CHAPTER 22.

GAMERS ARE LESS SUSCEPTIBLE TO A COGNITIVELY FATIGUING TASK COMPARED TO AGE-MATCHED CONTROLS

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ABSTRACT

Previous work shows that esports (particularly action video games; AVGs) place high demand on a number of cognitive abilities. Further work has demonstrated that this use of cognitive function manifests in the ability of AVGs to outperform non-gamer controls on a number of cognitive tests. With the large demand on cognitive resources over what can be long periods of time (i.e. over 2 hours) during gaming, we hypothesized that AVGs may have greater resistance to the effects of cognitive fatigue. To test this, we recruited a group of AVGs and Non-Gamers and randomly allocated them to a cognitive fatigue group or control group. Our results show that AVGs who underwent the cognitive fatigue intervention actually improved their performance on the cognitive tests more than AVGs in the control condition and NGs in both the control and cognitive fatigue conditions.

Introduction

Electronic sports, or esports, are sporting activities where individuals develop and train mental and physical abilities through the use of computing technologies (Wagner, 2006). Participation in esports has grown exponentially over the past decade and psychologists have recognized the potential positive impact of action video games on cognitive ability (Campbell, Toth, Moran, Kowal & Exton, 2018). For example, previous work has shown that individuals who play action video games display superior visuospatial attention under divided attention, superior attention allocation, and greater short-term memory capacity (Green & Bavelier, 2003), as well as enhanced processing speed and cognitive inhibitory ability (Kowal, Toth, Exton & Campbell, 2018).

Like any sport, in order to achieve a high level in esports, gamers must devote many hours on their PC to hone their skills. However, with the level of ease one can practice and play esports compared to many traditional sports (i.e. as simple as turning on a computer in the home and playing), it is very common for action video gamers (AVGs) to report gaming for more than 30 hours per week with some individuals reporting 80 hours allocated to gaming per week (Griffiths, Davies & Chappell, 2004). This prolonged period during which cognitive resources are taxed may increase cognitive load and fatigue, which has previously been shown to hinder cognitive performance (Boksem, Meijman & Lorist, 2005).

With this in mind, the question of whether AVGs are as susceptible to cognitive fatigue as NGs, or whether AVGs possess superior resistance to mental fatigue comes to the forefront. If AVGs are equally susceptible, it may be that new training and gaming practice regimens be implemented to control gaming time to maximize performance. This study aims to evaluate whether AVGs are more susceptible to cognitive fatigue compared to NGs. We hypothesize that AVGs will show similar decrements in cognitive test performance following a mental fatigue protocol to NGs.

Methods

Twenty-five male participants (N=25) (22.01; ± 2.95 years; Mean ± SD) from the University of Limerick student population with no history of neurological disorder provided informed consent prior to voluntarily participating in the study. The university's research ethics board authorized approval for the study in accordance with the Declaration of Helsinki.

Participants first completed a survey that gathered demographic information regarding their age, sex, handedness and color vision. It also gathered data regarding their gameplay; including the type of game genre they play the most (e.g. first person shooter games, massive online battle arena games etc.) and the average number of hours per week they estimated they spent on the game genre they played the most. Participants were then placed into an action video gamer group (AVG) if they reported playing more than 7 hours of action video games per week and a non-gamer group (NG) if they reported playing less than 1 hour of video games per week (Kowal et al., 2018).

Protocol

Following this initial survey, participants also completed the Brunel Mood Scale (BRUMS) questionnaire (Terry, Lane, Lane & Keohane, 1999) in order to quantify their current mood state prior to the start of testing. Following this, each participant sat in front of a 24 inch monitor with a consistent monitor refresh rate (144 Hz) and screen resolution (1920×1080), and completed 2 baseline tests of working memory using Inquisit 5.0 software by Millisecond; the corsi-block tapping task (visual and working memory; Kessels et al., 2000) and the Groton Maze task (immediate and short term visuospatial memory; Schroder, Snyder, Sielski & Mayes, 2004).

Corsi Block-Tapping Task

During this task, participants were presented with a screen of 9 boxes randomly allocated on a computer screen (Figure 1A). The boxes lit up in a pre-fixed sequence that was constant across participants. Participants were instructed to use the mouse to click on the boxes in the same order that they were lit. The sequence started at level 2 (2 boxes) and could increase up to level 9. Participants had two opportunities (2 trials) to respond to each sequence length and were able to move on to the next sequence as long as at least one of the two trials were responded to correctly.

