVA uncovered no significant small sized effect of gaming skill level on the verbal short-term memory of the participants [$F(2,85) = 0.69$, $p = .507$, $\eta^2_p = .02$], as well as on their verbal working memory [$F(2,85) = 2.04$, $p = .136$, $\eta^2_p = .05$], as they were measured by DST Forward and Backward respectively. These findings are visualized in Figure 1, and they indicate that gaming skill level does not significantly impact either the verbal short-term memory or the verbal working memory of adults.

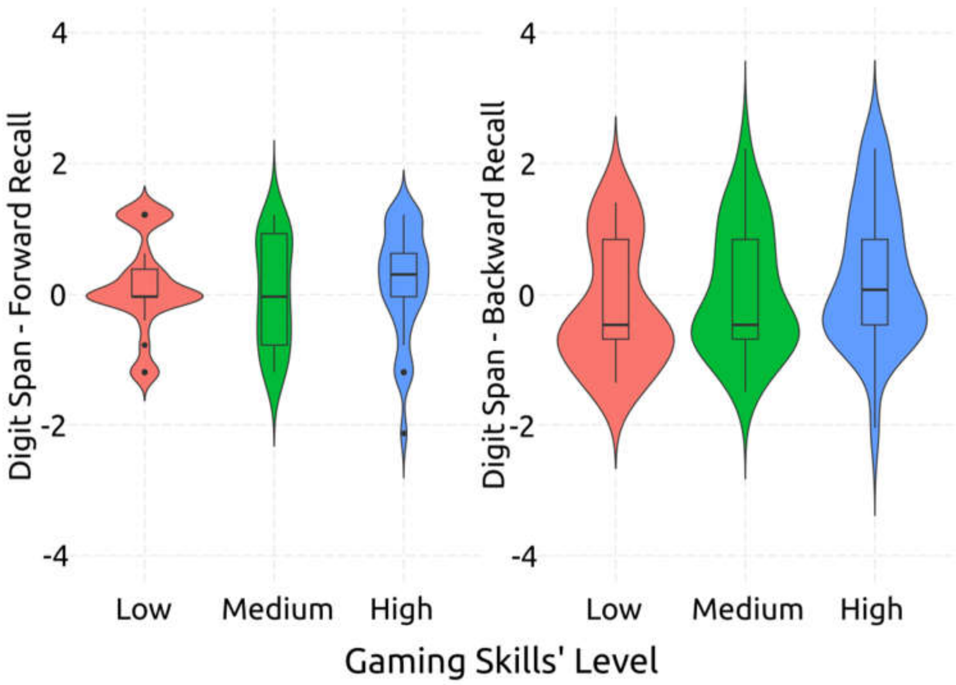

Figure 1. Post-Hoc Comparisons: Performance on Digit Span Tasks per Gaming Level.

Conversely, Visuospatial Memory performance was significantly affected by Gaming Skill Level. Specifically for Visuospatial Short-term Memory, as measured by CBT-Forward, the effect of Gaming skill level was significant and medium-sized [$F(2,85) = 4.99$, $p = .009$, $\eta^2_p = .10$]. Visuospatial Working Memory, measured by CBT Backward, was affected accordingly by Gaming Skill Level, with a significant medium-sized effect [$F(2,85) = 4.08$, $p = .020$, $\eta^2_p = .09$]. The post-hoc comparisons, which are visually presented in Figure 2, reveal that there is a medium effect size when comparing High Gaming Skill Level individuals to Low Gaming Skill Level ones, with the former having substantially better visuospatial short-term memory than the latter ones [$d = .78$, $p = .009$]. The same finding was uncovered in the case of visuospatial working memory [$d = .73$, $p = .017$]. Of interest was the fact that there was a marginally insignificant medium-sized effect between Medium and High gaming skills' level on the performance in the visuospatial short-term memory task [$d = .57$, $p = .070$].

