Setting the Scientific Stage for Esports Psychology: A Systematic Review

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Competitive gaming, better known as electronic sports (esports), is rapidly growing in popularity. We systematically reviewed the available literature regarding the psychological aspects of esports using the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) evidence-based reporting checklist and a Population, Intervention, Comparator, and Outcomes (PICO) framework with the following inclusion criteria: (i) published between 1994 and 2018; (ii) empirical investigation (as the current state of research is dense with positions and opinions but has few empirical investigations); and (iii) focussed on esports games that are associated with either cognitive performance or game performance. The goal of our research was twofold: to present a summary of the empirical evidence addressing the psychological characteristics of both cognitive and game performance in esports, and to integrate esports in the field of sport psychology. More specifically, our goals were to highlight the interplay of psychological aspects of performance and esports and to clearly define the theoretical foundations of the psychological aspects of esports performance. Underlining the differences from video gaming will inform future research directions and stimulate the development of high-quality practice in the applied field of sports and exercise psychology.

Keywords: esports; cognition; performance; sport psychology; game performance

Introduction

Historically, competitive video gaming tournaments started in 1972 at Stanford University with the game Spacewar (Li, 2016), but the pioneer of professional tournaments is the Cyberathlete Professional League, which started in 1997 (Goodale, 2003). These tournaments represent the first step towards establishing a professional electronic sports (esports) culture. The first recognition by a professional sports governing body took place in South Korea in 2000 when the Korea e-Sports Association was founded as part of the Ministry of Culture, Sports, and Tourism (Korea e-Sports Association, 2014). By the 2010s, esports had experienced a rapid rise, as teams and professional tournaments were founded and broadcasts became common (Popper, 2013; Tassi, 2012).

Even though the professional growth of esports as a performance environment continues, this is in clear contrast to the development of scientific knowledge on the factors involved in high-level esports performance (Campbell, Toth, Moran, Kowal, & Exton, 2018). For instance, there is increasing scientific research on video games (Anderson et al., 2010; Reeves, Brown, & Laurier, 2009; Witkowski, 2012; Yee, 2006), but not specifically on esports, where so far, the research is rather qualitative and exploratory (Hallmann & Giel, 2018). Hence, there is a need for experimental research on esports (Murphy, 2009), starting with a clear differentiation of the prerequisites of video game and esports performance (Dale & Green, 2017).

Overall, the role of psychological factors in esports is still poorly understood. To address this, we systematically reviewed the esports literature with two main aims: first, to systematically summarize the available literature on esports related to both cognitive and game performance, and second, to integrate esports in the field of sports psychology, more specifically, highlighting the role of psychological aspects of performance in esports. Our analysis is based on the building blocks of performance conceptualized in sports psychology (e.g., emotion, motivation, perception, action, and cognition; Raab, Lobinger, Hoffmann, Pizzera, & Laborde, 2015).

Transition From Video Games to Esports

Previous research on video games categorised many video games as action video games (Dale & Green, 2017; see Table 1) based on key characteristics of the game, for example, aiming, shooting, and running (Bediou et al., 2018), despite the games being in accepted genres of their own, for instance, first-person shooters (FPSs; e.g., Counter-Strike[1]), multiplayer online battle arenas (MOBAs; e.g., League of Legends; LoL), real-time strategy games (e.g., StarCraft), sports games (e.g., FIFA), or fighting games (e.g., Marvel vs. Capcom). Other well-known video game genres include role-playing games (RPGs), simulations, and puzzle games (Lemmens & Hendriks, 2016). Most of the genres and the video games within them share similar characteristics (e.g., within MOBA: LoL and Dota).

However, the transition of video games from recreational and unstructured use has evolved into a highly competitive domain that is now called professional esports. This evolution is changing not only how the video games' community interacts but also the way how empirical evidence is obtained in this field (Tang, 2018). For examples, researchers who have studied the effects of video games on cognition acknowledged that the effects found so far could be uncertain if the individual characteristics and the constant evolution of each video game and gamers is not considered (Dale & Green, 2017; Momi et al., 2018).

Consequently, one can see how over the years, the development of professional esports has positioned teams and players within a performance context, facilitating the

[1] Full names of all games discussed in this review can be found in Table 1.

initial understanding of psychological factors underlying esports expertise (Campbell et al., 2018; Himmelstein, Liu, & Shapiro, 2017; Pedraza-Ramirez, 2019).

[Table 1 near here]

Resolving the definitional dilemma in esports

It is important to mention that there is still a diverse number of spellings and definitions for esports. Therefore, we decided to address and contribute in this matter, aiming to concur in the terminology for future works.

First, we have decided to use the Associated Press's spelling of the competitive video gaming industry (Esports or eSports?, 2017): esports. Second, there are several definitions of the term, which still lack specificity. For example, esports has been defined as the form of competitive videogame playing against other players in person or online, playing for trophies or points, and playing for speed (i.e., competing for the fastest completion time in a game; Ruvalcaba, Shulze, Kim, Berzenski, & Otten, 2018, p. 296). Additionally, Hamari and Sjöblom (2017, p. 213) defined esports as 'a form of sports where the primary aspects of the sport are facilitated by electronic systems; the input of players and teams as well as the output of the eSports system are mediated by human-computer interfaces'. Even though this definition highlights the term 'sports', it can be debated whether esports require the same physical exertion as mainstream sports, such as football, tennis, or basketball. Additionally, according to the Council of Europe (2001), the word 'sports' refers to 'all forms of physical activity which, through casual or organised participation, aim at expressing or improving physical fitness and mental well-being, forming social relationships or obtaining results in competition at all levels'. However, we would argue that the physical exertion (i.e., energy expenditure, physical effort) in esports during competition and as part of participants' training can indeed be considered similar to that in other activities such as archery, shooting, bridge, or chess

(Schwarz, Schächinger, Adler, & Goetz, 2003; Troubat, Fargeas-Gluck, Tulppo, & Dugué, 2009), which are all recognized as sports by the International Olympic Committee.

Taking into account the different existing perspectives and the characteristics of esports, we propose the following definition that clearly differentiates esports from video gaming:

> *Esports is the casual or organized competitive activity of playing specific video games that provide professional and/or personal development to the player. This practice is facilitated by electronic systems, either computers, consoles, tablets, or mobile phones, on which teams and individual players practice and compete online and/or in local-area-network tournaments at the professional or amateur level. The games are established by ranking systems and competitions and are regulated by official leagues. This structure provides players a sense of being part of a community and facilitates mastering expertise in fine-motor coordination and perceptual-cognitive skills, particularly but not exclusively, at higher levels of performance.*

So, according to our definition, not every video game is an esports game but every esports game is a video game. Video games such as Super Mario Bros., The Sims, or Grand Theft Auto can be played casually, and in some cases, there are organized tournaments. But these types of games do not have ranking systems, and competitions regulated by official leagues.

The Psychology of Esports Performance

In sports psychology, researchers work to understand the underlying mechanisms of performance in different competitive domains (Ericsson, Krampe, & Tesch-Römer, 1993) within the sports context (e.g., Côté, Baker, & Abernethy, 2007;

Starkes & Ericsson, 2003). Accordingly, Murphy (2009) suggested that the physical (motor) and cognitive skills development that occurs when engaging in competitive video games could be of interest to sports psychologists. Consequently, we suggest that esports is an ideal domain for studying performance, and that this domain should be integrated in the research and applied field of sports psychology. In this review, we use cognitive and in-game performance measures to conceptually define and quantify esports performance.

High-level performance has received much attention in applied and research sports psychology, with research groups, journals (*Sport, Exercise, and Performance Psychology*), and books (e.g., *Performance Psychology* by Raab et al., 2015) devoted to the topic. Performance can be seen everywhere, and it is often used as an umbrella term to explain behaviour associated with the achievement of goals (Raab et al., 2015). Thus, esports performance, similar to physical sports performance, is an end outcome achieved across time that can be measured in different ways (e.g., winning or acquiring gold, being ranked, etc.). From a philosophical perspective, Nitsch and Hackfort (2015) addressed the importance of understanding the psychology of performance from two different angles: First, performance can be seen as the realization of a performance action driven by the motivation and interests of the person, that is, 'performance as a means to an end' (p. 13); second, performance can be seen as the realization and perfection of that performance action in itself, that is, 'performance as an end in itself' (p. 13). A competitive esports player requires the cognitive processes needed to meet the demands of the game (e.g., decision making, attention, and memory; Raab et al., 2015; Voss, Kramer, Basak, Prakash, & Roberts, 2010) and in-game skills (e.g., fine-motor coordination, game knowledge, etc.), which Donaldson (2017, p. 427) called 'mechanical expertise'.