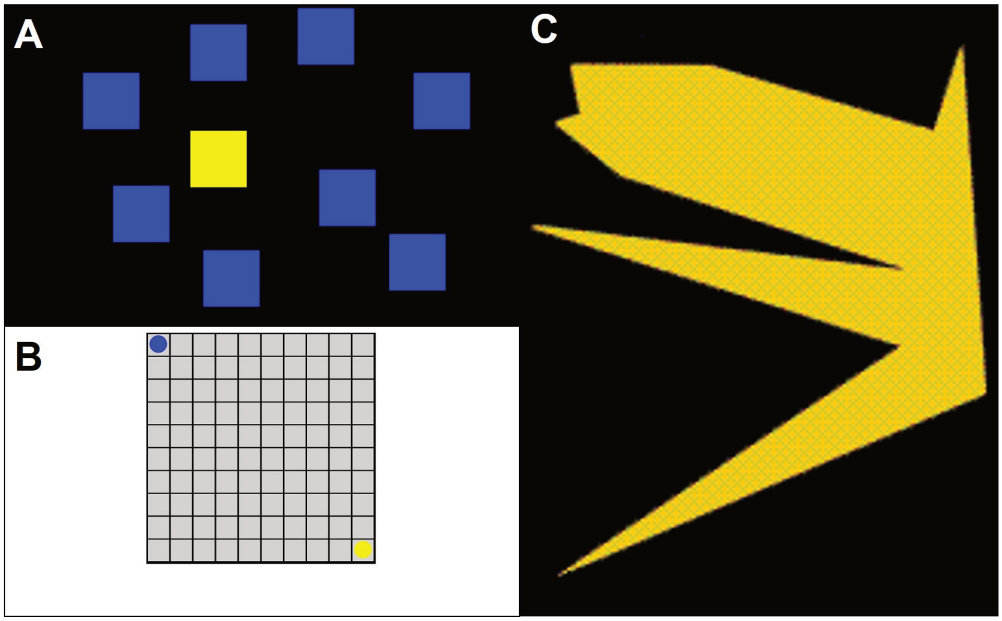


Figure 1: Layout of the Corsi Block-Tapping (A) and Groton Maze tasks (B) as well as one of the 8 sample shapes used during the N-Back task (C).

Groton Maze Task

Participants are presented a blank 10×10 grid and were asked to trace a hidden pathway by clicking on squares starting from the top left square to the bottom right square on the grid (Figure 1B). Participants could only move left, right, up, or down by one move at a time on the grid. After each move the computer indicated if the move was correct. If the choice was incorrect, the participant was required to touch the previous correct tile and then choose a different tile to continue. By default, the pathway always included 28 total moves (not including the start square) and 11 corners. Participants were presented with the same hidden maze six times.

Upon completion of the baseline tests, each participant was randomly allocated to either an active or control intervention group. Those individuals in the active group performed a spatial N-back test for 25 minutes. The N-back task is a difficult working memory task previously validated as a sufficient tool to induce cognitive fatigue (Tanaka, Ishii & Watanabe, 2015). Twenty-five minutes was chosen based on pilot work to be a sufficient amount of time to create mental fatigue in participants and because it temporally aligned well with Tanaka and colleagues who showed strong evidence of cognitive fatigue after 30 minutes. Participants in the control group were provided a neutral documentary video on irish railways to watch for the same amount of time (25 minutes).

N-Back Task

During the n-back one out of a set of 8 yellow irregular shapes appeared continuously on a black computer screen every 3 seconds (Figure 1C). Participants were instructed to mentally note the shapes and hold them in their memory so as to identify if the current shape was the same as the one 1, 2 or 3 shapes back by pressing “A” on the keypad. If the shape was different, they did nothing. The test consisted of a 5 minute bout of practice consisting of one block each of 1-back, 2-back and 3-back stimuli followed by a 20 minute testing phase. In the testing phase, participants completed 6 blocks of 21 shapes; 2 blocks of 1-back, 2-back and 3-back, respectively. Participants were encouraged to maintain their focus during the entire task and to do as well as they could. They were also told that if they forgot previous shapes that, rather than giving up, they could start their memory process at any shape so as to continue their performance on the task.

