Performance-influencing factors in esports: a review*

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Abstract

With the development of the video game industry during the last decade, esports has rapidly grown in global culture and industry. Fundamentally different from traditional physical sports, esports heavily relies on digital technology and is facilitated by human-computer interaction. While players' performance has been a central topic in esports research, there still lacks a comprehensive synthesis of the factors contributing to better esports performance in formal matches and training sessions. Therefore, this study systematically reviews the extant literature related to factors influencing esports players' performance. Seven themes are identified from 21 reviewed quantitative articles including equipment-related, nutritional supplements, individual attributes, training, team-related, environmental, and geopolitical factors. The effects of these esports performance-influencing factors are further synthesized and discussed based on empirical evidence. Furthermore, we propose theoretical, thematic, and methodological agendas for future esports studies. The findings of this study contribute to building a foundation for a systematic understanding of esports performance.

Keywords

Esports performance, esports athletes, competitive gaming, professional gamers, literature review

1. Introduction

Esports, broadly known as organized and competitive gaming [1 - 3], is a new competition in which electronic systems mediate players' inputs and outputs via human-computer interfaces [4]. Popular esports genres include shooting games like Counter-Strike, multiplayer online battle arena games such as DOTA 2, battle royale games such as PUBG: Battlegrounds, and real-time strategy games such as Starcraft-II. Over the past 20 years, the esports industry has witnessed profitable growth and generated 2 billion dollars in global revenue [5]. Shortly after the inaugural Olympic Esports Week, the 19th Asian Games debuted esports as a medal sport, highlighting the potential to recognize esports as a new sports discipline.

Athletic performance involves a series of physical behaviors and movements to achieve specific goals in sports [6], determined by athletes' skills and abilities including understanding tactics, personal techniques, physiological functions, and psychological skills [7, 8]. In contrast to traditional sports where performance is primarily defined in the 'physical world', esports performance is manifested in states of electronic and digital systems through control of interactive technologies and devices. Therefore, esports has been considered as a typical human-computer interaction (HCI) activity [9] and can be explained by the HCI Loop (see Figure 1). By referring to previous studies [10 - 12], this adapted HCI Loop illustrates how users interact and respond to the computer system. Therefore, from a technological point of view, we can define esports performance as gaming programs' feedback or reaction to human response via input devices.

Research on factors affecting esports performance has accumulated throughout the last years from multiple subject areas. For example, some nutritional supplements and orally taken performance enhancers could improve aiming performance by reducing reaction time [13, 14]. Thompson et al., [15] found that Starcraft II players' reaction time started to slow down around 24

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years old, indicating the impact of age on esports performance. The advantages of using advanced computer accessories, such as monitors with high refresh rates, have been found as well [12]. However, efforts to model esports performance systematically are still scarce. Nagorsky & Wiemeyer's esports performance model [16], which combines a game competence model [17] and a sports performance model [18], is probably one of the only few so far. It breaks down esports performance into seven sections: 1) tactical-cognitive abilities, such as working memory; 2) coordination, such as visual and acoustic perception; 3) psychic abilities, such as emotional control; 4) social abilities, such as communication; 5) conditioning, such as endurance; 6) demographic features, such as age; 7) media competencies, such as the skills to handle mouse and adjust monitor settings. While analyzing the human side in detail, this model seems to neglect some important factors on the technical side that are beyond players' control. For example, the network connection between the game server and players' computers, as well as some unique functions of computer accessories, may have significant effects on esports performance. Therefore, this literature review aims to create an overview of the existing body of literature on factors affecting esports performance. The results of this review aim to pave the way forward in understanding esports performance and identify challenges and opportunities for future research.