Cognitive Performance in Esports

In the domain of sports, cognitive performance has been studied from two theoretical perspectives. Some have focussed on experts' performance, in particular on sport-specific cognitive processes (Musculus, Ruggeri, Raab, & Lobinger, 2019; Raab, Masters, & Maxwell, 2005; Voss et al., 2010), and others have taken a more general approach, focussing on cognitive processes that are common to all sports (Voss et al., 2010). In esports, the majority of studies have so far focussed instead on esports-general cognitive processes (e.g., Seya & Shinoda, 2016). Given this lack of specificity in studies of the cognitive processes of certain video games (Bediou et al., 2018; Green & Bavelier, 2015), the cognitive processes underlying performance in esports are still unclear. The characteristics of the environment in which esports take place may offer improved ecological validity over laboratory-based research on traditional sports when exploring specific cognitive processes (Pluss et al., 2019). Yet, it is of utmost importance to determine if there is already empirical work testing cognitive processes in laboratory settings that could shed light on *esports cognitive performance.*

Game Performance in Esports

As in any other sports domain, the evaluation of game performance is fundamental to understanding progress and the attainability of desired outcomes. Usually in sports, such assessments are based on statistical and outcome parameters (Tenenbaum & Filho, 2016). In esports, it is possible to measure performance on the basis of results (i.e., win/lose) and in-game statistics (e.g., amount of gold acquired per minute, number of kills, deaths, assists [known in the games as KDA], points, etc.; Bertran & Chamarro, 2016) or other indicators such as positioning in league rankings or points. However, these game performance measures vary depending on the game. Multiplayer Online Battle Arena games have a very similar structure, and thus similar outcome measures (e.g., gold per minute, KDA, etc.) can be used. Similarly, FPS games use some of the MOBA game performance measures, such as kills, and deaths (KD) (Parshakov, Coates, & Zavertiaeva, 2018). However, it is important to acknowledge that even though esports can provide many different statistical measures coming directly from the games, these measures are still too unexplored and unreliable to lead to an understanding of the underlying cognitive processes on their own, so other measures of performance are still needed. Accordingly, we would like to consider these in-game performance outcomes as *esports performance.*

Previous Reviews and Meta-Analyses of Esports

Esports is a growing industry, and as yet, few theoretical models of the fundamental mechanisms of competitive performance have been developed. Although there are still not enough empirical studies to compare effect sizes in the field of esports, there are a few published meta-analyses of video game research and cognitive abilities. For example, Bediou and colleagues (2018) focussed on the impact of action video games on cognition. Medium effect sizes were found in cross-sectional studies of habitual action video game play, whereas in intervention studies a small to medium effect size was found in a few cognitive domains. Overall, Bediou and colleagues (2018) suggest that those who regularly play action video games display better cognitive processes than those who play little or none. Additionally, authors, concluded that the positive enhancements in cognition do not equally impact all cognitive functions. Thus, the cognitive processes associated with working memory and inhibitory control within perception, spatial cognition and top-down attention seem to show considerable promises in both the theoretical and practical understanding of action video games and cognition.

In another meta-analysis, Sala, Tatlidil, and Gobet (2017) concluded that video game training does not enhance cognitive abilities. The overall results showed, first, weak correlations between skill and cognitive abilities; second, small differences in the cognitive abilities between players and non-players; and third, no or insignificant effects between a video game training group and a control group. These findings do not support the theories of far transfer of video game training and cognitive training. However, there is the need of advanced experimental designs that allow us to better understand any far transfer effects or specific cognitive processes that are important for specific video games. In contrast, Wang and colleagues (2016) aimed to assess the effects of action video game training on cognitive abilities. They found moderate to small effect sizes in overall and specific cognitive improvement in healthy adults. Especially, improvements were shown in cognitive processes related to inhibitory control, such as visuospatial and attention processing. Similarly, a study testing the impact of video games on information processing (Powers, Brooks, Aldrich, Palladino, & Alfieri, 2013) found that in true experiments, video game training had a significant (small) effect on inhibition, whereas quasi-experimental studies showed moderate effects for dual/multitasking and switching, and small effects for inhibition, intelligence, and working/short-term memory. Even though the results from the quasi-experimental studies showed higher impact of action video game training on the four cognitive functions (e.g., working memory, inhibitory control, cognitive flexibility, and higher order), it is suggested that specific cognitive processes are closely related to the cognitive demands of the game used.

The above discussed results shed light on the importance to consider separately the cognitive demands of each video game to better understand the specific cognitive processes that could be more or less impacted by video game training.

Although the findings of these meta-analyses contribute to the understanding of the cognitive effects of video games in general, methodological limitations (publication bias, small effect sizes, and conceptual issues across different meta-analytic comparisons) have been acknowledged (Bediou et al., 2018). When considering esports, even if it is too soon to discuss the effects of training, the evidence from the meta-analyses in video games seems promising to understand key cognitive processes such as perception, spatial cognition, attention, intelligence and dual/multitasking in specific games that require high cognitive load (e.g., LoL, CS:GO, StarCraft, etc.).

Moreover, there are three important literature reviews that have highlighted the need to develop scientific knowledge on the psychological and cognitive concepts of esports.

Bányai, Griffiths, Király, and Demetrovics (2019) explored the relationship between esports and psychology. Eight studies were included and categorised into three main topics: (1) becoming an esport player, (2) the characteristics of esport players, and (3) the motivations of esport spectators. The authors concluded that the path of becoming an esport player is similar to that of a professional athlete in physical sports (e.g., training, preparation, mental skills, and obstacles). Furthermore, the authors argued that professional video gamers and professional gamblers have similarities, such as excessive time spent playing. Consequently, the authors suggested that future research should consider these similarities and focus on esport players' psychological vulnerability.

Garcia-Naveira, Toribio, Molero, and Suarez (2018) reviewed 26 articles on the cognitive and psychological benefits of video games and esports. They concluded that the regular practice of video games and esports stimulates specific brain structures and benefits the development of cognitive processes (e.g., intelligence, working memory, decision making, cognitive flexibility, etc.). Also, this practice was found to positively influence psychological skills such as motivation, self-regulation, self-confidence, and social skills. The authors acknowledged the need to study video games and esports separately, yet they included both in their review.

Lastly, Mora-Cantallops and Sicilia (2018) explored player behaviour in MOBA games, mainly focussing on two esports, LoL and Dota 2. This review restricted the search to articles on MOBA games published since 2011. The authors found 23 studies attempting to understand the behaviour and motivation of players, describe social interactions in the online world, and gain knowledge of game play and outcomes using computer modelling, topological measures, and spatio-temporal behaviours of the teams. The review concluded that researchers should cooperate with professional players to better understand tactical and strategy of the games to be able to combine traditional research approaches like survey and interviews with innovative computer science techniques.

Although Bányai et al.'s (2019) summary of the qualitative research on esports players is appreciated, our contribution is aimed at looking into only the *quantitative evidence* in relation to esports and performance. Additionally, whereas Garcia-Naveira et al. (2018) looked only at the research on the benefits of video games in general since 2012, we undertook a more specific exploration of both the cognitive and in-game outcomes of playing, and, as suggested by Garcia-Naveira et al. (2018), we included not only esports that were developed shortly before or after the ‘boom’ in esports in 2010 (e.g., LoL; Dota 2) but also those that have been around much longer, such as Tetris since 1984. Thus, we were not limited by the databases’ (see Information sources, below) maximum range (1994–2018) but could also include studies identified through other sources published before or after that range, in contrast to both Garcia-Naveira et al. (2018) and Mora-Cantallops and Sicilia (2018). Although they followed specific social science guidelines for systematic reviews (Petticrew & Roberts, 2008), Mora-Cantallops and Sicilia (2018) explored a wide range of topics not necessarily related to esports performance. We have focussed on integrating esports performance in sports psychology and have also followed the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) guidelines and the Population, Intervention, Comparator, and Outcomes (PICO) study design model for reporting systematic reviews and meta-analyses (Liberati et al., 2009; Shamseer et al., 2015).

The Current Systematic Review

Our systematic review yielded the added value of clarifying and highlighting relevant factors of cognitive and in-game performance in specific esports that have been previously studied in general video game research without considering the relationship of competition and performance in esports. Additionally, we provide a heuristic model to illustrate the current state of the art, suggesting that future research should test the bidirectional influence of all factors related to esports performance.

Methods

Eligibility Criteria

Studies were selected according to the PICO criteria (Table 2). The literature search covered the period of January 1994 (the earliest date allowed in one of the databases) to October 2018 (the point at which we conducted our search). Since one of the databases limited the period of our search (i.e., no earlier than 1994) and we wanted to include all relevant publications, we were slightly flexible and included records identified through other sources (see Information sources) that were published before or after that range. To ensure quality, our selection criteria were publications in a peer-reviewed journal and being written in either English or Spanish.

[Table 2 near here]

Information Sources

The literature search was conducted in the electronic databases Web of Science, Science Direct, and EBSCOhost. The latter allowed us to narrow the search to the most relevant databases for our interest (SPORTDiscus, PSYNDEX, and SocINDEX). Additionally, the reference lists from all selected papers and the respective citations of each study from the time of publication up to the date of our search were hand searched. Even though we did not include unpublished studies (e.g., conference posters and abstracts, theses, etc.), books, or position papers in or analysis, the reference lists from those sources as well as reviews and meta-analyses were checked and considered to establish the state of the art.