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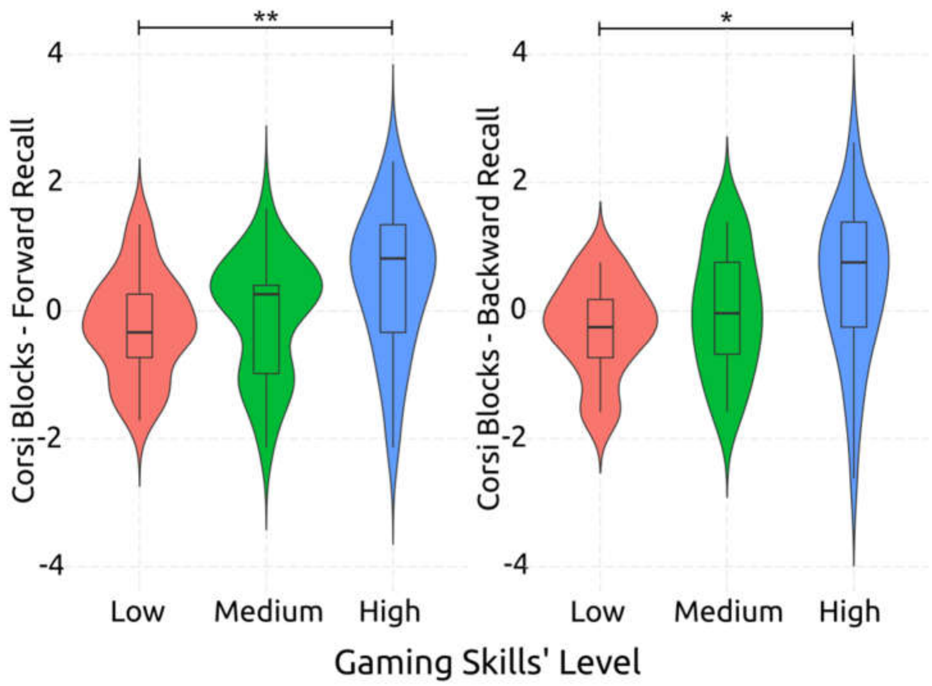

Figure 2. Post-Hoc Comparisons: Performance on Corsi Block Tasks per Gaming Level.

Psychomotor skills seem to also be significantly affected by the gaming skills' level of individuals. Specifically for Motor speed, measured by DLSRTT, the effect of gaming skills level was significant and medium sized [$F(2,85) = 4.36$, $p = .016$, $\eta^2_p = .09$], and the same held true for the case of Attentional Speed, as measured by DLCRTT [$F(2,85) = 3.10$, $p = .049$, $\eta^2_p = .07$]. The post-hoc comparisons, visualized in Figure 3, unveil that, for the case of motor speed, individuals with high gaming skill are faster than those with medium gaming skills, a moderately sized significant effect [$d = .62$, $p = .048$] as well as than those with low gaming skills, an effect that is also significant and moderately sized [$d = .73$, $p = .028$]. Furthermore, the attentional processing speed of the participants with high gaming skill level was faster than those with low gaming skill level, this effect also being significant and medium sized [$d = .47$, $p = .047$].

