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Pilot testing of a non-gaming cognitive battery in expert esports athletes

Abstract

Introduction: The esports industry is rapidly expanding, making it imperative to identify common data elements of expert gamers for the purposes of performance optimization and enhancement. We aimed to measure cognitive performance in a convenient sample of expert esports athletes, as well as to determine if cognitive performance of these individuals could be further enhanced through a novel non-gaming neurocognitive test battery.

Methods: Elite esports athletes (n = 5) participated in a four-day cognitive and strength & conditioning program at the Sports Academy (Thousand Oaks, CA). Cognitive performance was assessed through five tasks of increasing cognitive load. Baseline testing occurred on Day 1, followed by two hours of cognitive training at high cognitive load on Days 2 and 3, and re-testing on Day 4.

Results: During re-test on Day 4, Cognitive performance was improved during re-testing compared to baseline on all tasks of increasing cognitive load. Spatially oriented tasks showed the largest enhancement.

Conclusions: The present study identified baseline cognitive performance and reported performance enhancement through non-gaming cognitive tasks in expert esports athletes on Day 4, even after high-intensity physical training. Although the esports athletes improved on all cognitive tasks, we cannot conclude this has a direct transferability to actual game-play performance, which was not examined in the present case study. Future studies should focus on underlying neurophysiological mechanisms to predict future performance and develop an accession/selection tool in a sport with exponential growth.

Keywords

cognitive load; high-intensity physical training; military; neuroscience; performance; reaction time

Cover Page Footnote

The authors would like to express their gratitude to the CEO of MAMBA Sports Academy, Chad Faulkner, as well as their visionary leader, Kobe Bryant. Rest in peace, Kobe. We also thank the leadership of the United States Army Recruiting Command (Retired Major General Frank Muth and Retired Command Sergeant Major Tabitha Gavia) for their relentless support for reframing military cultural attitudes on Esports.

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Case Study

Pilot testing of a non-gaming cognitive battery in expert esports athletes

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Disclaimer: Material has been reviewed by the U.S. Army John F. Kennedy Special Warfare Center and School and the Walter Reed Army Institute of Research. There is no objection to its presentation and/or publication. The opinions or assertions contained herein are the private views of the author, and are not to be construed as official, or as reflecting true views of the Department of the Army or the Department of Defense. The investigators have adhered to the policies for protection of human subjects as prescribed in AR 70–25.

Introduction

The esports industry is rapidly expanding. Analysts predict that the net worth of the industry will exceed $3.5 billion, with over a billion esports athletes participating, by 2025 (Giwa-Osagie and Barker, 2021) across online PC and console gaming platforms. Regions of the world with the highest to lowest numbers of esports players are Asia/Pacific, North America, Europe, and South America, respectively. Despite industry growth, there are existing gaps in knowledge for identifying perceptual-cognitive traits that separate elite from novice esports athletes.

At present, research on video games has largely focused on the negative consequences of the gaming culture on brain health. Video games are linked to heightened anxiety (Loton et al. 2016), visual fatigue (Zwibel et al. 2019), and poor sleep habits (Wolfe et al. 2014) that are amplified, in part, by substance abuse of energy drinks (Brager et al. 2020; Gallimberti et al. 2016).

Several studies have reported neuroplastic benefits of video games for rehabilitation following traumatic brain injury (Betker et al. 2007; Levac et al. 2012). Specifically, video games have been used as cognitive remediation tools to improve deficits associated with neural injury by means of improving functional connectivity through neuroplasticity (Pietrzak et al. 2014; Chanpimol et al. 2017; Straudi et al. 2017; Umm Eman-Syed et al. 2021; Pappas et al. 2019).

Neuroimaging studies have also shown changes in functional connectivity associated with hours of video game playing for both action- and strategy-based games in expert gamers versus novice gamers versus non-gamers (for a review, see Bavelier & Green 2019). These studies have shown interrelationships between skill acquisition and regional changes in cortical/sub-cortical areas in elite vs. novice esports athletes and/or vs. non-gamers. For example, greater regional changes in grey matter volume measured through voxel-based morphometry are predictive of better performance on strategy-based games, particularly for brain areas regulating executive function -- the anterior cingulate cortex (ACC) and dorsolateral prefrontal cortex (DLPFC) -- and motor control, the cerebellum (Basak et al. 2011). Novice gamers show greater cortical/sub-cortical recruitment and activation of both top-down and bottom-up neural networks, including the DLPFC (Bavelier et al. 2012), hippocampus (Gleich et al. 2017), and striatum (Kuhn et al. 2011; Lorenz et al. 2015) compared to non-gamers. These same studies have also demonstrated that the differences in cortical/sub-cortical recruitment and activation of both top-down and bottom-up neural networks are even more pronounced between expert gamers versus novice gamers versus non-gamers.