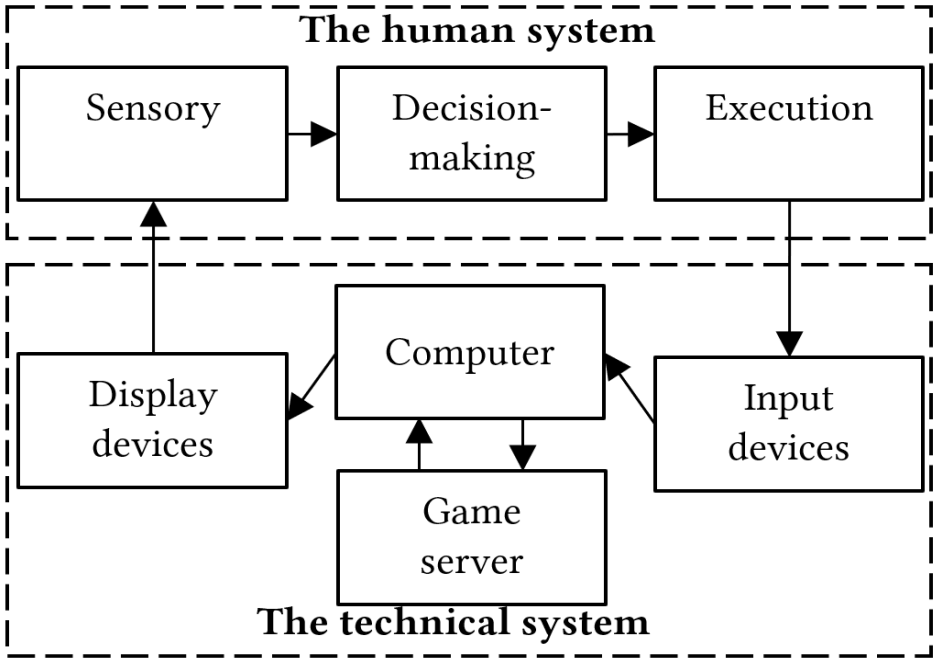

Figure 1: The HCI loop.

2. Review methods

This review is conducted by referring to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [19], which offers a systematic and standardized framework for review-type studies. We used Scopus as the only database because using multiple databases, with different structures and searching queries, might generate potential errors and make the search results inconsistent. Scopus, as one of the largest databases for peer-reviewed literature, can ensure that the articles to be reviewed maintain relatively high academic quality. The following search query was formed as the following:

"(TITLE-ABS-KEY ("competitive gam*" OR cybersport* OR "digital sport*" OR "electronic athlete*" OR "electronic sport*" OR esport* OR "esport* athlete*" OR "esport* expert*" OR "esport* player*" OR e-athlete* OR e-sport* OR "internet sport*" OR "online sport*" OR "professional gam*" OR pro-gam* OR "virtual sport*") AND TITLE-ABS-KEY (abilit* OR capabilit* OR competenc* OR

expert* OR performanc* OR practic* OR proficien* OR prowess OR skill* OR "skill* level*" OR succes* OR train*)) AND (LIMIT-TO (LANGUAGE , "English"))".

The search query consists of two core keyword sets referring to esports and performance. The synonyms of esports are retrieved from a study by Scott et al., [20] and esports is performed by players who are the core stakeholders of the esports industry [21]. To date, the boundaries between esports players at different skill levels have not been clearly defined. However, esports researchers seem to agree on the features of professional esports athletes, who represent the highest skill level [22]. For example, having a working contract with an esports team [23 - 27], competing in international-level events [26, 28 - 31], earning income via playing esports [29, 32], the hours in training and competition [32 - 34]. Because of the esports skill gap, professional esports athletes and amateurs might react differently to some performance-influencing factors. To minimize the discrepancies in research results caused by research participants' different esports skill levels and maintain the esports professionalism of this review, the selected articles should either recruit self-claimed (semi)professional athletes or study esports match results at an international, national, college, or local level. While performance can be directly evaluated via esports match records such as wins/losses and in-game statistics (e.g., kill-death ratio), it can be also measured using training programs (e.g., Aimlab or the training mode in Counter-Strike), or cognitive tests (e.g., go-no-go test) [35, 36]. In addition, esports performance should be measured clearly as the outcomes or dependent variables in selected articles because this study focuses on how other variables influence esports performance, not the effects of esports performance on other aspects. In this study, we review papers by quantitative research approaches that clearly indicated influencing factors and examined their effects on esports performance. The selection of quantitative studies can ensure consistency in synthesizing results and provide reliable and objective outcomes based on statistical analyses.