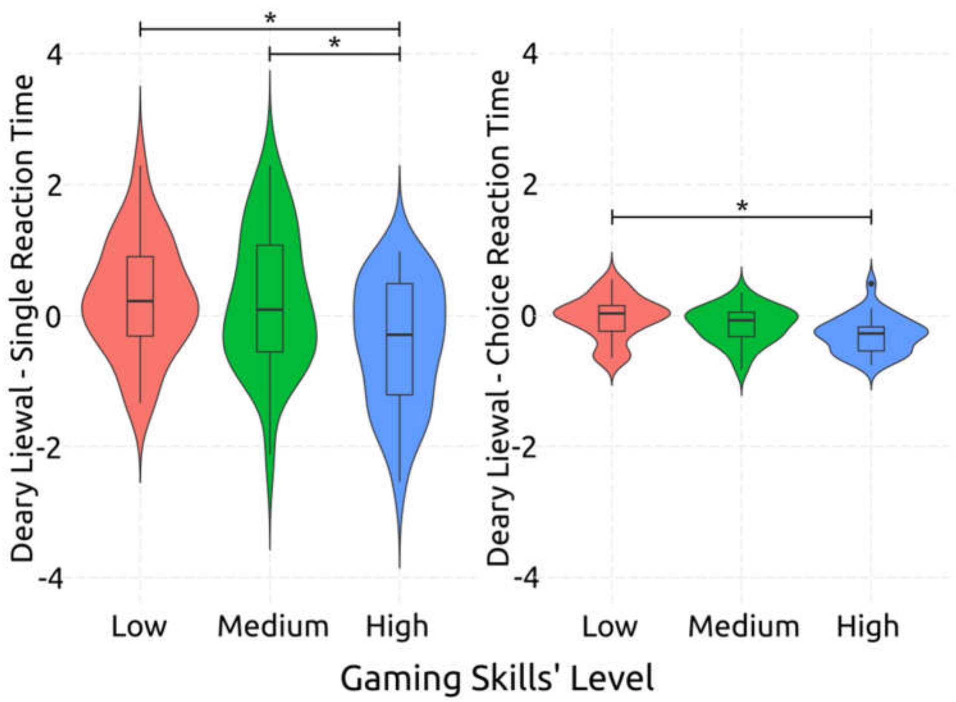

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Figure 3. Post-Hoc Comparisons: Performance on Deary Liewald Reaction Time Tasks per Gaming Level.

Finally, regarding Empathy, ANOVA analysis did not uncover any significant effect of gaming skill level on it [$F(2,85) = 0.92$, $p = .404$, $\eta^2_p = .02$]. It has to be noted that there was a decreasing trend, inversely related to gaming skill level, hinted in Figure 4, but not reaching significance.

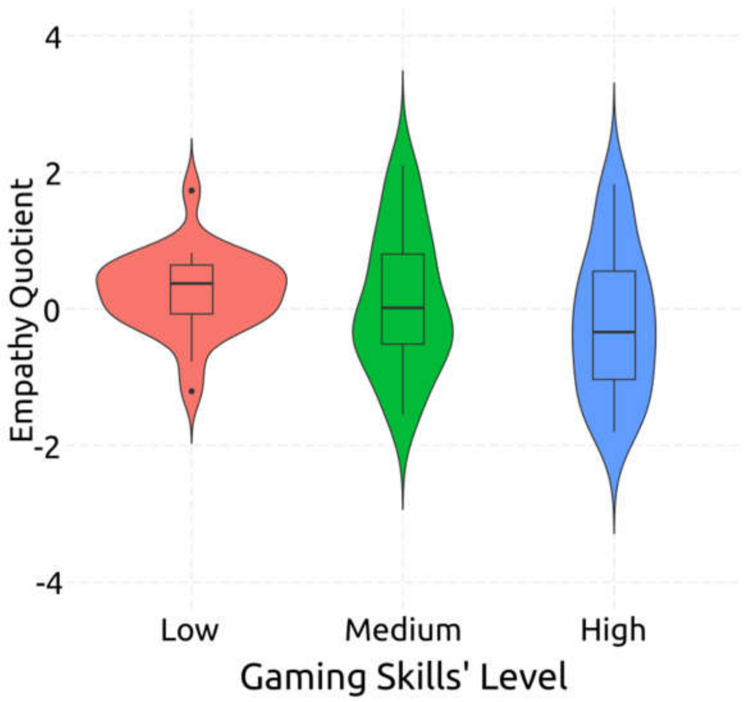

Figure 4. Post-Hoc Comparisons: Performance on Empathy Quotient Questionnaire per Gaming Level.

4. Discussion

This study aimed to investigate the impact of video game engagement on cognitive functions and empathy. Specifically, it focused on investigating the effects of gaming skills across six different gaming genres and gaming generally on six cognitive abilities and on empathy. These cognitive abilities included verbal short-term memory, verbal working memory, visuospatial short-term memory, visuospatial working memory, psychomotor skill, and attentional speed. These were assessed, in order, by the Digit Span Test Forward, Digit Span Test Backward, Corsi Block Test Forward, Corsi Block Test Backward, Deary-Liewald Simple Reaction Time Task, and Deary-Liewald Choice Reaction Time Task. Empathy was quantified using the Empathy Quotient Questionnaire, while gaming skills were identified using the Gaming Skills Questionnaire. Key findings from this study indicate that High Gaming Skills were consistently associated with better visuospatial memory, both short – term and working, and faster psychomotor and attentional speed. Especially for psychomotor speed, High Gaming Skill resulted in faster response times than both Low and Medium Gaming Skill levels.

