CHAPTER 21.

IS COGNITIVE INHIBITION AN INDICATOR OF EXPERTISE AMONG COMPETITIVE ESPORTS GAMERS?

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ABSTRACT

This study for the first time tested whether cognitive inhibition, the mind's ability to disregard stimuli that are irrelevant to the task at hand, and a known attribute of successful action video gaming (Castel, Pratt & Drummond, 2005; Kowal, Toth, Exton & Campbell, 2018), could be a marker of expertise among players of one of the most popular first person shooter esports, Counter-Strike: Global Offensive. Here we tested low, intermediate, and high ranked gamers and compared their performance on a color word stroop task and also compared the performance of players in each gaming rank group to non-gamers. We found that when considering both accuracy and response times, elite gamers performed significantly better than both intermediate and low ranked gamers on the simple choice reaction time condition (Accuracy, $p<0.025$; Response Time $p<0.001$) and significantly better than intermediate ranked gamers on the incongruent condition (an measure of cognitive inhibitory ability)(Accuracy, $p<0.001$; Response Time $p<0.001$).

Introduction

Competitive video gaming, or esports (electronic sport), is a phenomenon that has grown dramatically over the past decade. From the development of professional gaming leagues, to the staggering numbers of spectators drawn to watching players compete, to the ever rising revenues every year, esports are solidifying their place in competitive sport culture (Wagner, 2006). Typically, sport involves the display of elite physical and cognitive skill in competition for entertainment purposes (Campbell, Toth, Moran, Kowal & Exton, 2018). However, where traditional sports to a great extent rely on the development and performance of complex motor skills for success, gamers seem to rely more on cognitive skills (Himmelstein, Liu & Shapiro, 2017). As society continues to rely on digital technology for their entertainment, platforms such as twitch have revealed the immense popularity of watching elite gaming across the world. As we enter what may be the era of the cognitive athlete, the scientific investigation of esports must continue to grow.

Previous research on video gaming has debated numerous topics including the potential negative effects of action video gaming on behavior (Ferguson, 2007) and the effects of screen time on our physiology (Swing, Gentile, Anderson, & Walsh, 2010). However, a growing body of research has emerged demonstrating the benefits of video games for cognition. For example, a meta analysis conducted by Bediou and colleagues (2018) demonstrated positive effects of gaming on cognitive abilities such as spatial memory, multi-tasking and inhibition. Moreover, recent evidence has demonstrated that when compared to non-gamers, action video gamers display enhanced cognitive ability when evaluated using standardized cognitive measures of processing speed, visual search and response inhibition (Kowal, Toth, Exton & Campbell, 2018). However, despite the recent evidence in support of the effects of gaming

on cognitive ability, no research to date has investigated whether superior cognitive ability is a hallmark of elite gaming performance.

Counter-Strike (now Counter-Strike: Global Offensive; CS:GO) is a first person shooter computer game that has been one of biggest success stories for esports. Released in 1999, there have been a number of game releases prior to the current version and the game has been played professionally since 2012. In CS:GO, two teams of 5 players battle on a small map to either plant (terrorists) or diffuse (counter-terrorists) a bomb. Players are armed with weapons and while weapon proficiency is important, so are cognitive abilities like decision-making and response inhibition as friendly fire, an enabled feature of competitive CSGO, makes recognizing the difference between friend and foe crucial for success. Despite the fact that anecdotally, elite players have a learned understanding of some of the important fundamentals to play CS:GO at a high level, gamers at all levels tend to practice very little on those specific abilities but rather, simply play more matches (Campbell et al., 2018). By better understanding the specific skills required for success in esports, players would be better equipped to understanding areas of strength and weakness in their performance, which has the potential to completely alter how esports athletes train and align esports training with the type of training observed in traditional skill-based sports.

The purpose of this study is to determine whether the skill of cognitive inhibition is an indicator of elite gaming performance among players of the FPS game, CS:GO. To address this purpose, we will evaluate the color word stroop performance of ranked CS:GO players and determine if higher ranked gamers show superior cognitive inhibitory ability compared to those with lower game rank. We hypothesize that CS:GO players of higher rankings will demonstrate superior cognitive inhibitory ability compared to lower ranked CSGO players evidenced by

higher accuracy and faster response times, specifically on incongruent stimuli in the test.

Methods

Participants

One hundred and twenty-nine CSGO players (N=129; 126 Males, 3 Females) were recruited from attendees at the 2018 Gamescom and PAX gaming conference in Cologne, Germany and Melbourne, Australia respectively. Each provided informed consent prior to voluntarily participating in the study. The research ethics board at the University of Limerick authorized approval for the study in accordance with the Declaration of Helsinki.