Search Strategy

We searched for only quantitative studies, using terms combined with different expressions (esports OR e-sports OR electronic gaming OR competitive gaming OR online gaming OR professional video gaming) AND (psychology OR cognition OR psychological skills OR performance OR neural basis). The combination of such terms was applied in each of the databases (i.e., Web of Science, Science Direct, and EBSCOhost).

Study Records

Data Management

The first phase of the literature search involved exporting the results (title/abstract) to a Word document to determine which studies were potentially relevant to our systematic review. The first author screened the titles and abstracts to remove any that did not meet our inclusion criteria, after which the selected studies were uploaded to the reference manager software Mendeley to check for duplicates. The results were exported to an Excel spreadsheet, where the articles were numbered. Subsequently, the titles and abstracts went through a second phase consisting of extracting initial information from each article in the Excel spreadsheet (e.g., study title, author, year, journal, the aim of the study, etc.) while verifying once more whether the article met the selection criteria.

Data Collection Processes

Using the Excel spreadsheet, the first author extracted data that included demographic information, design information, performance measures, the aim of the study, the intervention details, and the outcomes. Each study that was included in the final pool and any whose inclusion was unclear after the selection criteria assessment were discussed in a team meeting, by at least two more authors, until consensus was reached. Figure 1 shows a flow diagram of the selection process, following the PRISMA-P methodology. Fifty-two studies were included for final analysis.

[Figure 1 near here]

Data Items

Some studies considered for inclusion focussed on specific esports but others on many different video games, so we considered only those studies that clearly addressed esports. Also, some focussed on either one or both performance outcomes (i.e., game performance and cognitive performance). Therefore, we extracted the specific measures used. Lastly, we conducted a search on the journal names to get a better understanding of where the initial research on esports performance has been published.

Outcomes and Prioritization

The main outcomes of our review were (1) the types of esports video games analysed in the studies, which were dependent on our esports definition, and (2) esports performance outcomes: (a) the performance on cognitive tasks (cognitive processes tested in a laboratory setting or controlled environment) and (b) the game performance measures coming from the games themselves (e.g., winning/losing, KDA, gold per minute, etc.).

Risk of Bias in Individual Studies

Risk of bias within the included studies was assessed by two of the authors using the Joanna Briggs Institute Critical Appraisal Checklist for Analytical Cross Sectional studies (Moola et al., 2017). This tool contains eight risk-of-bias questions to determine the extent to which the selected studies addressed the possibility of bias in their design, running, and analysis. Using validated definitions, each item was answered with yes, no, unclear, or not applicable (see Appendix A).

Results

Study Description

The $N = 52$ publications that met the inclusion criteria (see Figure 1) were published between 1992 and 2019. The studies were published in many different journals ($N = 40$). *PLoS ONE*, with six, published the most, and four were published in *Computers in Human Behavior*. For the cognitive science journals, *Applied Cognitive Psychology* published four and *Topics in Cognitive Science* three. The majority of studies ($n = 35$) were the only publications on the topic in the respective journal (e.g., *Nature*, *Proceedings of the National Academy of Science of the United States of America, etc.*; see Appendix B). The studies were divided into the two main categories of esports performance: (a) cognitive performance and (b) game performance. An extra category was created for studies combining the two measures. The main findings of the systematic review are presented in Table 3 for cognitive performance and Table 4 for game performance. Overall, 25% ($n = 13$) of the research on esports performance targeted only cognitive performance, 46.2% ($n = 24$) targeted only game performance, and 28.8% (n = 15) reported both of these characteristics.

[Tables 3 and 4 near here]

The publications exploring the cognitive performance of esports (n = 28) were of an experimental (n = 11), quasi-experimental (n = 14), cross-sectional (n = 1), quasi-experimental and cross-sectional (n = 1), or longitudinal (n = 1) design. These publications were divided by the different cognitive functions they assessed (Diamond, 2013; Miyake et al., 2000): (a) working memory (n = 8), (b) inhibitory control (n = 2), (c) cognitive flexibility (n = 2), (d) higher order functions, and any combination of two or more (n = 16; Table 3). The publications on game performance (n = 39) were of an experimental (n = 14), quasi-experimental (n = 6), cross-sectional (n = 13), longitudinal (n = 3), experimental and cross-sectional (n = 1), quasi-experimental and cross-sectional (n = 1), or cross-sectional and longitudinal (n = 1) design. These publications were divided into two main categories that enabled us to differentiate the purpose of the studies (following Nitsch & Hackfort, 2015): (a) expertise differences (i.e., esports performance as a means to an end; n = 20) and (b) effects of esports participation/training (i.e., esports performance as an end in itself; n = 19; Table 4).

Cognitive Performance

The studies measuring cognitive performance used a great variety of cognitive tasks to understand the link between esports and cognitive functions (e.g., Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Kokkinakis, Cowling, Drachen, & Wade, 2017; Table 3). For example, the most frequent cognitive tasks used by authors to assess working memory were mental rotation tasks (n = 6) and the operation span task (n = 6); inhibitory control was investigated with the useful field of view (n = 4) and multiple object tracking (n = 4) tasks, cognitive flexibility with task-switching paradigms (n = 3), and higher order functions with Raven's matrices (n = 3) and the Wechsler Abbreviated

Scale of Intelligence (*n* = 2).

Working Memory

Overall, mixed effects were reported regarding the relationship between esports training and *working memory*. That is, positive effects of training/participation were found in working memory tasks such as spatial resolution and mental rotation in Unreal Tournament, Tetris, CoD, and CS:GO (C.S. Green & Bavelier, 2007; Lau-Zhu, Holmes, Butterfield, & Holmes, 2017; Momi et al., 2018; Okagaki & Frensch, 1994; Seya & Shinoda, 2016; Terlecki, Newcombe, & Little, 2008), but some counter-evidence exists of the effects of esports training in working memory tasks in Dota 2 and Tetris (Boot et al., 2008; Pilegard & Mayer, 2018; Röhlcke, Bäcklund, Sörman, & Jonsson, 2018).

In terms of expertise differences, researchers found that expert LoL, Dota, StarCraft, Guilty Gear, CoD, Halo, and Battlefield players outperformed amateur players in spatial and visual working memory tasks (Chang, Liu, Chen, & Hsieh, 2017; Gong et al., 2016; C.S. Green & Bavelier, 2006; Kowalczyk et al., 2018; Pereira, Wilwert, & Takase, 2016; Seya & Shinoda, 2016; Tanaka et al., 2013). Additionally, studies found higher activation of the brain network structure associated with spatial and visual processing of the working memory functions in expert Guilty Gear, LoL, Dota, and StarCraft players in comparison to non-expert players (Gong et al., 2016; Kowalczyk et al., 2018; Tanaka et al., 2013). In sum, although there are exceptions, positive effects of training and expertise differences on working memory have been observed in a great variety of esports.

Inhibitory Control

In terms of *inhibitory control*, positive effects of esports training were found in LoL, Unreal Tournament, CoD, Halo, Counter-Strike, Gears of War, and Tetris players in comparison to non-players on visual selective attention and multiple-object tracking tasks (Bavelier, Achtman, Mani, & Föcker, 2012; Bejjanki et al., 2014; Ding et al., 2018; C.S. Green & Bavelier, 2006; Qiu et al., 2018). Additionally, brain networks associated with inhibitory control, in expert LoL, Dota 2, and FIFA 15 players showed enhanced functional integration between salience and central executive networks of the brain and stronger activation in comparison to non-experts (Aliyari et al., 2015; Ding et al., 2018; Gong et al., 2016). Furthermore, Halo, Counter-Strike, Gears of War, and CoD players had faster reaction times and presented lower activity in the frontoparietal network that mediates attention location in comparison to non-players (Bavelier et al., 2012). Overall, positive effects of esports training on inhibitory control processes were found in different types of esports, especially in those that require fast reaction times, such as Counter-Strike and CoD, but also those in which strategy and planning are highly important, such as LoL and Dota 2.

Cognitive Flexibility

Overall, only a few studies have explored the relationship between esports training or expertise and cognitive flexibility (e.g., Glass, Maddox, & Love, 2013; Hyun et al., 2013; Klaffehn, Schwarz, Kunde, & Pfister, 2018). The main findings were found in StarCraft I and II for long-term engagement and training. Researchers found an increased volume of the prefrontal cortex and positive significant correlations of training and performance on cognitive flexibility tasks (Glass et al., 2013; Hyun et al., 2013). However, in a study with many different types of esports, Klaffehn et al. (2018) found that Age of Empires, LoL, Dota, StarCraft II, Battlefield, CS:GO, CoD, and Counter-Strike players did not show higher task-switching performance in comparison to non-players.