In the present study, we explored perceptual-cognitive performance in a small sample of expert esports athletes using a novel non-gaming cognitive battery developed by the Sports Academy Venture Lab (Thousand Oaks, CA). The aims of the present study were as follows: First, we aimed to baseline cognitive performance using a novel non-gaming cognitive battery in a sample of expert esports athletes. Second, we aimed to determine if the cognitive performance of expert esports athletes is further enhanced on the fourth day of cognitive training (as part of a four-day cognitive and strength & conditioning program [see methods and discussion] hosted at the Sports Academy (Thousand Oaks, CA)). Cognitive performance was assessed through five tasks of increasing cognitive load (i.e., mental demand). Overall, the aims of this case study were to: (1) inform future studies using esports athletes as a demographic population for cognitive performance enhancement; and (2) provide a preliminary evidence as impetus to study higher-order neuroplasticity, functional connectivity, and cognition of the human brain in gaming performance environments.

Methods

Participants and Research Assurance

The present pilot study included five participants using a within-subject test/re-test design. All participants are expert esports athletes (play and compete full-time professionally for the United States Army) who play first-person/multi-person shooter and strategic quest games. Data collected represent programmatic evaluation as part of a paid training camp at the Sports Academy Venture Lab (Thousand Oaks, CA). All participants volunteered to have their performance data used for programmatic evaluation for the Venture Lab and the United States Army.

Cognitive Conditioning Tasks

All tasks were completed on an Apple iPad® tablet positioned horizontally and affixed to an adjustable stand positioned at eye level. Each athlete had their own noise-cancelling headset wired to the tablet to limit performance interference and/or competitive advantages while completing the cognitive tasks in a group setting. Tasks were completed in order of increasing cognitive load, with Task 1 requiring the least amount of mental effort and Task 5 featuring the greatest amount of cognitive load. A description of each task is presented below.

- **Task 1:** Simple – Tap *stationary* circle when it flashes GREEN after an unpredictable time domain and don't tap when RED.
- **Task 2:** Search - Tap *moving* circle when it flashes GREEN after an unpredictable time domain and don't tap when RED.

- **Task 3:** Spatial - "Destroy" one of eight targets arrayed in a circle. The moving arrow in the center shows which target to destroy. If the dial is GREEN – destroy target above arrow; if the arrow is ORANGE – destroy target below.
- **Task 4:** Search/Search - "Search and destroy" a moving green target (like Task 2) simultaneously presented during conflicting or congruent auditory stimuli (i.e., voice shouting "red" (conflicting) or "green" (congruent))
- **Task 5:** Spatial/Spatial - "Destroy" correct target above or below a moving arrow based on color designation of the arrow (Task 3) simultaneously presented during conflicting or congruent auditory stimuli

Study Timeline
Day 1 (**Test**) – Baseline cognitive performance was assessed using the aforementioned domain-generic (i.e., non-gaming) cognitive battery. Testing was conducted in the early afternoon on Day 1 of the training camp. All athletes completed a thirty-minute priming session familiarizing themselves with the cognitive tasks earlier that morning. Esports athletes did not engage in high intensity physical training prior to completing this baseline assessment.
Days 2 and 3 (**Training**) – Cognitive training was conducted for an hour on two occasions in the morning and afternoon on Days 2 and 3 following two hours of high intensity physical training in between. Cognitive performance was continually assessed for each individual task. The speed at which targets were presented was manipulated throughout testing, producing a high level of cognitive load. The physical training program included a minimum of two hours of strength & conditioning modalities testing muscular power (deadlifts and squats), anaerobic fitness (line sprints), agility (ladder sprints), and mixed-modal endurance (bodyweight and free weight exercises completed in thirty-minute circuits).
Day 4 (**Re-test**) - Cognitive re-testing was completed on Day 4 to examine changes from baseline. The re-test battery, identical to the baseline assessment, with the exception that it was conducted in the early afternoon following two hours of high intensity physical training.

Statistical Analysis
For within-subject analyses, two-tailed, paired *t*-tests were used to determine extent of performance change from baseline levels. Significance was set at $p < .05$. Summary statistics, including means +/- standard error (SE) are reported across the training program.

Results

A four-day regimen of conditioning improved speed across tasks of increasing cognitive load in expert esports athletes.