Following the completion of the Control or Cognitive Fatigue interventions, participants the BRUMS questionnaire a second time followed by Post tests of the Corsi-block and Groton Maze tasks

Data Processing

Basline and Post scores were calculated separately for the BRUMs questionnaire, Corsi-Block Tapping and Groton Maze tasks. BRUMS Baseline and Post test scoring was performed according to (ref). Metrics for the Corsi-Block Tapping and Groton Maze tasks are outlined below.

Corsi Block-Tapping Task

The average latency to tap each block was calculated as the difference between the time of clicking on a box and the time at which the previous box was clicked. Memory capacity score was recorded as the highest number sequence successfully completed by a participant. In order to differentiate participants who may have achieved the same memory capactiy score by either responding to both trials correctly or one of the two trials of a sequence correctly, we also calculated the product of the memory capactiy and total number of trials correctly responded to (Total Score).

Groton Maze Task

The time taken to complete (TTC) the Groton Maze was calculated for each of the 6 Mazes in the Baseline and Post tests as the elapsed time from clicking on the first square to clicking on the last square in the grid. The total number of moves (Total Moves) is the sum of all correct and incorrect moves taken per Maze trial. Finally, we calculated the correct moves per second (CMS) as the number of correct moves (by default, 28) divided by the total time (in seconds) to complete the Maze.

N-Back Task

The number of hits, false alarms, correct rejections and misses were recorded. From these data, we calculated the average number of hits, average sensitivity (d') and decision criterion (c) for each block of n-back.

Statistical Analyses

Statistical analyses were performed using IBM SPSS Statistics v.25.0 software. After removing outliers (data points exceeding 1.5 times the inter quartile range) the Shapiro-Wilk test statistic and observation of the histogram plots verified the normality of the dependent variables. Two way (Gamer Type x Intervention) ANCOVAs were used to test for differences between groups for each Post test dependent variable, while controlling for respective baseline test performance for the BRUMS questionnaire and Corsi Block Tapping task (i.e. baseline scores were input as a covariate in the model). A three-way (Gamer Type x Intervention x Maze trial) ANCOVAs were used to test for differences between groups for each Post test dependent variable, while controlling for respective baseline test performance for the BRUMS questionnaire Where multiple post hoc comparisons were performed, the Holm-Sidak p-value adjustment was used. Effect sizes are reported using η2 and results are reported as means ± SE with a significance alpha level of $p<0.05$.

Results

12 AVGs and 13 NGs were allocated to either the Control (6 AVGs; 7 NGs) or Cognitive Fatigue (6 AVGs; 6 NGs) intervention. AVGs and NGs who completed the N-back cognitive fatigue task did not differ in their performance when comparing sensitivity (d') and decision criterion values. (Figure 2).

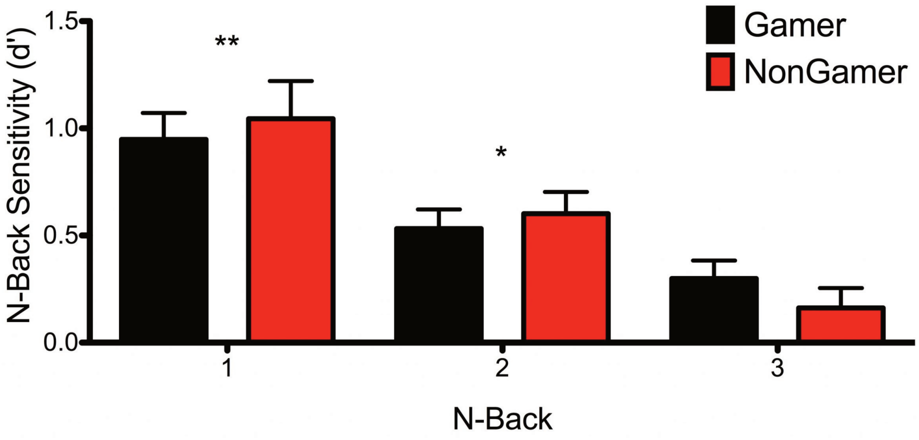


*Figure 2: Sensitivity scores (d') for action video gamers (AVGs; black bars) and Non Gamers (red bars) on 2, 3 and 4-back tasks. ** and * represent significantly different d' scores between 2, 3 and 4 back tasks. Error bars indicate SE.*

A significant interaction effect was found for BRUMS fatigue scores after controlling for baseline scores (F(1,20)=9.233, p=0.006, η2=0.316). Post hoc comparisons revealed that NGs were significantly more fatigued following the N-back task compared to NGs who watched a video for a similar time period (p=0.015, η2=0.262) and also that AVGs who performed the N-back task were the least fatigued of all the groups (Figure 3).