3. Results

The search was conducted on 2024 August 31st and yielded 2825 records. After the screening process shown in Table 1, 21 records were included in the final review. The publication years of the included articles are presented in Table 2. 17 of the 21 reviewed articles were published after 2021, indicating larger than expected recency in the accumulation of literature. According to the Scopus subject area categorization, the included articles are published under nine disciplines (see Table 3), with most publications under Medicine (n = 5) and Computer Science (n = 4). In terms of research methodology, 10 adopted interventional designs and 11 adopted non-interventional designs. Table 4 presents the game genre and title specialization of the researched participants and matches. The most popular genre is shooting games such as Counter-Strike (n = 7). Regarding esports performance, 11 of the reviewed articles measured performance via cognitive tasks or training programs while the other 10 articles directly evaluated the performance by esports match results such as the match wins and kill-death ratio. In the following sections, detailed analyses and discussions are provided on how different factors have been researched across seven identified themes including equipment-related factors, nutritional supplements, individual attributes, training, team-related, environmental, and geopolitical factors. The results involving significant and non-significant effects on different esports performance contexts are presented in both Table 5 and Table 6.

Table 1
The screening process

Step	Description	Amount
1	Search query applied	2825
2	Removing duplicates	(−32)
3	Articles off the topic, such as game theory, traditional sports performance, esports broadcasting	(−2545)
4	Not full paper or not access; not written in English; not empirical study; review-type articles; no or very simple results	(−14)
5	Research participants were self-claimed (semi)professional esports athletes, and researched esports matches were at either international, national, college, or city level.	(−191)
6	Articles that do not report quantitative results	(-7)
7	Esports performance was measured by either esports match records or results in training tasks	(−14)
8	Esports performance was measured as the outcome or dependent variable	(−1)
9	One round of backward and forward citation search	(+1)
10	Total included articles	21

Table 2
The publication year of the 21 included articles

Publication year	# of articles
2013	1
2019	1
2020	1
2021	1
2022	4
2023	6
2024	7

3.1. Equipment-related factors

Among the reviewed papers, only two examined the influence of equipment-related factors – the attributes of gaming mice [29, 31]. In the study by Li et al., [29], the Logitech G Pro Wireless Optical Gaming Mouse was applied and the mouse weight, 80g or 87g, was manipulated by adding or removing a 7g weight block to the mouse chassis. When using the lighter mouse, improvement was observed in movement time per target (506 vs 510 ms) and error rate (7.2 vs 7.8 %) in the Fitts' task, but the mouse weight was not significant for both performance measurements. In a similar study by the same authors [31], they tested the effects of both mouse weight and connection method (wireless vs wired) using the same gaming mouse. While less mouse weight was positively correlated to better performance in task finishing time and error rate without statistical significance, mixed results were found in the connection method. When using the wireless mouse than the wired one, participants performed better in error rate (8.36 vs 9.41 %, with statistical significance) but worse in movement time (497.44 vs 485.29 ms, without statistical significance). Based on participants' subjective preferences, wireless connection and lighter weight were favored respectively. However, when these two factors were combined, the 87g-wireless combination received the highest ratings.

3.2. Nutritional supplements

Three papers discussed the effects of caffeine on esports performance. In the study by Wu et al., [49], three cognitive tests were conducted to test the effects of caffeine. In the color-word Stroop task, the caffeine group outperformed the placebo group in four test items, with the only statistically significant improvement observed in the reaction time in the congruent condition. In the visual search test, the caffeine group's 20-item search reaction time was shorter than the placebo trial with statistical significance; however, the placebo group outperformed the caffeine group in the 5-item and 15-item visual search, with no statistical significance. In the 3D aim trainer-Burst Flick shooting test, the caffeine group performed significantly better than the placebo group in kill ratio, accuracy, and average time to target. Similar results were found in the study by Sainz et al. in which the caffeine group performed better than the placebo group in a simple reaction and a shooting test, both with statistical significance [14]. In the study by Thomas et al. [37], the caffeine group was treated with an energy drink that contained about 150mg caffeine rather than directly taking caffeine. Research participants were required to play three League of Legends games and take cognitive tests before being treated with an energy drink or placebo and after each game. Both the caffeine and the placebo group performed inconsistently across the four test points and the caffeine group did not perform significantly better than the control group in all test items.