Table 1 presents mean reaction time (+ SE) in milliseconds at baseline (Day 1) and at re-test (Day 4). On average, reaction time decreased relative to baseline levels across the sample by 11.1% for the search task (Task 2; mean response time = 413.4

± 12.1 ms, day 1; 367.6 ± 6.9, day 4; $p < 0.01$), by 14.2% for the spatial task (Task 3; mean response time = 588.8 ± 24.0 ms, day 1; 505.0 ± 21.4 ms, day 4; p < 0.01), by 20.0% for the search/search task (Task 4; mean response time = 425.2 ± 15.0 ms, day 1; 340.0 ± 39.2 ms, day 4; $p = 0.03$), and by 16.7% for the spatial/spatial task (Task 5; mean response time = 649.8 ± 20.2 ms, day 1; 541.6 ± 6.0 ms, day 4; $p = 0.01$; see **Figure 1**). The only task in which reaction time did not decrease relative to baseline was that with the lowest level of cognitive load (i.e., Task 1; mean response time = 304.0 ± 12.3 ms, day 1; 278.0 ± 6.6 ms, day 4; $p = 0.06$).

Response accuracy remained stable for the search (Task 2) and search/search tasks (Task 4; $p > 0.05$) but marginally decreased relative to baseline levels by 6.4% ($p = 0.02$) for the simple task and by 6.8% ($p < 0.01$) for the most complex task (spatial/spatial). Accuracy improved by 5.8% ($p < 0.01$) for tasks of moderate cognitive load (spatial; Task 3). Overall, expert esports athletes in this sample showed greatest improvement on the spatial task (Task 3; -14.2% response time; +5.8% accuracy) during re-test.

Discussion

The present study aimed to assess changes in cognitive performance using a novel non-gaming cognitive battery developed by the Sports Academy Venture Lab (Thousand Oaks, CA) in a sample of expert esports athletes. More specifically, we aimed to determine if the cognitive performance of expert esports athletes could be further enhanced (or remain stagnant) on the fourth day of cognitive training (as part of a four-day cognitive and strength & conditioning program hosted at the Sports Academy, Thousand Oaks, CA). Cognitive performance was assessed through five cognitive tasks of increasing cognitive load. On the fourth day, cognitive performance was tested after two hours of high intensity physical training. Data suggest that baseline cognitive performance among these esports athletes was enhanced across the cognitive and physical conditioning program. Improvements in esports performance post-cognitive testing was not evaluated. The intent of this study was to test and evaluate this non-gaming cognitive battery in expert esports athletes.

Enhanced neuroplasticity, functional connectivity, and cognition achieved from gaming is a burgeoning area of study. Of relevance to the present study, recent research has shown that video game players have better skill acquisition and end point performance for strategy-based games (i.e., Space Fortress) when individuals focus on specific drills/skills inherent of the game compared to full game mode during training sessions (Lee et al. 2012). A recent study of another strategy-based video game (i.e., League of Legends) lends further credence to enhancing skill acquisition and end point performance through a regimen of non-gaming cognitive tasks (Large et al. 2019), similar to the experimental design and intent of the present study. Thus, overall achievement on League of Legends in Large et al. (2019) was highly predicted from performance achieved on non-gaming tasks of processing speed, deductive reasoning, and inhibitory/cognitive control compared to full game mode.

A lesser explored yet salient area of research involves the neural substrates and perceptual-cognitive mechanisms through which cortical/sub-cortical recruitment and activation is differentiated between novice compared to elite gamers. At present, the extant literature contains no research studies to that end; however, data extrapolations to gamers can be hypothesized from neuroimaging studies in athletes, particularly sport domains with comparable cognitive attributes of success (accuracy, precision, and fine motor, inhibitory control).

One key factor of the present investigation is that a significant amount of prior research has focused on novice gamers gaining experience during a domain-specific training period, whereas the present study focused on elite-level esports athletes using domain-generic (i.e., non-gaming) training. The present study also examined cognitive performance as part of a high-intensity physical training program tailored for esports athletes. Thus, by the time cognitive performance was re-tested (and improved) on day 4 (relative to baseline), the athletes had completed a multi-day regimen of high-intensity physical training. Given the present design of this pilot, it is likely that self-regulation skills were depleted due to fatigue by the time testing on day 4 began. In other words, these data can also be interpreted as an improvement in domain-generic neurocognitive skills while individuals are in a fatigued state, which potentially increases the generalizability of findings to competitive (e.g., sport) and combat (e.g., military) domains.