Higher Order Functions

Mixed evidence has been reported regarding the relation between esports and *higher order functions*. Esports training and practice in expert and non-expert Unreal Tournament, CoD, Tetris, and LoL players were found to be associated with an improvement in fluid intelligence and higher order function tasks (Bejjanki et al., 2014; Kokkinakis et al., 2017; Lau-Zhu et al., 2017). Conversely, other studies of Dota 2 and Tetris players found experience had no effect on fluid intelligence (Boot et al., 2008; Röhlcke et al., 2018).

Game Performance

Thirty-nine studies investigated expertise variables of in-game performance or the effects of esports participation or training by using specific in-game variables (e.g., results, KDA, and ranking) to observe game-playing effects or to measure engagement (e.g., Boot et al., 2008; Breuer, Scharkow, & Quandt, 2013; C.S. Green & Bavelier, 2007; Huang, Yan, Cheung, Nagappan, & Zimmermann, 2017; Table 4).

Expertise Differences in Esports Performance

Several studies reported that expert LoL and Tetris players were faster and more accurate in decision-making situations and better than non-experts at performing under high pressure, as measured via biosignals of the autonomic nervous system (e.g., heart rate variability, and respiration rate; Ding et al., 2018; Lindstedt & Gray, 2019; Maglio, Wenger, & Copeland, 2008). Furthermore, during a simulated tournament, higher cortisol levels were found for high-ranked Unreal Tournament players immediately before and after a winning match (Oxford, Ponzi, & Geary, 2010). Conversely, measures of game experience and performance in LoL players were unrelated to hormone changes (e.g., cortisol, testosterone, etc.) between playing against humans compared to playing against machine (i.e., artificial intelligence) (Gray, Vuong, Zava, & McHale, 2018).

Additionally, expert Dota 2 and StarCraft II players were found to be significantly better than non-experts at in-game tasks such as mini-map recall, players allocate more time to look at certain regions of the map such as HP/Mana and Shop Button, extrapolating information with one fixation, distinctive use of Hotkey Selects (i.e., keys combination; shortcuts) and the levels of Action Latency (i.e., interval between action and response) (Bonny & Castaneda, 2016; Castaneda, Sidhu, Azose, & Swanson, 2016; Thompson, Blair, Chen, & Henrey, 2013). In Tetris, novice players' ability to place the Zoids (i.e., blocks) seemed to show a lack of the perceptual-motor skills involved in planning and decision making, a difference from experts who are more engaged in the game strategy process (Sibert, Gray, & Lindstedt, 2017).

Mixed evidence has so far been reported regarding the effects of age and amount of practice on expertise. In terms of the amount of practice, authors have found on the one hand that the number of games played in Dota 2 is a strong predictor of expertise (Röhlcke et al., 2018). On the other hand, in LoL, researchers have reported a weak relationship of the number of games played and expertise (Kokkinakis et al., 2017). In regard to the relationship of age and expertise, authors have suggested that there is a cognitive-motor decline in StarCraft II players associated with age that seems to begin around 24 years (Thompson, Blair, & Henrey, 2014). Also, it has been suggested that in Destiny, Battlefield, LoL, and Dota 2, peak performance is experienced at around 22–27 years old (Kokkinakis et al., 2017). However, findings have shown that performance in Battlefield 3 peaks around the age of 20 and that older players show weaker performance and offset this deficiency by practicing more (Tekofsky, Spronck, Goudbeek, Plaat, & van den Herik, 2015; Thompson et al., 2014). These mixed results show that the expertise differences attributable to age and amount of practice should be considered and researched individually for better clarification, as they may be unique to each esport.

In terms of practice and learning styles, establishing consistent habits and forming routines were found to be important characteristics of expert Halo, StarCraft II, and LoL players. Research showed that the most effective strategy to improve players' skills included both playing a moderate number of matches and taking short breaks (Huang et al., 2017; Sapienza, Zeng, Bessi, Lerman, & Ferrara, 2018). Furthermore, Destiny and LoL players who more regularly chose to play with self-selected teammates tended to have higher game performance than those who decided to play with random teammates (Kahn & Williams, 2016; Pirker, Rattinger, Drachen, & Sifa, 2018). Sapienza et al. (2018) also found that individual and team performance in LoL can be affected by the presence of friends on a team.

At the team level, authors have identified specific characteristics of successful teams. For example, Xia, Wang, and Zhou (2017) found in Dota 2 that the frequencies of kills by one player, kills by multiple players, initiation of fights, and activation of runes were significantly higher on the winning teams than on the losing teams. Additionally, it was found that the successful teams in LoL were those that showed the highest scores on the Transactive Memory System Scale, which measures a group's ability to learn, remember, and communicate knowledge relevant to the group (i.e., shared knowledge; Kahn & Williams, 2016). Moreover, Wang, Yang, and Sun (2015) found that those teams that possessed at least one player with a global-liberal playing style, that is, a player who assisted teammates (i.e., collaborative style), had significantly higher win rates than teams without this type of player.

Effects of Esports Participation/Training

Several psychosocial characteristics of participation and training in esports have been shown to affect performance. For example, looking into the cooperative and competitive aspects of FIFA, Dota 2, and LoL players' style, researchers found that players' behaviour, attitudes towards winning and losing, and harmonic and obsessive passion had significant effects on affect and performance (Bertran & Chamarro, 2016; Breuer et al., 2013; Hudson & Cairns, 2016). In regards to the effects of motives for participating in Dota 2, improvement in solo matches (i.e., no predetermined teams) suggests that skill improvement or the sense of personal achievement were primary motivators for playing (Bonny & Castaneda, 2017). Furthermore, exploring CS:GO and WoW participation, studies showed gender and game performance interactions as a predictor of enjoyment, with women deriving enjoyment from discovering the games, while men were more interested in the competition aspect of the games (Billieux et al., 2013; Hopp & Fisher, 2017). Another esports characteristic, the presence of an audience, was shown to decrease players' performance while playing Tetris (Kimble & Rezabek, 1992). However, a positive association between audience presence and improved performance was discovered for the game Quake (Bowman, Weber, Tamborini, & Sherry, 2013). Finally, in Doom, Tafalla (2007) found positive effects of playing with the in-game sound on performance.

Discussion

Beginning in the early 1990s and for almost 30 years since (see Appendix C), researchers have been exploring the psychosocial aspects of competition and cognitive processes in esports. The early works acknowledged that certain video games could facilitate a deeper understanding of human performance. However, it took almost 20 years, from the first study in 1992 until 2010, for 10 studies related to the performance of what we now call esports to be published. Finally, from 2011 to the beginning of 2019, an additional 42 studies were published on esports performance. This systematic review of 52 articles, following the PRISMA-P guidelines, presents the available evidence regarding the psychological aspects of esports performance.

Cognitive Performance in Esports

The mixed effects found for esports training on working memory tasks might have been due to differences in the methodological designs and aims of the studies, with low sample size and the inclusion of many different cognitive tasks possibly affecting the results. The effects of expertise on working memory tasks are in line with the positive effects of esports training and the demands that strategy and FPS esports make in terms of holding and monitoring information. Furthermore, the higher levels of expertise in esports (e.g., LoL, Dota 2, Counter-Strike, etc.) and the activation of the brain networks associated with inhibitory control processes show the importance of information processing for game performance. Although we encourage to understand the specific individual cognitive demands for each esports, it is necessary to acknowledge that there will be an overlap when referring to cognitive functions. For instance, working memory and inhibitory control generally need one another, especially in complex esports such as LoL, StarCraft, and Counter-Strike where there is a vast amount of information available from opponents, teammates, and the game environment. Consequently, players need to assess what information is relevant for their goal, hold it using their working memory capacity, and determine what to inhibit to make favourable decisions.

Despite the mixed evidence found between cognitive flexibility processes and esports, the research is promising to understanding the cognitive demands of changing perspectives and adapting to new information in specific esports. The constant changes in esports like LoL (e.g., creation of new avatars, skills, rules, etc.) force players to find ways to adapt and keep up with those changes, which means structure training methodologies and learning styles are important during this process.

Fluid intelligence positively correlates with experience in LoL players (Kokkinakis et al., 2017), but not in players of the similar game, Dota (Röhlcke et al., 2018). Consequently, these results indicate, first, the importance of considering the uniqueness of each esports (e.g., frequency of game updates) and how this could be associated with specific cognitive demands on players. Second, one must consider the methodological designs of these two studies, which might explain the contrasting results: Röhlcke et al.'s (2018) study that found no effects was not carried out in a controlled environment, which could have affected the reliability of the results. Furthermore, improvements in performance found after Unreal Tournament and CoD training (Bejjanki et al., 2014) might suggest that higher-order functions are related to the more unpredictable and cognitively demanding type of esports.