Participants began by completing a survey that gathered demographic information regarding their age, sex, handedness and color vision. It also gathered data regarding their gameplay; including the average number of hours per week they estimated they spent playing CSGO and their current CSGO ranking. Following completion of the survey, participants sat in front of a computer with a 24-inch monitor, were instructed to wear headphones to reduce the volume of external noise and asked to complete a color-word stroop test.

Stroop Test

The color-word stroop test used in this study was administered using Inquisit 4 software by Millisecond. Participants were presented with either the word 'red' 'green', 'black' or 'blue' on a white screen in either red, green, black or blue colored font. In Congruent trials the printed word and the color it was printed in matched. Incongruent trials were those in which the printed word on screen and the font color it was printed in did not match. In addition to Congruent and Incongruent trials, Control trials were also included and consisted of a colored box presented on screen. In total, 7 trials of each of the 4 colors

within each condition (84 total trials) were presented randomly to participants during the test. In every trial, participants were instructed to respond to the color of the ink used to present the word or box on screen and not the written word on screen. Participants were instructed to respond as quickly and accurately as they could using the keyboard keys 'd', 'f', 'j' and 'k', which corresponded with answers red, green, blue and black respectively. To aid participants, the key bindings were indicated in 18% neutral grey ink along the top of the screen throughout the test (see Figure 1). For each trial, the response was recorded as well as the reaction time, in milliseconds, between the presentation of the stimulus and the participants' response.

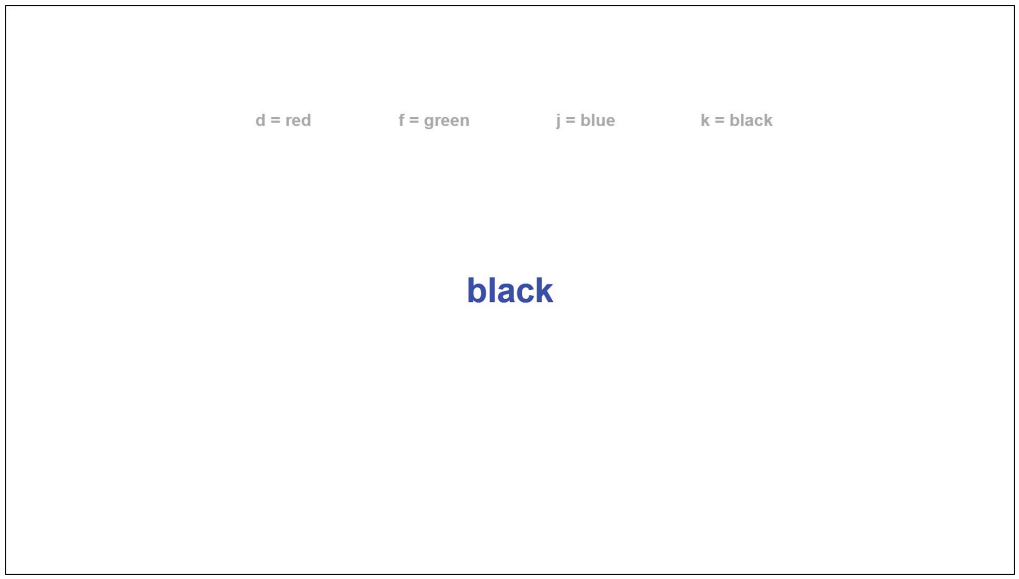

Figure 1: Example trial presentation during the color-word stroop task completed by participants.

Participants' data were excluded from analyses if they were under 16 or over 35 (n=7), indicated they were colorblind (n=8) or were left-handed (n=13). As evidence exists suggesting a female advantage on color-word stroop tasks (Golden, 1974) and due to our inability to compare male and female performance (low female n) we also excluded the data from the 3 females from further analyses. The remaining participants

were categorized based on their in-game ranking. In total, there are 18 CSGO rankings (see Figure 2). We grouped participants based on their individual CSGO ranking into one of three Rank groups. The Low Skill group consisted of gamers with rankings from Silver 1 to Silver Elite Master (n=12, Age=19.42 ± 3.44; Mean±SD). The Intermediate Skill group contained gamers with rankings from Gold Nova 1 to Master Guardian 2 (n=26, Age=20.46 ± 4.16). Finally, the Elite Skill group consisted of gamers between the Master Guardian Elite to The Global Elite rankings (n=60, Age=19.77 ± 3.84).