3.3. Individual attributes

3.3.1. Physiological factors

Three studies investigated the relationship between physiological factors and esports performance. Hyun et al., [46] studied the brain structures of 23 professional StarCraft athletes with a high-resolution magnetic resonance scan. A significant positive correlation between the cortical thickness in the right superior frontal gyrus and the winning rate of professional StarCraft matches was found but no significant correlation between the cortical thickness of other brain areas and the winning rate was found.

Table 3
The 21 included articles by subject area

Subject area	Articles
Medicine (n=5)	[31, 37 - 40]
Computer Science (n=4)	[29, 41 - 43]
Psychology (n=3)	[44, 45, 54]
Neuroscience (n=2)	[14, 46]
Engineering (n=2)	[47, 48]
Multidisciplinary (n=1)	[49]
Environmental Science (n=1)	[50]
Business, Management and Accounting (n=1)	[51]
Social Sciences (n=1)	[52]
Biochemistry (n=1)	[53]

Parshakov et al., [38] collected 821 professional Counter-Strike athletes' profiles and match records from HLTV, a leading Counter-Strike database. They analyzed the relationship between players' body mass index (BMI), estimated by face-based artificial intelligence, and players' performance, measured by the HLTV rating. In matches no more than 28 rounds, athletes with lower BMIs performed better than those with higher BMIs on average; however, in matches more than 28 rounds, athletes with obesity of Class III outperformed all other BMI. In another study [41], seven team captains wore heart rate measurement belts when playing at a Team Fortress 2 event in Moscow, and a negative but non-significant correlation between increased heart rate and match wins was observed.

3.3.2. Psychological factors

Four of the 21 reviewed articles investigated psychological factors, focusing on stress. Stress has been identified as a type of high-arousal affective state as a response to demands for change [55]. Sharpe and his colleagues tested the effects of pressure on esports performance [45]. The first experiment consisted of 33 national-level and 57 university-level Counter-Strike athletes. Participants were required to complete a Counter-Strike task that recorded the task-finishing time and the shooting accuracy. The high-pressure condition was manipulated via five stressors, respectively 1) emphasizing the importance of the training tasks, 2) informing participants that their performance would be watched by others, 3) informing participants that all participants' scores would be compared against each other on a public scoreboard, 4) displaying five professionals' test results and three "fictional" test results, 5) informing that low-performing participants would be interviewed. The low-pressure group was offered with no specific guidance. The results showed that both national-level and university-level athletes performed worse in high-pressure than low-pressure situation with statistical significance but national athletes were less affected. The second experiment tested a different high-pressure situation, with another 28 national-level athletes. Some viewers were invited to watch the experiment in person and

participants were frequently criticized for their performance while playing. The performance-inhibiting effects of high pressure were also found in the second experiment, with statistical significance.

Table 4
Included articles by participants' specialization

Game genre and title	Articles
Shooting games (n=13)	[14, 29, 31, 38, 41, 43 - 45, 48, 49, 52 - 54]
Counter-Strike (n=7)	[14, 38, 44, 45, 48, 52, 54]
Overwatch (n=2)	[29, 31]
Team Fortress 2 (n=2)	[41, 43]
Fortnite (n=1)	[14]
Not specified (n=2)	[49, 53]
Multiplayer online battle arena (n=4)	[37, 42, 50, 51]
League of Legends (n=3)	[37, 42, 50]
DOTA 2 (n=1)	[51]
Real-time strategy (n=1)	[46]
Starcraft II (n=1)	[46]
Fighting games (n=1)	[47]
Super Smash Bros (n=1)	[47]
Not specified (n=2)	[39, 40]