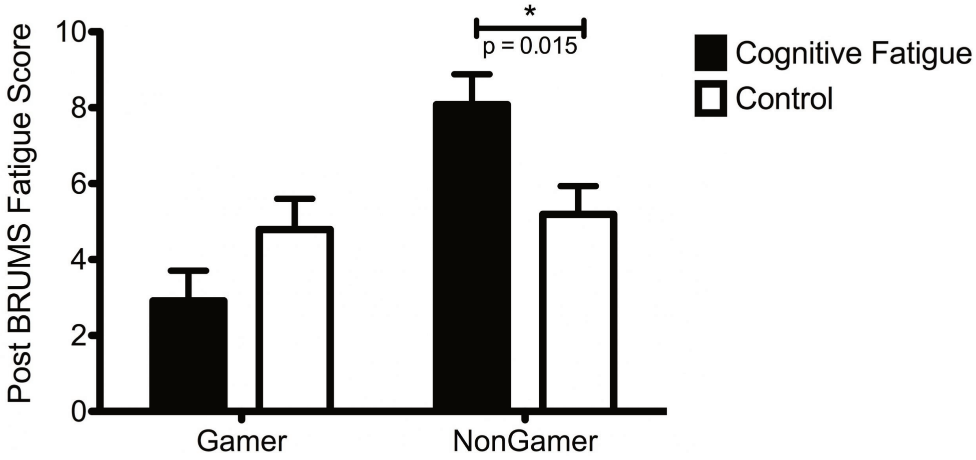
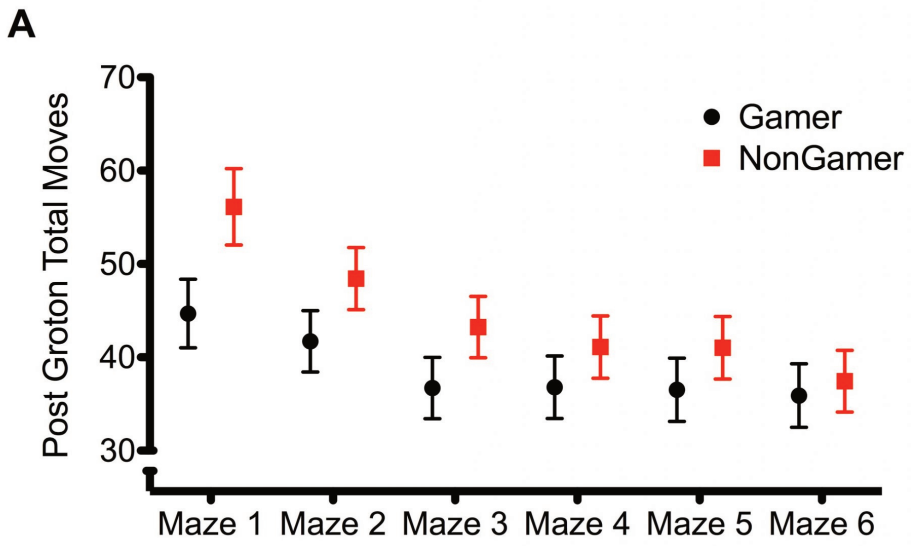
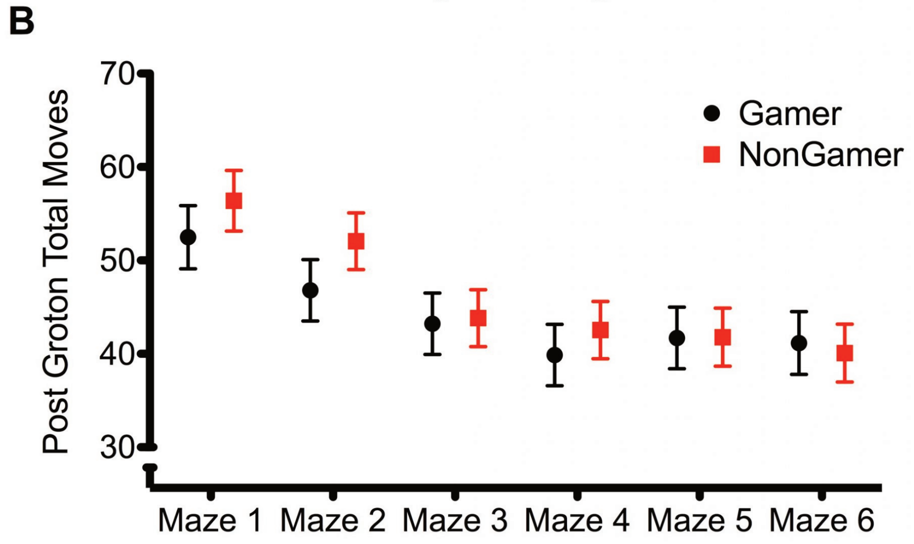