Overall, researchers have started to recognize that different esports require different cognitive processes and motor abilities. Consequently, esports research and sports psychologists will benefit from understanding the underlying cognitive mechanisms of each esports, in order to adapt training strategies to the specificities of each game. For example, some esports are very stable in the way they need to be played across years or months, while in other esports, very specific characteristics can change every 2 weeks (e.g., LoL) and players are required to adjust, adapt, and learn the new demands of the game, which may require higher levels of cognitive flexibility and higher order functions (e.g., fluid intelligence, decision making, etc.) to achieve peak performance. Brain imaging and psychophysiological tools will facilitate this understanding of cognitive processes and possible predictors of performance among players due to the ecological validity that esports can provide.

Even though we agree that there is increasing empirical evidence of the relationship between playing esports and improved cognitive performance, the mixed evidence and methodological limitations cannot be ignored (e.g., Boot et al., 2008; Klaffehn et al., 2018). Consequently, it is necessary to consider the potential confounding variables of the studies included in this review that could affect the reliability of the results, such as the learning curves of participants (Röhlcke et al., 2018; Tekofsky et al., 2015) that varied according to gender and age (Terlecki et al., 2008; Thompson et al., 2014). Thus, we recommend that esports researchers change the methodology of their research to move away from exploring video games as a genre (e.g., action video games, FPS, MOBA, real-time strategy, etc.) and more towards considering individual esports. For instance, although soccer, basketball, American football, and rugby share many similar characteristics, they are individually quite distinct sports. Consequently, while the overall findings on cognitive performance are promising, they reveal that the way forward is to consider the methodological design issues: A more controlled design of the experiments should be considered that takes into account, for example, individual differences, gender, gaming experience, playing frequency, and nature of the game (Boot et al., 2008; Dale & Green, 2017; Klaffehn et al., 2018). This will lead to a better understanding of task transferability in esports training as well as the cognitive functions underlying performance in each esports.

Game Performance in Esports

The results of our game performance analysis provide several takeaways related to expertise differences and the effects of taking part in esports. First, the findings highlight specific player characteristics that are important when differentiating expertise, particularly in LoL and Tetris, such as fast and accurate decision making and performing under pressure (e.g., Ding et al., 2018; Gray et al., 2018). These characteristics are particularly important when players are competing at the highest levels, where different types of pressure (e.g., time, prizes, expectations, audience, etc.) are present and could define outcomes. Second, results show that there are specific psychological and in-game skills that players can develop to achieve higher levels of performance. Skill development, in particular, seems to be an area where sports psychologists could help in the development of expertise in esports players, particularly as relates to deliberate practice (Ericsson et al., 1993). For instance, in LoL, a performance decline occurs when playing sessions are too long (Sapienza et al., 2018), but experienced players showed fewer performance declines over the course of a session than newer players. Supporting this idea, Halo players showed that less intense and frequent training can result in skill development, but breaks that are too long result in a loss of skill (Huang et al., 2017). Coaches and players can benefit from this crucial information to optimise their training programs according to the characteristics of each esports. Since players experience different performance peaks and declines depending on the esports. For example, StarCraft player suffers from performance declines starting at around 24 years of age (Thompson et al., 2014), in LoL and Dota performance peaks are experienced between 22 and 27 years of age (Kokkinakis et al., 2017), and in Battlefield, a shooting game, peaks are seen at an earlier age: 20 years old (Tekofsky et al., 2015). It is important (a) to consider how players are practicing to improve their skills and (b) to understand the requirements and characteristics of each esport, as, for example, in shooting games more reaction time and attention are needed than in strategy games, where extracting information, planning, and decision making may be more important. In terms of skill acquisition, results are promising, as they show it is possible to implement training models that aid the development of players.

Psychosocial characteristics in esports have been considered to understand how participation or training is related to player behaviour, motivation, affect, and performance. Thus, coaches need to adapt their training methodologies to fulfil players psychological needs, considering the differences in the effects of cooperation and competition concerning gender seen in CS:GO and WoW. Also, in Dota 2 the sense of personal achievement and skill improvement were primary motivators to play (Bonny & Castaneda, 2017). Additionally, the impact of winning and losing in WoW (Hudson & Cairns, 2016) and the psychological characteristic of harmonic and obsessive passion in LoL (Bertran & Chamarro, 2016) show the influence of fulfilling the psychological needs of autonomy, competence and relatedness in relation with future game results. This may be an area where sports psychologists can offer interventions tailored to specific players and the competitive characteristics of esports. Thus, acknowledging the impact of social-cognitive and affective behaviour on esports players could facilitate learning and the optimisation of performance (Wulf & Lewthwaite, 2016).

Given previous findings, future studies should consider an appropriate methodological design that acknowledges specific variables that can alter performance, such as considering randomised and blinded experiments, gender and age differences, game history, and the so-called hybrid games (i.e., games with shared characteristics of two or more genres; Dale & Green, 2017). Similarly, authors have suggested that some games share identical characteristics across genres (e.g., FPS, MOBA, etc.), but some have unique elements that need to be considered individually (e.g., CS:GO; Dale & Green, 2017; Momi et al., 2018). Also, the biosocial influence of competition has to be considered, as playing against the artificial intelligence of the game (i.e., bots) is not the same as playing against humans.

It is necessary to better understand expertise and the performance indicators in esports that could support this developmental process. Consequently, having set the scientific stage for esports psychology, first, future investigations should consider recent appeared papers that may be relevant for the development of esports and its alignment with sport psychology (e.g., Gong, Ma, Liu, Yan, & Yao, 2019; Maciej, Kosakowski, & Kaczmarek, 2020; Thompson, McColeman, Blair, & Henrey, 2019). Second, investigations should test the bidirectional influence of the factors related to esports performance and the strength of their influence and should explore those factors that are theoretically plausible but empirically not yet tested. Such as the interplay of high order functions like decision making and affect to understand expertise differences in esports performance. Thus, we provide a heuristic model to illustrate the current state of the art (see Figure 2).

[Figure 2 near here]

Conclusion

The present systematic review highlights that research in esports could greatly benefit from a closer alignment to the field of sports psychology, leading to a better understanding of the underlying mechanisms of performance, especially by focussing on cognitive functions and game performance. By integrating the two disciplines, each can help the other overcome theoretical and methodological constraints. For example, esports as a field of research can help efforts to reveal cognitive processes involved in performance and understand individual development and can serve as a domain for the use of neurophysiological markers. This review provides a starting point for future research endeavours, because it is the first systematic review following the PRISMA-P guidelines that explores and separates the empirical evidence on general video games (from their inception) from evidence on esports. Although the research in this field is promising, much work remains. Therefore, to promote the development of research on esports performance we offer our list of the top 10 challenges esports performance research will likely face in the future.

Top 10 Future Challenges of the Psychology of Esports Performance

(1) **Implementing rigorous methodological designs:** The research in esports needs to acknowledge the experimental design constraints, already addressed by video game researchers (Dale & Green, 2017), and implement appropriate methodological designs, for instance, avoiding grouping games according to genres, using randomised and blinded experimental designs, and implementing the appropriate statistical power. Also, there is a need to consider homogeneous sample issues (i.e., females and males) and to apply a rigorous criterion for age and video game experience, given the influential differences in cognitive and skill development.

(2) **Acknowledging the impact of cognition in esports performance:** As shown in this review, different esports rely on different cognitive functions and at times the cognitive requirements are unclear. Thus, it is important to understand (a) how cognitive demands change across different esports and how specific cognitive functions could be more relevant for specific games, (b) what specific esports measures could be defined to understand performance, and (c) the contribution of the building blocks of psychology, that is, perception, memory, emotion, and cognition, to esports performance (Raab et al., 2015).

(3) **Identifying performance indicators:** Any esports offers a great range of statistical variables that could be connected to player performance. However, these variables can be misinterpreted, generating incorrect information related to performance. Therefore, it is necessary to understand (a) how game performance

characteristics change across games, and (b) what reliable data or performance measures will lead to an accurate understanding of esports expertise. For instance, in sports expertise, differences have been revealed by the decision making of athletes (Musculus, 2018). Additionally, in auto racing, Formula 1 drivers are known for using telemetry information to optimise the performance of the car; using telemetry in esports (see Thompson et al., 2017) could be an interesting way to understand the great number of parameters that can potentially provide performance indicators of esports, ultimately improving esports players' and coaches' cognitive and motor processes for competition.

(4) **Building expertise in esports:** In sports, deliberate practice has been used to help players systematically optimise improvement and achieve higher levels of expertise (Ericsson, 2019). However, esports is still working on finding reliable systems that help players and coaches improve performance (Green, 2018). Therefore, a big challenge will be to provide adequate tools and structures to help players and coaches learn and improve performance. One example could be to apply the principles of motor learning theory (OPTIMAL; Wulf & Lewthwaite, 2016), in which performance and learning are thought to be influenced by positive motivational and attentional focus. This approach enables players with a safe environment for satisfaction of the psychological need for competence, establishing situations for choice and a sense of autonomy, which aims to provide feedback that focusses on an external focus of attention, and contributes to enhancing expectancies for success.