Sharpe and his colleagues conducted another study on how arousal reappraisal influences esports performance under pressure [44]. Arousal reappraisal is a stress-coping method that instructs people to perceive stress as a performance enhancer rather than an inhibitor [56]. 44 university-level Counter-Strike e-athletes were divided into two groups. The arousal reappraisal group read a printed arousal reappraisal instruction that guided them to perceive stress positively, like "The increase in arousal you may feel during stressful situations is not harmful. In fact, recent research has shown that this response to stress can be beneficial and aid performance in stressful situations"; the control group read a printed document about birds with roughly the same word count. Right after the intervention, a high-pressure situation similar to Sharpe's previous study [45] was applied. The results showed that the arousal reappraisal group outperformed the control group with a faster finish time without statistical significance, and better shooting accuracy with statistical significance. The relationship between pre-competition arousal, an indicator of perceived stress level, and match results was also found by Nolla et al. [47] in a national-level Super Smash Bro tournament. Before each match, competitors' pre-competition arousals were measured and the results showed that higher pre-competition arousal was associated with loss, with statistical significance.

In the study by Trotter et al., [54], self-regulation was found to mediate the impacts of reappraisal on esports performance. Self-regulation is the human ability to control and regulate one's behavior against any incentive [57, 58]. In this study, the demand-resource evaluation score (DRES) developed by Tomaka et al., [59] was used to assess participants' reappraisals and the self-regulation questionnaire (SRQ) by Brown [60] was applied to measure participants' self-regulation ability. A Counter-Strike training task was used to evaluate esports performance. During the data collection, 53 Counter-Strike athletes were instructed with the following steps: 1) finishing the SRQ; 2) getting familiar with the Counter-Strike task; 3) completing the DRES; 4) playing four rounds of the Counter-Strike task with a one-minute break between every two rounds. The mediation analyses showed that self-regulation significantly mediated the relationship between reappraisal and esports performance.

The effects of emotion on esports performance are supported by three studies. Mateo-Orcajada et al. [42] conducted a longitudinal study to observe whether pre-game iceberg profile was correlated with match wins. The Iceberg profile is an emotional state when vigor outweighs negative emotions [61]. The existence of the iceberg profile was calculated by the Profile of Mood States (POMS) questionnaire that measures 6 types of emotions - tension, depression, anger, vigor, fatigue, and confusion [62]. Five athletes from one of the participating teams in the League of Legends SuperLiga Orange league were invited to join this study. The data collection lasted about three months covering all eighteen matches in the spring season. Participants individually completed the POMS questionnaire before and after every match. 50 observations without pre-game iceberg profiles and 40 with pre-game iceberg profiles were found. Participants' average kill-death-assist ratio, a key performance indicator, was only slightly higher without statistical significance in situations without pre-game iceberg profiles than with pre-game iceberg profiles. Orlova et al., [48] and Abramov et al., [43] collected participating teams' voice recordings in two esports events and analyzed those data with machine learning and acoustic databases. A positive but non-significant correlation between positive emotion and match wins was found in both studies.

3.4. Training programs

Muhid et al., [53] tested whether physical reaction time training programs improved esports athletes' esports reaction time. In this study, 10 participants formed the training group and took a four-week physical reaction time training program, while the other 10 formed the control group. Both groups took a reaction time test before and after the physical reaction time training program via Aimlab, which is a popular training software for practicing shooting games. A statistically significant improvement in mean reaction time was observed in the training group but not in the control group.

Bonnar et al. tested if a sleep intervention could improve the cognitive performance of e-athletes [40]. 56 professional e-athletes took a two-week sleep intervention offered by clinical psychologists. Before and after the intervention, all participants were required to take a 5-minute Psychomotor Vigilance Task (PVT-5). After the intervention, their PVT-5 test results improved slightly in mean reaction time and the number of errors, with no statistical significance.

Zhang et al. tested whether acute aerobic exercise improves esports performance with 34 esports athletes [39]. In the first experiment, the exercise group took a 30-minute exercise while the control group took a 30-minute control; after the intervention, both groups took a 30-minute rest. The cognitive performance of both groups was tested before the intervention, right after the intervention, and right after the 30-minute rest. The second experiment was conducted one week after the 1st experiment and all settings were the same except the intervention of two groups being crossed over. In both experiments, the exercise group's performance in some test items right after the intervention was significantly better than the control group but this improvement did not last until the end of the 30-minute rest.