Figure 3: BRUMs fatigue scores for both AVGs and NonGamers who engaged in the cognitive fatigue (N-Back; black bars) or Control (Video; white bars) interventions. Error bars indicate SE.

Upon evaluating the total moves required to complete the Groton Maze task, we found significant main effects were observed for Gamer Type ($F(1,125)=8.569$, $p=0.004$, $\eta2=0.064$) intervention ($F(1,125)=7.076$, $p=0.009$, $\eta2=0.054$) and Maze trial ($F(5,125)=5.411$, $p<0.001$, $\eta2=0.178$) after controlling for baseline scores. Data show that AVGs overall took fewer moves to complete the Groton Mazes and that participants who completed the N-back task took fewer moves compared to participants who watched the video (Figure 4).



Cognitive Fatigue



Control

Figure 4: Total number of moves required by AVGs (Black circles) and Non-Gamers (red squares) across Groton Maze trials after either a cognitive fatigue (N-back; A) or Control (Video; B) intervention. Error bars indicate SE.

Similarly, we also found significant Gamer Type (F(1,125)=12.364, p=0.001, η2=0.090), intervention (F(1,125)=10.398, p=0.002, η2=0.077) and Maze trial (F(5,125)=2.382, p=0.042, η2=0.087) effects for Post CMS after controlling for baseline scores. Post hoc comparisons showed that AVGs made significantly more CMS compared to NGs and participants who performed the N-back task had significantly more CMS compared to those who watched the control video (Figure 5).