(5) **Defining career development of esports players:** The current route to excellence in esports is still unclear. So, there are no developmental stages defined or real career plans (Abbott & Collins, 2004). Thus, one of the roles of

sports psychology in esports should be to facilitate (a) the identification of players' career paths, and (b) the adaptation and transferability of skills during different transition stages that esports may have (e.g., leagues, countries, different esports, retirement, etc.). This support can facilitate talent development and proper institutionalization of esports as a performance domain.

(6) **Addressing the needs of coaches and coaching development:** The proper creation of training models that coaches can implement or adapt to their daily practices supports talent development. However, before that, understanding how esports skill acquisition and development work is necessary. Also, educating coaches on how to coach is crucial. Thus, establishing esports coaching courses could be a good first step. Supporting and developing places where coaches could develop themselves, such as in academy teams, could facilitate developmental processes at the professional level where the performance pressure is higher. Providing more opportunities for research and applied sports psychology would help sustain the healthy evolution of esports (Cottrell, McMillen, & Harris, 2018). Thus, the requirement of certification for coaches and managers should be implemented in the future.

(7) **Stopping opportunistic esports enhancement tools:** The development of lucrative opportunistic tools will be likely to increase in the applied field. For example, the large number of publications in low-quality journals and the amount of grey literature in esports is rapidly expanding. Also, the development of cognitive training devices to improve performance has earned a bad reputation. While it is very useful to understand the foundations of esports performance and use innovative tools, it is necessary to avoid the support of unreliable non-scientific knowledge. Thus, there is a need for more quality

research to develop a better understanding of cognitive training in sports (as suggested by Walton, Keegan, Martin, & Hallock, 2018).

(8) **Integrating machine learning models:** Motor learning is an important internal process in the development and retention of skills in sports. This is characterised by a set of stages in which cognition is highly relevant to determining appropriate strategies that influence learning processes (e.g., mental practice, observational learning; Schmidt, Lee, Winstein, Wulf, & Zelaznik, 1999). In esports, the proper understanding and use of algorithms and statistical models for performance could greatly advance the development of psychological and cognitive tools that can positively impact performance and training methodologies and facilitate the comprehension of the cognitive and motor behaviour of esports expertise (Lindstedt & Gray, 2019). However, suitable comprehension and multidisciplinary collaboration are essential to make good use of technological advances.

(9) **Developing knowledge from biological markers:** The high ecological validity of the esports setting for neurophysiological research of performance is undeniable. Consequently, developing an understanding of the psychophysiological and neuropsychological aspects of esports players is an appealing avenue of research for the scientist (Campbell et al., 2018; Murphy, 2009). Thus, future research on biological markers should be carried out. Understanding the interplay of cognitive and behavioural performance in esports could be facilitated by studies on, for instance, hormone responses and heart rate variability and by making use of brain stimulation techniques, eye tracking, and brain activation measures such as electroencephalography and functional magnetic resonance imaging.

(10) **Understanding the impact of a rapidly changing esports system:** Esports is evolving into a high-performance environment where coaches and players are required to implement appropriate structures and models to achieve higher levels of performance (Pedraza-Ramirez, 2019). This continuous evolution could be a challenge in its own right from a research and applied sports psychology perspective (Cottrell et al., 2018; Steinkuehler, 2019). Even though the introduction of expert knowledge from traditional sports into esports is required to develop sustainable performance, there have been a few cases where this introduction has failed (Green, 2018). Consequently, understanding the specific cultural characteristics of each esport itself is necessary to contribute to the transfer of expert knowledge to esports systems.

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Figure captions

Figure 1. Flow diagram of the article-identification process following the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols.

Figure 2. Heuristic model of esports performance, depicting the bidirectional influence of esports cognitive and in-game factors of performance. All constructs could be connected but are not display in the figure.

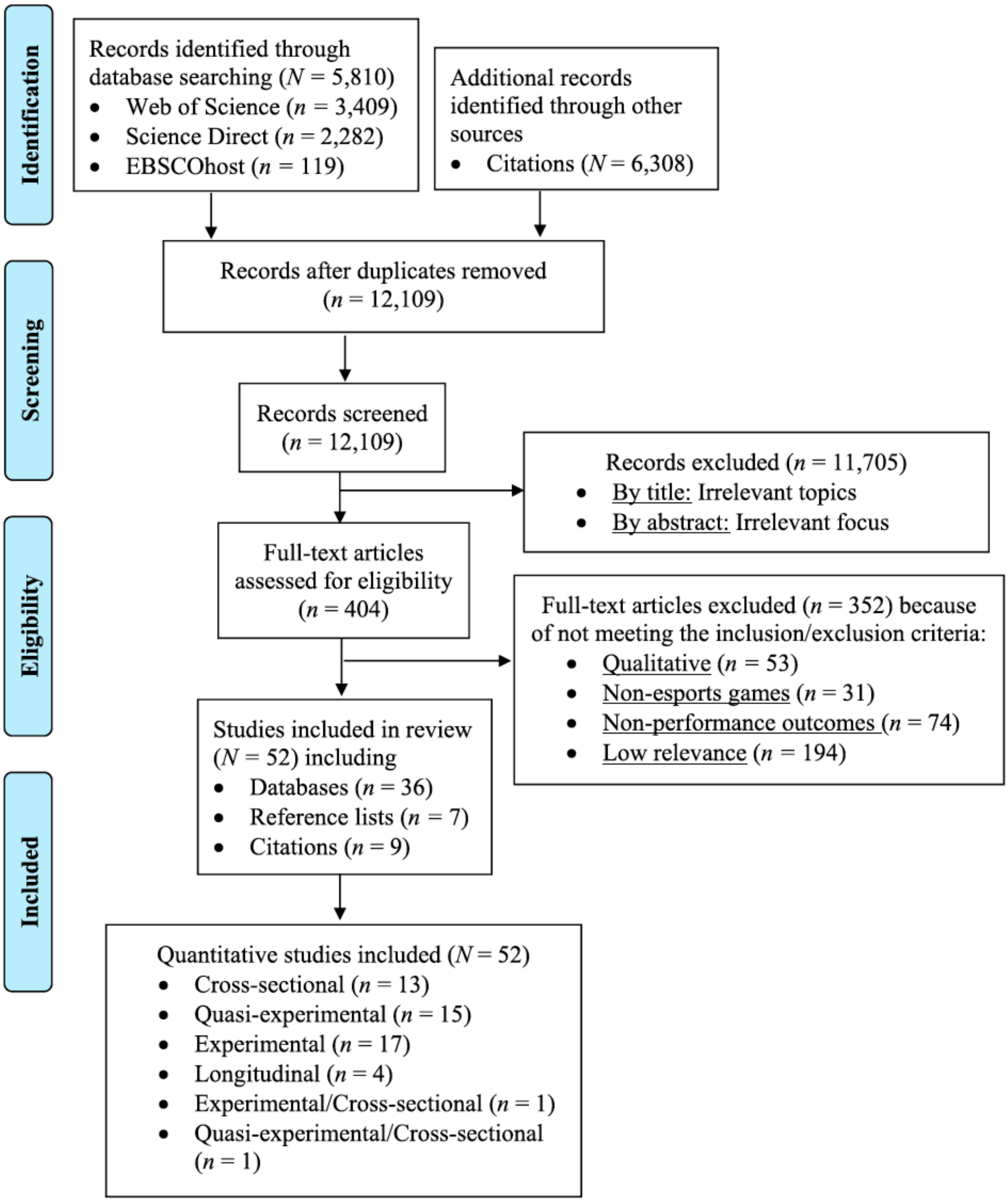
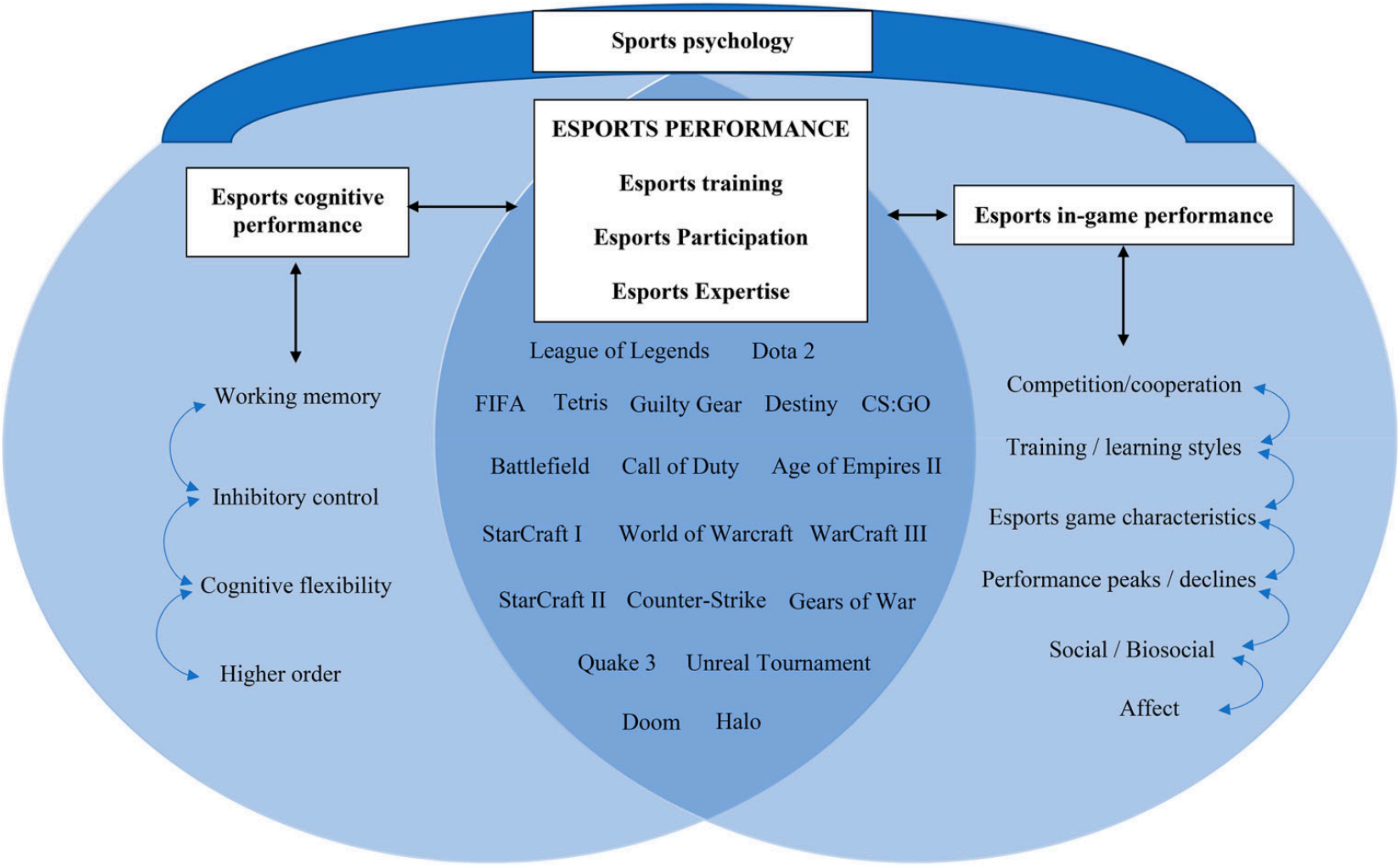