3.5. Team-related factors

Ching et al., [51] studied the effects of team familiarity on esports performance with the game records of 4272 professional DOTA2 athletes. Two types of team familiarity were studied: 1) competitive familiarity was calculated as "the mean of the sum of the number of times each player has played against each of their teammates in the past"; 2) cooperative familiarity was calculated as "the mean of the sum of the number of times each player has played on the same team with each of their teammates in the past." To minimize endogenous team-ups, professional DOTA2 match records, and game records in DOTA2 "Team play" mode were eliminated. Through regression analysis, both competitive and cooperative familiarity were positively correlated with winning probability with statistical significance.

In another study, Korotin et al. analyzed the voice recordings of a Team Fortress 2 tournament through machine learning [41]. The results showed that the winning teams communicate more often than the losing teams and talk more in positive tones (e.g. happy) than negative tones (e,g. angry), without statistical significance.

Table 5
Articles that measured esports performance by cognitive/training tasks

Performance-influencing factors		Task finishing time	Error rate
Equipment-related (n = 2)	less mouse weight [29]	+	+
	less mouse weight [31]	+	+
	wireless mouse [31]	-	+*
Nutrition and supplements (n = 3)	caffeine [37]	Mixed	Mixed
	caffeine [14]	+*	+*
	caffeine [49]	+*	+*
Training programs (n = 3)	reaction time training [53]	+*	
	aerobic exercise [39]	+*	
	sleep intervention [40]	+	+
Individual attributes – psychological factors (n = 3)	arousal reappraisal [44]	+	+*
	self-regulation [54]	+*	+*
	high pressure [45]	-*	-*

Note: in Table 5 & 6, "–": all test items showed negative effects, with no statistically significant difference or not clearly mentioned; "–": at least one test item showed negative effects with a statistically significant difference; "+": all test items showed positive effects, with no statistically significant difference or not clearly mentioned; "+*": at least one test item showed positive effects with a statistically significant difference; "Mixed": some test items showed negative effects while others showed positive effects; all studies in Table 5 except for [54] adopted interventional designs;*

3.6. Environmental factors

The study by Mo et al., [50] was one of the first few to test how air pollution affects esports performance. 2638 official match records of China's premier League of Legends league were acquired. The air pollution data on match days, characterized by the hourly PM 2.5 observation, were obtained from the China National Environmental Monitoring Center. While a significantly negative correlation between air pollution and key in-game statistics was found, air pollution did not equally influence the stronger and weaker teams, respectively defined by the authors as a team with a higher or lower average winning rate in a season than its rival. As PM 2.5 concentration grew, the stronger teams gained more average team kills and assists while the weaker teams gained less. Moreover, a 10 μg/m3 increase in PM 2.5 concentration brought a 1 % drop in the weaker teams' winning probability and a 1% increase in the stronger teams', both with statistical significance.

3.7. Geopolitical factors

In 2022 February, Russia launched a "Special Military Operation" on Ukraine [63], which brought extreme mental pressure on many Ukrainian citizens [64]. Nesseler studied the effects of this uncontrollable geopolitical event on the performance of Russian and Ukrainian professional Counter-Strike athletes [52]. The results showed that after this military operation both Russian and Ukrainian e-athletes achieved significant improvements in kill-to-death ratio, a key performance indicator in Counter-Strike. However, regarding e-athletes above the mean age, the Russians performed significantly better after the operation started while the Ukrainians had the opposite effects also with statistical significance.

Table 6
Articles that measured esports performance by esports match records

Performance-influencing factors		Win or loss	In-game statistics
Individual attributes – psychological factors (n = 4)	positive emotions [48]	+	
	pre-competition arousal [47]	–*	
	pre-game Iceberg profile [42]		–
	positive emotions [43]	+	
Individual attributes – physiological factors (n = 3)	obesity [38]		Mixed
	cortical thickness [46]	+*	
	heart rate [41]	-	
Team-related factors (n = 2)	positive communication [41]	+	
	team familiarity [51]	+*	
Environmental factors (n = 1)	air pollution [50]	Mixed	–
Geopolitical factors (n = 1)	the RU-UA geopolitical conflict [52]		Mixed

Note: all studies in Table 6 adopted non-interventional designs.