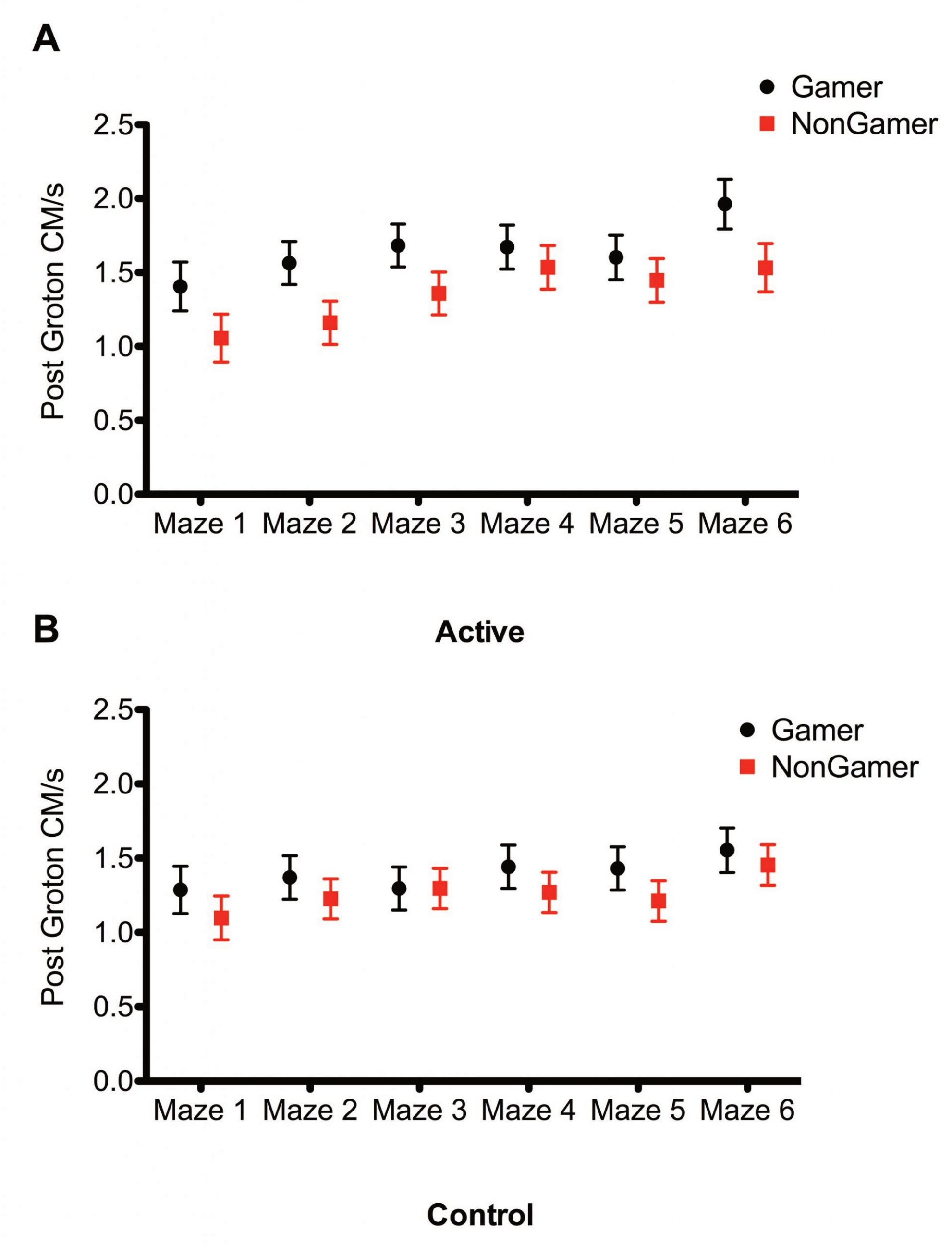


Figure 5: Correct Moves per second by AVGs (Black circles) and Non-Gamers (red squares) across Groton Maze trials after either a cognitive fatigue (N-back; A) or Control (Video; B) intervention. Error bars indicate SE.

When analyzing participants' performance on the Corsi Block-Tapping task, we found a significant Gamer Type by intervention interaction effect for participants' average latency (F(1,20)=5.601, p=0.028, η2=0.219) after controlling for baseline scores. Post hoc analyses revealed that AVGs who performed the N-Back task were responded to the corsi block task significantly faster than those who watched the video, whereas NGs who performed the N-Back task were significantly slower than NGs in the Control intervention group (Figure XXXXX). No main or interaction effects were found for either Memory Capacity or Total Score indices.

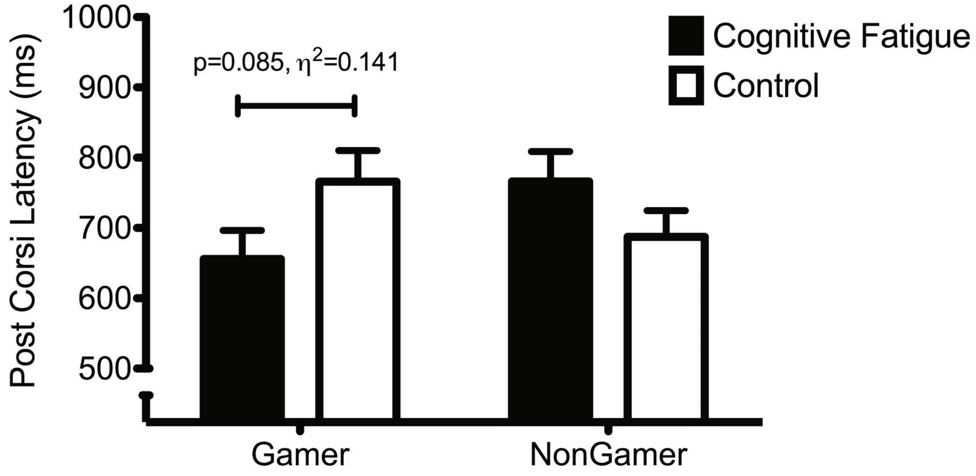


Figure 6: Average latency scores during Corsi Block-Tapping performance by AVGs and NonGamers who engaged in the cognitive fatigue (N-Back; black bars) or Control (Video; white bars) interventions. Error bars indicate SE.