Figure 1. Flow diagram of the article-identification process following the preferred reporting items for systematic review and meta-analysis protocols.



1255 **Figure 2.** Heuristic model of esports performance, depicting the bidirectional influence of esports cognitive and in-game factors of performance.

Table 1. Esports games

Game genre[a]	*Esports game*[b]	*Release date*	*Tournaments*[c]	*Participating players*[d]
Fighting games	Super Street Fighter Series	1994	255	297
	Guilty Gear Series*	1998	77	262
	Street Fighter Series	1999	120	518
	Super Smash Bros. Series	1999	3701	3452
	Marvel vs. Capcom Series	2000	41	108
	Tekken Series	2002	227	350
	Killer Instinct	2013	43	120
Real-time strategy (RTS) games	Age of Empires Series*	1997	205	549
	StarCraft: Brood War	1998	536	642
	WarCraft III *	2002	1286	563
	World of WarCraft (WoW)*	2004	115	406
	StarCraft II*	2010	5308	1895
Shooters: First-person shooters (FPSs) and *third-person shooters (TPSs)*	Doom Series*	1994	7	21
	Quake Series*	1996	769	829
	Unreal Tournament Series*	1999	39	118
	Call of Duty Series (CoD)*	2003	930	2919
	Halo Series*	2004	284	887
	Painkiller	2004	13	48
	Battlefield Series*	2006	169	224
	Rainbow Six: Vegas	2006	7	137
	Counter-Strike (CS)*	2000	894	3677

Game genre[a]	*Esports game*[b]	*Release date*	*Tournaments*[c]	*Participating players*[d]
	Counter-Strike Series Global Offensive (CS:GO)*	2012	3870	11119
	Gears of War Series*	2006	34	182
	CrossFire	2007	292	600
	Team Fortress 2	2007	131	795
	Rainbow Six: Siege	2015	58	435
	Overwatch	2016	631	2925
	Fortnite	2017	173	1426
	PlayerUnknown's Battlegrounds (PUBG)	2017	116	1319
	Apex Legends	2019	6	72
Multiplayer online battle arenas (MOBAs)	League of Legends (LoL)*	2009	2208	6125
	Defense of the Ancients (Dota 2)*	2013	1062	2859
	Smite	2014	94	513
Sports games	FIFA Series*	1999	879	1399
	Madden NFL Series	2003	15	114
	Pro Evolution Soccer Series	2003	36	102
	Rocket League	2015	259	502
	NBA 2K	2017	3	78
Racing	TrackMania	2006	146	196
	iRacing	2008	45	317
	Project CARS	2015	8	19
	F1 esports Series (simulation racing)	2017	2	44

Game genre[a]	*Esports game*[b]	*Release date*	*Tournaments*[c]	*Participating players*[d]
	NASCAR Heat 3	2018	1	32
Mobile	Vainglory	2014	35	247
	Arena of Valor	2015	24	260
	Clash Royale	2016	27	133
	PlayerUnknown's Battlegrounds (PUBG)	2017	6	90
Other	Tetris*	1989	7	232
	Hearthstone	2014	821	2116

Notes. [a]Authors doing action video game research usually combine games from the RTS, FPS, and MOBA genres. [b]Games with an asterisk were found in publications included in the review. [c]Exact number of official tournaments could vary (taken from www.esportsearnings.com; data retrieved January 2019. [d]Exact number of official players of the tournaments could vary (taken from www.esportsearnings.com; data retrieved January 2019.

Table 2. PICO model of the systematic review

Population	Intervention/Phenomena	Comparators	Outcomes
Esports games, general healthy human population research, excluding older adult population and machine modelling or artificial intelligence	Psychological aspects of cognitive and game performance. We included papers that exclusively tested esports games.	(1) Expertise level (2) Differences between players and non-players in cognitive and game performance (3) Differences between games in cognitive and game performance.	Esports performance: (a) Cognitive performance: participants' behaviour from measures of cognitive processes in a laboratory setting associated with esports games. (b) Game performance: winning or losing, placement in a ranking system, points scored, KDA, gold acquired per minute, etc.

Note. KDA = In-game kill–death–assist ratio.

Table 3. Cognitive performance

Study (first author)	Year	Esports game[b]	Purpose of study	No. of participants	Study design	Cognitive function	Biological marker
Okagaki[a]	1994	Tetris	Effects of esports participation	Exp. 1: N = 57; Exp. 2: N = 53	Experimental	WM	–
C.S. Green[a]	2007	Unreal tournament 2004 / Tetris	Effects of esports training	Exp. 2: N = 32	Experimental	WM	–
Terlecki	2008	Tetris	Effects of esports training	N = 180	Quasi-Experimental	WM	–
Tanaka	2013	Guilty Gear	Expertise differences	N = 50	Quasi-experimental	WM	GM volume
Pereira	2016	LoL	Expertise differences	N = 5 pro players	Experimental	WM	HR
Chang	2017	LoL	Expertise differences	N = 116	Quasi-experimental	WM	–
Bonny[a]	2017	Dota 2	Effects of esports participation	N = 288	Quasi-experimental	WM	–
Kowalczyk	2018	StarCraft II	Expertise differences	N = 62	Quasi-experimental	WM	WM structure
Aliyari	2015	FIFA 15	Effects of esports participation	N = 32	Experimental	IC	Cortisol, brainwaves
Qiu	2018	LoL	Expertise differences	N = 29	Experimental	IC	N1, N2, P2, P3
Hyun	2013	StarCraft	Expertise differences	N = 23 pro players	Experimental	CF	Cortical thickness
Klaffehn	2018	Age of Empires II, LoL, Dota 2, StarCraft II, Battlefield, CS:GO, CoD, Counters-Strike	Effects of esports participation	N = 1,155	Quasi-experimental	CF	–
C.S. Green[a]	2003	Tetris	Effects of esports training	Exp. 5: Exp. group: n = 8; control: n = 8	Experimental	WM, IC	–