Figure 2: The 18 current competitive skill rankings for first person shooter esports game, Counter-Strike:Global Offensive (CS:GO).

Although previous work has determined that action video gamers possess superior cognitive ability compared to non-gamers, this work never compared non-gamers to gamers of a specific game nor has it evaluated whether only gamers of a particular ranking showed superior performance. In order to address these questions, we also included stroop performance

data from a group of Non-Gamers published in a previous study (Kowal, et al., 2018) and compared the performance of male participants in this group to the performance of ranked CSGO players. Data for trials across all participants were also excluded if the response time (RT) for that trial exceeded the overall average by two standard deviations. The average (±SE) percent correct and average (±SE) response times are reported for each condition and each rank group.

Statistical Analyses

In order to compare stroop performance between the three CSGO rank groups, we conducted 2-way ANCOVAs on both Accuracy (% Correct) and Reaction Time (RT; milliseconds) dependent variables with condition (Control, Congruent and Incongruent) and rank group (Non-Gamers, Low Skill, Intermediate Skill and Elite Skill) as independent variables. Previous work has demonstrated superior cognitive performance with greater time allocated to gaming. Therefore, the average number of hours reported gaming per week by participants was used as a covariate in in the ANCOVA. Post hoc analyses were performed with Tukey's correction for multiple comparisons and significance was determined at an alpha level of 0.05.

Results

Response Accuracy

Participants responded with accuracies of 94.4%, 95.3% and 91.0% on Control, Congruent and Incongruent trials respectively with response accuracy on incongruent trials being significantly poorer compared to those on control ($p<0.001$) and congruent trials ($p<0.001$). There was a significant interaction between condition and rank group on response accuracy when controlling for the average hours per week participants gamed for ($F(6, 1434) = 3.918$, $p= 0.001$, $h2=0.016$). Post hoc

comparisons revealed that Non-gamers were significantly more accurate than CS:GO gamers across all stroop conditions (Figure 3). Also, while no difference in accuracy was found between CS:GO rank groups for Congruent trials, Intermediate ($p=0.008$) and Elite ($p=0.025$) ranked CS:GO players were significantly more accurate than Low ranked gamers In the Control condition. In the Incongruent condition, Elite ranked gamers were significantly more accurate compared to intermediate ranked gamers ($p<0.001$) but not Low ranked gamers ($p=0.723$).

Response Times

A significant main effect of condition ($F(2, 1443) = 13.49$, $p<0.001$, $h2=0.018$) was found and post hoc comparisons demonstrated that although participants responded to congruent and control trials with average latencies of 778.939ms and 779.364ms, they took significantly longer to respond to Incongruent trials (855.683ms; $p<0.001$). There was also a main effect of rank group ($F(3,1442) = 17.962$, $p <0.001$, $h2 = 0.036$) whereby Non-Gamers were significantly slower than gamers in all CS:GO rank groups (Low; $p<0.001$, Intermediate; $p=0.027$, Elite; $p<0.001$) and Elite ranked gamers showed significantly faster response times compared to Intermediate ranked gamers ($p<0.001$).