Discussion

This study aimed to evaluate whether action video gamers were less susceptible to the effects of a cognitively fatiguing task compared to non-gamers. Contrary to our hypothesis, we found that AVGs who engaged in a cognitively fatiguing task for 25 minutes, were actually less fatigued based on their BRUMs fatigue scores compared to AVGs who passively watched a video for the same amount of time (Figure 3). Alternatively, non-gamers reported being significantly more fatigued after the cognitive fatigue task than when they passively watched the provided video. As a result, AVGs performed better after the cognitive fatigue intervention compared to the control intervention whereas non-gamers performed more poorly. This was evidenced by Gamers after the cognitive fatigue intervention who recalled items more readily with no decrement in total memory capacity (Figure 6) and who also completed the Groton Maze task more efficiently across trials (Figures 4 & 5).

N-Back as a Cognitive Fatigue Tool

Previous work has demonstrated the N-Back task to be a sufficiently difficult task requiring sustained attention and tasking working memory for a long duration. Tanaka and colleagues (2015) demonstrate that following 30 minutes of a N-back task, participants report being significantly mentally fatigued via a visual analog scale and their MRI shows significant event-related desynchonization of the alpha frequency band in the visual cortex. Previous work by Tanaka has also demonstrated that cognitive fatigue induced by the N-back task hinders selective attention (Tanaka et al., 2012) and reduces alpha power in the occipital and parietal cortices as well as theta power over region Cz (Tanaka, Shigihara, Funakura, Kanai & Watanabe, 2012). This aligns well with work by Trammell and colleagues (Trammell, MacRae, Davis, Bergstedt & Anderson, 2017), who demonstrate that for younger adults, an increased theta-alpha ratio over Cz is associated with improved short-term memory performance. That Tanaka and colleagues see a reduction in theta power over Cz, may suggest that the cognitive fatigue effects of the N-back predominantly affect memory processes.

In the current study, non-gamers performed more poorly on the Corsi Block-Tapping task and Groton Maze task following the N-back intervention. Alternatively, AVGs' performance improved following the same intervention. The Groton maze task and Corsi Block-Tapping tasks test visuo-spatial working memory (Thomas et al., 2008; Furley & Memmert, 2010), which is a key cognitive ability displayed during action video gaming. For example, Colzato, van den Wildenberg, Zmigrod and Hommel (2013) found that playing first person shooter action video games is associated with spatial working memory but not action inhibition performance. Moreover, West's group (West et al., 2018) recently discovered that AVGs who employ hippocampus-dependent spatial strategies during gaming show increased hippocampal and functionally associated entorhinal grey matter volume, and that controls who train on a 3D action video game can increase their spatial memory and grey matter volume in these regions as well. That AVGs' performance improves on these spatial working memory tasks following the N-Back intervention may be explained by the fact that the N-back task for AVGs serves as a kind of cognitive warm up.

A plethora of evidence exists that engaging in a cognitive task can improve subsequent cognitive test performance (Kesler et al, 2013; Foster, 2004; Wexler et al., 2016). Here, what may be a cognitively fatiguing task for Non-gamers, may serve as an ideal spatial working memory priming task for AVGs, especially since the N-back task chosen used abstract shapes as stimuli, which are 'stored' in similar brain regions as spatial (location) stimuli (Sanada et al., 2015). That cognitive priming may enhance subsequent cognitive performance in AVGs suggests that implementing a pre-gameplay cognitive warm-up regimen may enhance subsequent gaming performance, however this remains to be examined and we would encourage future work to examine whether priming other aspects of cognition improves subsequent performance on those abilities and whether the application of improved cognitive abilities through a warm-up during gameplay can improve overall gaming performance.