Study (first author)	Year	Esports game[b]	Purpose of study	No. of participants	Study design	Cognitive function	Biological marker
C.S. Green[a]	2006	Tetris, Unreal Tournament	Effects of esports training	Exp. 2: *N* = 17 Exp. group: *n* = 9; control: *n* = 8; Exp. 5: *N* = 32 Exp. group: *n* = 16; control: *n* = 16	Experimental	WM, IC	–
Hubert-Wallander	2011	Halo, CS:GO, Gears of War, CoD	Expertise differences	Exp. 1: *N* = 20 / Exp. 2: *N* = 34	Quasi-Experimental	WM, IC	–
Bavelier	2012	Halo, Counter-Strike, Gears of War, and CoD	Expertise differences	*N* = 26	Quasi-Experimental	WM, IC	Fronto-parietal network
Bowman[a]	2013	Quake 3	Effects of esports participation	*N* = 62	Quasi-experimental	WM, IC	–
Gong	2016	LoL / Dota 2	Expertise differences	*N* = 45	Quasi-experimental	WM, IC	SN, CEN
Seya[a]	2016	CoD, Halo, and Battlefield	Expertise differences	Exp. 1: *N* = 29; Exp. 2: *N* = 8; Exp. 3: *N* = 7	Quasi-experimental	WM, IC	–
Pilegard[a]	2018	Tetris	Effects of esports training	Study 1: *N* = 49; Study 2: *N* = 17	Quasi-experimental	WM, IC	–
Kokkinakis[a]	2017	LoL, Dota 2, Destiny, Battlefield	Expertise differences	Study 1: *N* = 56; Study 2: *N* =28,559	Quasi-experimental / Cross-sectional	WM, HO	–
Lau-Zhu[a]	2017	Tetris	Effects of esports participation	*N* = 46	Experimental	WM, HO	–
Röhlcke[a]	2018	Dota 2	Expertise differences	*N* = 304	Cross-sectional	WM, HO	–
Ding[a]	2018	LoL	Expertise differences	*n* = 10 pro players; *n* = 10 semi-pro	Experimental	IC, CF	Frontal midline theta, frontal alpha asymmetry,

Study (first author)	Year	Esports game[b]	Purpose of study	No. of participants	Study design	Cognitive function	Biological marker
				trainees; *n* = 20 students			occipital alpha, HR, HRV, respiration rate
Bejjanki	2014	Unreal Tournament 2004, CoD	Effects of esports training	Exp 2. *N* = 26 participants; long-term retention: *n* = 16	Quasi-experimental	IC, HO	–
Boot[a]	2008	Tetris	Effects of esports training	*N* = 20	Longitudinal	WM, IC, HO	–
Momi[a]	2018	CS:GO	Effects of esports training	*N* = 29; follow-up *N* = 29	Quasi-experimental	WM, CF, HO	Cortical thickness
Glass[a]	2013	StarCraft I, II	Effects of esports training	*N* = 72	Experimental	CF, IC, WM	–

Note. Cognitive functions: CF = cognitive flexibility; HO = higher order; IC = inhibitory control; WM = working memory. Biological markers: GM volume = grey matter volume; HR = heart rate; HRV = heart rate variability; N1, N2, P2, P3 = event-related potentials; SN = salience network; CEN = central executive network; WM structure = white matter structure.

[a] Studies selected in both categories: cognitive and game performance.

[b] Full names of all games discussed in this review can be found in Table 1.

Table 4. Game performance

Study (first author)	Year	Esports game[b]	Purpose of study	No. of participants	Study design	Performance domain	Biological marker
Maglio	2008	Tetris	Expertise differences	Exp. 1–3: *N* = 30, 32, and 30; Exp. 4: *N* = 15	Cross-sectional	Other	–
Oxford	2010	Unreal Tournament 2004	Expertise differences	*N* =42	Experimental	Result	Testosterone, cortisol
Thompson	2013	StarCraft II	Expertise differences	*N* = 3,360; Survey: *N* = 3,305	Cross-sectional	Other	–
Thompson	2014	StarCraft II	Expertise differences	*N* = 3,360	Cross-sectional	Other	–
Tekofsky	2015	Battlefield 3	Expertise differences	*N* = 10,942	Cross-sectional / Longitudinal	Other	–
Wang	2015	LoL	Expertise differences	Main: *N* = 185,158; post: *N* = 26	Cross-sectional	Other	–
Bonny	2016	Dota 2	Expertise differences	*N* = 171	Quasi-experimental	Rank	–
Castaneda	2016	Dota 2	Expertise differences	*N* = 64	Experimental / Cross-sectional	Rank	AOI
Kahn	2016	LoL	Expertise differences	*N* = 16,499	Cross-sectional	Other	–
Huang	2017	Halo Reach, StarCraft II	Expertise differences	*N* = 3.2 million Halo players	Cross-sectional	Other	–
Kokkinakis[a]	2017	LoL, Dota 2, Destiny, Battlefield	Expertise differences	Study 1: *N* = 56; Study 2: *N* = 28,559	Quasi-experimental / Cross-sectional	Rank / KDA	–
Sibert	2017	Tetris	Expertise differences	*N* = 67	Cross-sectional	Result	–
Thompson	2017	StarCraft II	Expertise differences	*N* = 3,317	Cross-sectional	Other	–

Study (first author)	Year	Esports game[b]	Purpose of study	No. of participants	Study design	Performance domain	Biological marker
Xia	2017	Dota 2	Expertise differences	*N* = 370 pro players; *n* = 37 replays pro games	Cross-sectional	Other	–
Ding[a]	2018	LoL	Expertise differences	*N* = 40	Experimental	Other	Frontal midline theta, frontal alpha asymmetry, occipital alpha, HR, HRV, respiration rate
Gray	2018	LoL	Expertise differences	*N* = 26	Experimental	Rank / KDA	Testosterone, cortisol, DHEA, androstenedione, aldosterone
Pirker	2018	Destiny	Expertise differences	*N* = 10,000	Cross-sectional	Other	–
Röhlcke[a]	2018	Dota 2	Expertise differences	*N* = 304	Cross-sectional	Rank	–
Sapienza	2018	LoL	Expertise differences	*N* = 16,665	Longitudinal	Other	–
Lindstedt	2019	Tetris	Expertise differences	*N* = 240	Experimental	Other	–
C.S. Green[a]	2003	Tetris	Effects of esports training	Exp. 5: Exp. Group: *n = 8;* Control: *n* = 8	Experimental	Result	–
C.S. Green[a]	2006	Tetris	Effects of esports training	*N* = 17 Exp. group: *n* = 9; Control: *n* = 8	Experimental	Result	–
Boot[a]	2008	Tetris	Effects of esports training	*n* = 20	Longitudinal	Result	–
Glass[a]	2013	StarCraft I, II	Effects of esports training	*N* = 72	Experimental	Other	–

Study (first author)	Year	Esports game[b]	Purpose of study	No. of participants	Study design	Performance domain	Biological marker
Seya[a]	2016	CoD, Halo, Battlefield	Effects of esports training	$N = 8$	Quasi-experimental	Result	–
Momi[a]	2018	CS:GO	Effects of esports training	$N = 29$; follow-up $N = 29$	Quasi-experimental	KDA	Cortical thickness
Pilegard[a]	2018	Tetris	Effects of esports training	Study 1: $N = 49$; Study 2: $N = 17$	Quasi-experimental	Result	–
Kimble	1992	Tetris	Effects of esports participation	$N = 46$	Experimental	Result	–
Okagaki[a]	1994	Tetris	Effects of esports participation	Exp 1.: $n = 57$; Exp 2.: $n = 53$	Experimental	Result	–
C.S. Green[a]	2007	Unreal Tournament 2004 / Tetris	Effects of esports participation	Exp. 2: $N = 32$	Experimental	KDA	–
Tafalla	2007	Doom	Effects of esports participation	$N = 73$	Experimental	KDA	SBP, DBP, HR
Billieux	2013	WoW	Effects of esports participation	Prestudy: $N = 1{,}059$; main: $N = 690$	Longitudinal	Other	–
Bowman[a]	2013	Quake 3	Effects of esports participation	$N = 62$	Quasi-experimental	KDA	–
Breuer	2013	FIFA World Cup 2010	Effects of esports participation	$N = 76$	Experimental	Result	–
Bertran	2016	LoL	Effects of esports participation	$N = 369$	Cross-sectional	KDA	–
Hudson	2016	Study 1. Dota 2, WarCraft III	Effects of esports participation	Study 1: $N = 18$	Experimental	Result	–
Bonny[a]	2017	Dota 2	Effects of esports participation	$N = 288$	Quasi-experimental	Rank	–
Hopp	2017	CS:GO	Effects of esports participation	Prestudy: $N = 114$; main: $N = 104$	Cross-sectional	KDA	–

Study (first author)	Year	Esports game[b]	Purpose of study	No. of participants	Study design	Performance domain	Biological marker
Lau-Zhu[a]	2017	Tetris	Effects of esports participation	*N* = 46	Experimental	Result	–

Note. AOI = areas of interest; DBP = diastolic blood pressure; DHEA = dehydroepiandrosterone; HR = heart rate; HRV = heart rate variability; KDA = kills, deaths, assists; SPB = systolic blood pressure; Other = in-game measures (e.g., hotkey usage, last hitting, earned/spent gold).

[a] Studies selected in both categories: cognitive and game performance.

[b] Full names of all games discussed in this review can be found in Table 1.