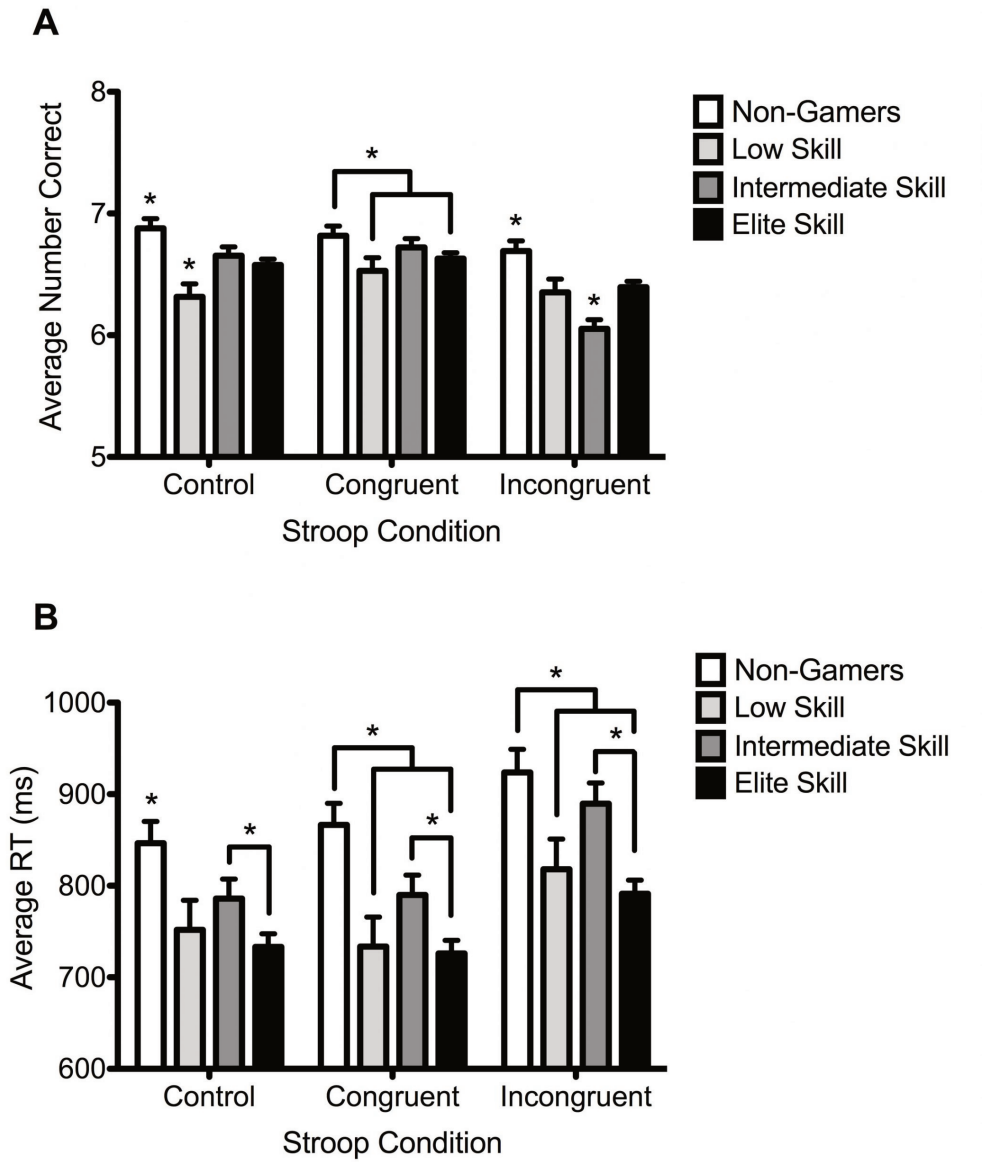

*Figure 3: Average number of correct respnses (A) and average response latencies in milliseconds (B) for Non-Gamer (white bars) and Low ranked (silver bars), intermediate ranked (charcoal bars) and Elite ranked (black bars) CS:GO gamers across Control, Congruent and Incongruient stroop conditions. Error bars represent ±SE. * indicates significant differences and ɤ signifies that the individual bar is different from all other bars within a stroop condition.*

Discussion

This study set out for the first time to identify whether a specific cognitive skill, previously suggested to be relevant for gaming

performance, could be a marker for rank in a prominent esports game. To do this we tested gamers of the FPS game, CS:GO, on a standardized color word stroop test and found evidence that elite ranked gamers show superior cognitive ability compared to lower ranked gamers. Specifically, we found that elite gamers have higher accuracy and faster response times for simple choice reaction time stimuli (control trials). However, where Elite gamers were far superior in their cognitive inhibitory ability compared to Intermediate ranked gamers, they did not significantly perform better on Incongruent trials when compared to Low ranked players. Finally, we corroborate previous work by demonstrating that gamers of all rankings prioritize speed over accuracy as a strategy when performing the stroop task.

Traditional sport science, motor earning and neuro-psychology research have identified the importance of identifying and training the individual fundamental skills required for high performance (Conte, Tessitore, Smiley, Thomas, & Favero, 2016; Mané, Adams, & Donchin, 1989; Boot et al., 2010). It is through the identification of an individual's competency with the many physical and cognitive skills required for elite sports performance that tailored training plans can be developed to more rapidly improve performance. In fact, this has been shown using a game developed for psychological research called Space Fortress (Boot et al., 2010). Previous research used this game to show that those players who practiced the individual skills of the game in isolation improved their in-game performance significantly faster and to a greater extent compared to those who spent their training time simply playing the game. In addition to improving individual performance, knowledge of the unique combination of strengths and weaknesses across skills for all players of a team allows for the development of superior strategies that utilise players to maximize strengths and mitigate the effects of weaknesses during matches. Currently,

very little research to date has attempted to identify the crucial cognitive and physical skills required for elite esports performance. Moreover, competitive players often cite their practice regimen to involve a steady diet of matches or scimmages to improve perfofmance with little to no objective approach to training the fundamental skills required for high performance at their chosen game (Hollist, 2015). As esports performance research grows and competitive franchises begin to identify player skillsets and alter training strategies to improve performance, we may observe a significant evolution in esports and the quality of play required to compete at a high level.