Overall, this study has demonstrated that AVGs are less susceptible to the effects of a cognitively fatiguing task on their subsequent cognitive performance compared to Non-gamers. Future work should expand on these findings and investigate not only the effect of priming other cognitive abilities, but also should work to determine the differential mechanisms behind such cognitive improvements and decrements which follow the same cognitive intervention in AVGs and NGs respectively.

REFERENCES

Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: an ERP study. *Cognitive brain research, 25*(1), 107-116.

Campbell, M. J., Toth, A. J., Moran, A. P., Kowal, M., & Exton, C. (2018). eSports: A new window on neurocognitive expertise?. *Progress in brain research, 240,* 161-174.

Foster, K. K. (2004). Warming up to learn: Using introductory questions to activate critical thinking. *Thinking Classroom, 5*(4), 38.

Furley, P. A., & Memmert, D. (2010). The role of working memory in sport. *International Review of Sport and Exercise Psychology, 3*(2), 171-194.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*(6939), 534.

Griffiths, M. D., Davies, M. N., & Chappell, D. (2004). Demographic factors and playing variables in online computer gaming. *CyberPsychology & behavior, 7*(4), 479-487.

Kesler, S., Hosseini, S. H., Heckler, C., Janelsins, M., Palesh, O., Mustian, K., & Morrow, G. (2013). Cognitive training for improving executive function in chemotherapy-treated breast cancer survivors. *Clinical breast cancer, 13*(4), 299-306.

Kessels, R. P., Van Zandvoort, M. J., Postma, A., Kappelle, L. J., & De Haan, E. H. (2000). The Corsi block-tapping task:

standardization and normative data. *Applied neuropsychology, 7*(4), 252-258.

Kowal, M., Toth, A. J., Exton, C., & Campbell, M. J. (2018). Different cognitive abilities displayed by action video gamers and non-gamers. *Computers in Human Behavior, 88,* 255-262.

Schroder, M. D., Snyder, P. J., Sielski, I., & Mayes, L. (2004). Impaired performance of children exposed in utero to cocaine on a novel test of visuospatial working memory. *Brain and cognition*, *55*(2), 409-412.

Tanaka, M., Ishii, A., Shigihara, Y., Tajima, S., Funakura, M., Kanai, E., & Watanabe, Y. (2012). Impaired selective attention caused by mental fatigue. *Journal of Neurological Sciences (Turkish), 29*(3), 542-553.

Tanaka, M., Shigihara, Y., Funakura, M., Kanai, E., & Watanabe, Y. (2012). Fatigue-associated alterations of cognitive function and electroencephalographic power densities. *PLoS One, 7*(4), e34774.

Tanaka, M., Ishii, A., & Watanabe, Y. (2015). Effects of mental fatigue on brain activity and cognitive performance: A magnetoencephalography study. *Anat. Physiol, 5,* 1-5.

Terry, P. C., Lane, A. M., Lane, H. J., & Keohane, L. (1999). Development and validation of a mood measure for adolescents. *Journal of sports sciences, 17*(11), 861-872.

Thomas, E., Snyder, P. J., Pietrzak, R. H., Jackson, C. E., Bednar, M., & Maruff, P. (2008). Specific impairments in visuospatial working and short-term memory following low-dose scopolamine challenge in healthy older adults. *Neuropsychologia, 46*(10), 2476-2484.

Trammell, J. P., MacRae, P. G., Davis, G., Bergstedt, D., &

Anderson, A. E. (2017). The relationship of cognitive performance and the theta-alpha power ratio is age-dependent: An eeg study of short term memory and reasoning during task and resting-state in healthy young and old adults. *Frontiers in aging neuroscience, 9,* 364.

Wagner, M. G. (2006, June). On the Scientific Relevance of eSports. In *International conference on internet computing* (pp. 437-442).

West, G. L., Konishi, K., Diarra, M., Benady-Chorney, J., Drisdelle, B. L., Dahmani, L., … & Bohbot, V. D. (2018). Impact of video games on plasticity of the hippocampus. *Molecular psychiatry, 23*(7), 1566.

Wexler, B. E., Iseli, M., Leon, S., Zaggle, W., Rush, C., Goodman, A., … & Bo, E. (2016). Cognitive priming and cognitive training: immediate and far transfer to academic skills in children. *Scientific reports, 6,* 32859.