To this end, one limitation of this pilot study is the lack of a crossover design. There is a possibility that we saw cognitive improvements on day 4 because the esports athletes experienced high-intensity training before the cognitive testing in contrast to being rested during baseline testing; cognitive testing immediately after and/or after several days of high-intensity physical training may have improved cognitive scores. To conclude, the present study aimed to test and evaluate a novel non-gaming cognitive platform in a sample of expert esports athletes. Findings lends further credence to the utility of esports and gaming-like tasks to enhance neuroplasticity, functional connectively, and cognition. Performance from these platforms have direct application for cyber security, intelligence organizations, and drone operators, particularly as military operations become more automated and integrated with robotics and artificial intelligence. Future studies should aim to replicate these findings in a larger sample size using a crossover design. Future studies should also aim to investigate the direct effects of non-gaming cognitive training on competitive esports performance (e.g., at a tournament) across a more heterogenous population (first-person/multi-player shooter and fight games and multi-player strategic quests) . This future work will help to better predict future performance in gaming athletes and develop an accession/selection tool in a sport with exponential growth as well as for military application.

Media-Friendly Summary

We demonstrated that cognition within a small sample of expert esports athletes improves through "offline" non-gaming training without requiring individuals to play the game they specialize in, providing the field of neuroscience with a novel demographic to study higher-order cognition in future research.

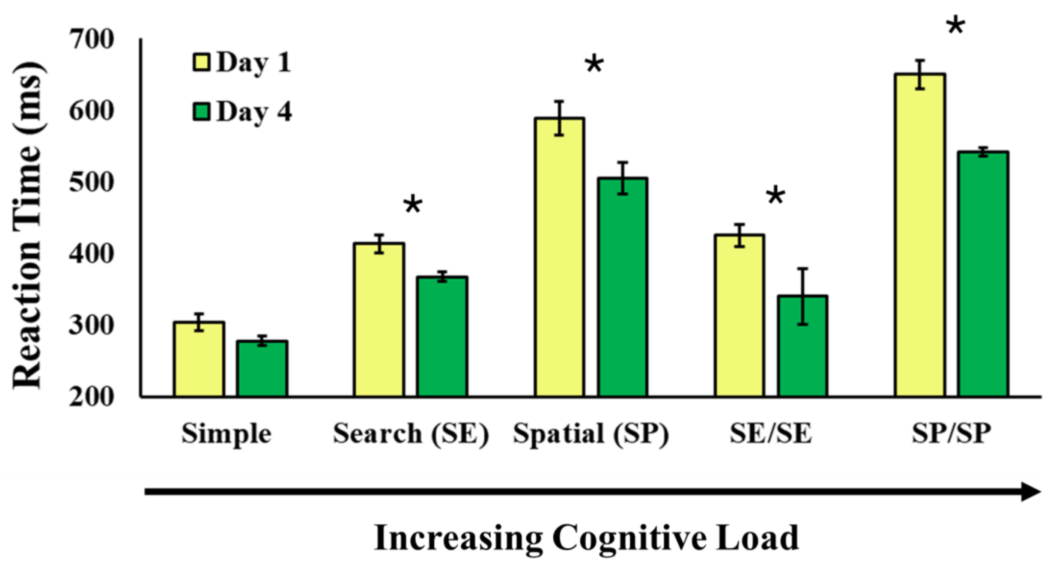
Table 1. Mean ± *SEM* reaction time in milliseconds (ms) amongst expert esports athletes (*n* = 5) at baseline (Day 1) and at re-test (Day 4) for cognitive tasks of increasing load.

Task	Day 1	Day 4	Δ ms	Statistical Test
Simple	304.0 ± 12.3	278.0 ± 6.6	26.0	*p* = .06
Search (SE)	413.4 ± 12.1	367.6 ± 6.9	45.8	*p* < .01
Spatial (SP)	588.8 ± 24.0	505.0 ± 21.4	83.8	*p* < .01
SE/SE	425.2 ± 15.0	340.0 ± 39.2	85.2	*p* = .03
SP/SP	649.8 ± 20.2	541.6 ± 6.0	108.2	*p* = .01

Note: Testing on Day 4 occurred after two hours of high intensity physical training; *SEM* = standard error of the mean; SE/SE = Search-search destroy task; SP/SP = Spatial-spatial destroy task; *p* = statistical test for within-subject comparisons.

Figure Legend

Figure 1: Figure 1: Mean + SEM reaction time in milliseconds (ms) by cognitive task across a four-day training regimen in expert esports athletes. * denotes significant 4-day change at p < .05 threshold.



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