4.1. The Effect of Gaming Skill Level on Cognitive Functions and Empathy

4.1.1. Verbal Short-Term Memory

Verbal Short-Term Memory measured by the Forward variant of the Digit Span Test, was examined. The ANOVA results were non-significant suggesting that verbal short-term memory is not affected by gaming skill levels. At the same time, the best regression model for the DST Forward

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was the null. Combined, these two results show that none of the predictive factors included in our study had any effect on the Verbal Short-Term Memory of individuals. There is a lack of consensus on how videogame play affects verbal short-term memory in literature, with some studies claiming it is beneficial [53,79] while others claim it is detrimental [80]. In addition, some found no effect of videogame play on Verbal Short-Term Memory [81]. The above stated outcomes of ANOVA and regression analysis are accompanied by the results of correlation analysis, where no factors reached any significance for the DST Forward.

4.1.2. Verbal Working Memory

Similar to verbal short memory, the ANOVA performed on the scores of DST Backward revealed no significant difference between the 3 different levels of gaming skill, low, medium, and high. This outcome is in-line with the results of the ANOVA on the DST Forward, as well as with the lack of consensus in literature, with different studies reaching different conclusions [53,79–81]. In contrast with the DST Forward, the best regression model produced for the DST Backward wasn't the null but had RPGS as its sole predictor. In support of this finding, prior research suggests a positive relationship between increased videogame play and improved verbal working memory. It is also in line with literature on RPGs which supports the same results for this specific gaming genre [53,68]. Finally, the only correlations regarding DST Backward that reached significance were those with SpGS, RPGS, and TGS, suggesting a potential link between these specific gaming genres and verbal working memory.

4.1.3. Visuospatial Short-Term Memory

This study measured the Visuospatial Short-Term Memory using the Corsi Block Test – Forward. The ANOVA analysis revealed that there was a significant difference between high and low gaming skill levels, with high skill gamers performing better. This finding is consistent with the relevant literature which claims that visuospatial short-term memory benefits from videogame play [79,92,115–117]. Furthermore, this finding is reinforced by the best regression model with Age and RPGS as the two predictors. RPGs are one of the genres which seem to improve one's visuospatial memory skills, as well as perception skills in general, and thus the inclusion of RPGS as a predictor of CBT Forward is warranted [68,118]. Age and visuospatial short-term memory seem to have an inverse relationship after one's mid-20s [84,119]. Finally, the CBT Forward was significantly correlated with Age, FPSGS, RPGS, StGS, and TGS suggesting that a wide array of videogame gernes, along with age, significantly influence one's visuospatial short-term memory.

4.1.4. Visuospatial Working Memory

The ANOVA conducted on CBT Backward, which was used to measure Visuospatial Working Memory, revealed that high-level gaming skills result in significantly better Visuospatial Working Memory than low-level gaming skills. This is in line with most of the literature, which claims that visuospatial working memory benefits from regular videogame play [51,53,120–123]. The ANOVA findings are further reinforced by the best regression model produced, the two predictors of which were PGS and Age. Puzzle games seem to contribute to one's Visuospatial Working Memory, which is possibly due to the nature of these games, which are taxing on the visuospatial domain [68,93,118]. Increasing age seems to improve the Visuospatial Working Memory, something that is in contrast with literature that claims that cognitive decline begins at around the age of 24 [84,119]. Finally, the CBT Backward was significantly correlated with age and a variety of videogame skills which included FPSGS, RPGS PGS, and TGS suggesting that playing these genres, along with gaming skills in general, significantly influence one's visuospatial working memory. All three of these genres, namely FPS games, Role-Playing games, and puzzle games have been correlated with improvements in one's visuospatial working memory [93,118].

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4.1.5. Psychomotor Speed

The Deary-Liewald Simple Reaction Time Task was employed in this study to measure one's Psychomotor Speed. The results of the ANOVA on DLSRTT were of interest, as high gaming skill level individuals showed better psychomotor speed than both medium-level and low-level participants. As psychomotor speed is essentially hand-eye coordination, there is a plethora of studies advocating that gaming is leading to improvements in that area of cognition [52,72,73,77,124]. Furthermore, the best regression model identified AGS as a predictor, reinforcing the role of action games in enhancing psychomotor skills [77,125,126]. Finally, the correlation analysis revealed that FPSGS, AGS, and TGS are significantly correlated with psychomotor speed, further supporting the ANOVA and regression analysis' outcomes.