In this study, we focused on the cognitive ability of cognitive inhibition, which has been identified as a skill superiorly displayed by action video gamers when compared to non-gamers. However, previous research has often combined gamers of different action video game genres. Previously, Campbell and colleagues (2018) suggested that esports games or genres should be viewed separately from one another, similar to the differentiation of different traditional sports. Here for the first time, we examined the stroop performance of a homogeneous group of gamers of the FPS game CS:GO and compared their performance to a non-gaming sample. Moreover, we show that cognitive flexibility is a marker of in-game expertise as categorized by players' in-game ranking. The apparent importance of cognitive flexibility for CS:GO and first person shooter games in general may be tied to the importance of this cognitive skill for military personnel (Makhani, Akbaryan, & Cernak, 2015; Irgens-Hansen, Gundersen, Sunde, Baste, Harris, Bråtveit, & Moen, 2015). The scenario where distinguishing between friend and foe and deciding quickly and accurately whether to engage a target occurs regularly during CS:GO matches and often has a significant consequence to the outcome of a match.

This research is the first to attempt to quantify the influence that an individual cognitive skill has on differentiating players of different expertise level in a prominent esport. However, many more cognitive and physical abilities are also likely to display as indicators of performance and by identifying the key skills and attributes that differentiate esports players of different expertise, we may better understand how to develop training programs and in-game strategies to improve the probability of success for these individuals. To determine additional cognitive abilities associated with esports expertise, we may look to previous research that has identified specific cognitive abilities that are enhanced through gaming or which gamers show superiority with compared to non-gamers. For example, the meta-analytic work by Bediou and colleagues found that gamers were superior to non-gamers in the cognitive domains of inhibition, verbal cognition, perception, top-down attention and spatial cognition (Bediou et al., 2018). These findings are supported by experimental work showing gamers possess enhanced spatial memory (Clemenson & Stark 2015; Bonny, Castaneda, & Swanson, 2016) as well as visual attention and processing speed (Kowal et al., 2018) compared to non-gamers, but also that some of these cognitive aspects can be improved by gaming (Green & Bavelier, 2012; Boot, Blakely, & Simons, 2011; Green, Li & Bavelier, 2010).

In addition to the cognitive skills that may mark performance, there remains a gap in esports performance science highlighting the physical skills and attributes that highlight expertise within different games. For example, it has been well established that elite players of the game *Starcraft* possess a unique ability to output a significantly higher number of actions per minute compared to low ranked players and non-gamers (Hotz, 2012). In CS:GO, players have highlighted skills such as 'flicking' and 'tracking' to be key mouse control skills allowing players to hit and kill targets with the greatest speed and efficiency. However,

no research into the biomechanical and motor control skills displayed by elite esports players has been conducted to date and the area would immensely benefit from experiments that aim to quantify the magnitude of effect that different physical skills have on gaming performance.

While we do find that, among our sample of CS:GO players, elite ranked gamers perform superiorly on the Stroop task, they do not significantly out-perform the lowest rank group. This may be due to a differential influence that the many esports skills have on one's performance as they gain expertise in the game. For example, a lack of expertise across a number of mechanical skills using their mouse and keyboard may more strongly differentiate low from intermediate rankings. In this way, low ranked players may be more largely differentiated in game by their physical rather than cognitive ability. As mechanical skill develops and becomes less influential on overall ranking differences among intermediate players, perhaps cognitive abilities such as cognitive inhibition become more important and thus, the main obstacle for those unable to achieve an elite ranking status. In order to address this hypothesis, we recommend future research to identify the likely many more cognitive and physical markers of esports expertise, particularly in FPS games, and establish the other skills that differentiate specifically low ranked gamers and those in both intermediate and higher rankings.

Overall, this study for the first time has demonstrated that a cognitive ability shown to be enhanced in action video gamers can be used as a marker of expertise in players of the prominent FPS game, CS:GO. However, further research is required to identify the other essential ingredients required within the recipe of successful esports performance. It is our hope that the current study helps to accelerate a new and emerging body of esports performance research that aims to revolutionize the

methods used by gamers to train and prepare for elite competitive esports competitions.

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