4.1.6. Attentional Speed

Attentional Speed was quantified using the Deary-Liewald Choice Reaction Time Task. The ANOVA revealed that participants with high gaming skill level had a significantly faster attentional speed than those with how gaming skill level, consistent with literature. [62,72,126–130]. This finding is partially supported by the best regression model of the DLCRT, whereby AGS is the sole predictor, influencing the attentional speed positively. This is further supported by the notion that Action video games in particular have benefits for the players' attentional speed [61,63,131–133]. Finally, FPSGS, AGS, and TGS were significantly correlated with DLCRT, further supporting the findings of both ANOVA and the best regression model for Attentional Speed.

4.1.7. Empathy

The ANOVA of Empathy, as measured by the EQ Questionnaire, has revealed no significant association with the level of gaming skills of the participants. Our findings align with previous studies that report no significant association between gaming skill and empathy [29,38,42,44]. Despite that, it has to be noted that there was a, non-significant, decreasing trend when the level of videogame skill increased, hinting to a possibility that increases in gaming skill leads to less empathy, supporting a part of the literature that supports the notion that videogames have a negative effect on empathy [22,134–138].

The best regression model produced for empathy included only RPGS as a predictor, further supporting the notion that an increase in gaming skill, which includes experience and frequency of play, results in decreased empathy [22,134–138]. However, the type of game, in this case RPGs, disagrees with the body of literature which supports that role-playing games tend to increase the empathy of their players [39,43,46,139]. Finally, Empathy was significantly correlated with RPGS and Age, with an inverse relationship in both.

4.2. Limitations & Future Studies

The present study had some limitations. Firstly, the relatively small sample size might have limited the ability to detect significant correlations such as in empathy, as a non-significant tendency was found between gaming skill levels and empathy. Furthermore, he use of the convenience sampling method is possible to have led to a less diverse sample regarding their gaming habits, affecting the generalizability of the results. Finally, the lack of variability in gaming experience could have barred the study from obtaining more detailed effects gaming on cognitive functions and empathy.

Future research on the subject could certainly benefit from larger and more diverse samples, which would result in a broader representation of gaming experiences, and in turn would lead to more generalized results. Additionally, longitudinal studies could be insightful on the long – term effect of gaming on cognitive and affective domains, as well as investigation of the fluctuations in gaming skill levels over time. Moreover, comparison of different game types, both in genres but also as in content, could potentially yield interesting results regarding their effects on cognition. Furthermore, both the scientific community and the public could benefit from further research on the

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use of videogames as a cognitive training tool, aimed at bolstering specific cognitive domains of their players. Finally, experimental designs which implement videogames in controlled interventions could provide valuable data on the causality of the interactions uncovered.

5. Conclusions

The aim of the present study was to identify the effects of engagement in videogame play, a widespread source of entertainment, on cognitive domains and empathy. Some of the cognitive functions investigated in the current study, as well as Empathy, were not affected by the different levels of gaming skills of the participants, specifically Verbal Short-Term Memory and Verbal Working Memory. The other cognitive tasks, namely Visuospatial Short-Term and Working Memory, Psychomotor Speed, and Attentional Speed, were significantly improved in High-level gaming skill individuals when compared to Low-level gaming skill participants. In the case of Psychomotor Speed, High gaming skill level was superior in that domain than low and medium gaming skill level. Gaming skills in different genres appear to influence different cognitive domains, with RPGs positively influencing verbal working memory and visuospatial short-term memory, and negatively influencing empathy. Action-adventure games were beneficial for one's psychomotor speed, ergo hand-eye coordination, and attentional speed, while puzzle game play lead to improvements in visuospatial working memory. All in all, these findings contribute to the ever-growing literature regarding the effects of videogames on different areas of cognition as well as regarding the different influence of a variety of videogame genres. Further research is of course needed on the ever so popular domain of video games and the brain.

Supplementary Materials: The GSQ (English version) can be accessed here: http://dx.doi.org/10.13140/RG.2.2.27257.24160 accessed on 10 January 2024.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to ethical approval requirements.

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