4. Discussion

4.1. Conceptual agenda

This literature review systematically synthesized the findings from 21 articles on esports performance-influencing factors from nine different subject areas and identified seven categories of esports performance-influencing factors. While those articles explained in detail how different variables influence esports performance independently, a proper theoretical framework that systematically integrates findings from different areas is still missing. Theories in traditional sports might not be the best choice because most traditional sports involve little human-computer interaction. The esports performance model by Nagorsky and Wiemeyer [16] overlaps with some findings in this review, such as physiological and psychological factors. However, the "media competencies" section in this model, which focuses on human efforts in handling technical equipment, is far from enough to explain the significant effects of technical devices on esports performance. In addition, the rules and mechanisms of esports game titles may change more frequently than traditional sports because game developers always release new updates. Evidently*, a systematic esports performance framework that covers both the human and technical side of esports is urgently needed* ***(Agenda 1).*** Such a framework will guide esports researchers with future studies, assist esports teams in talent scouting and training, expand traditional sports research in the current digital era, and bring HCI studies with more interesting findings.

4.2. Thematic agenda

*Only t*wo of the included articles discussed how equipment-related factors influence esports performance [29, 31]. Such scarcity is probably because of equipment producers' policies that prevent them from presenting the product development processes in the form of academic articles. While the advantage of using lighter gaming mice was observed in both studies, there might be a ceiling in reducing mouse weight. In 2024, the lightest gaming mice are below 40g – for example, the Ninjutso Sora V2. However, according to prosettings.net, gaming mice from 50g to 70g are still very popular among professional esports athletes. Except for mice, other gaming devices, such as monitors and mousepads, also play important roles in esports performance [9]. In the study by Wang et al. [31], the benefits of using wireless mice were attributed to feeling less "tethered" when moving the mouse. In fact, wireless mouse connection may also influence esports performance via the data transmission between the mouse and the computer. Wireless mice were not popular in professional esports matches before 2020 because the latency of wireless data transmission was not acceptable for high-level competitions by then. Though not tested by Wang et al. in their study, the potential effects of wireless data transmission on esports performance should not be neglected. Therefore, *more research is needed to find a balance between the advanced gaming devices and the best esports performance* ***(Agenda 2)***. Not only would it help professional esports players to select suitable equipment but also provide more valuable practical guidance on product development.

Though practicing esports is less physically demanding than many traditional sports, physiological factors may still influence esports performance. However, each of the included articles on physiological factors tested the effects of only one factor. *Future studies should consider jointly testing multiple physiological factors to gain a more comprehensive understanding of the role of physiological functions in esports performance* ***(Agenda 3)***. In addition, nutritional supplements, training programs, and environmental factors may indirectly influence esports performance by improving or impeding physiological functions. However, their effects may not last for long. For example, the enhancing effects of caffeine on cognitive functions have been revealed for long [65]. After intaking, caffeine is rapidly absorbed within 45 mins [66] and its half-life in the human body ranges from 2 hours to 12 hours [67]. In the study by Thomas et al. [37], the whole experiment process contained four 15-minute cognitive tests and three League of Legends games, which normally last about 30 minutes per game. Thus, the inconsistent results in their study might be caused by a long experiment that exceeded caffeine's normal functioning hours.

Seven included articles studied the effects of psychological factors on esports performance. Common stressors include 1) team issues, such as losing and communication problems, 2) individual issues, such as work-life balance and personal lifestyles, 3) scrutiny and criticism, such as social media posts and opponents' comments, 4) event-related issues, such as tight event schedules and technical problems [68]. Thus, the positive correlation between positive emotions and team victory in two included studies [43, 48] might be explained by team-related stressors. Stress might generate physiological responses, such as an increase in blood pressure and heart rate [69]. Therefore, the increase in heart rate in the study by Korotin et al. [41] might be a stress indicator and thus negatively correlated to match wins. Five common stress-coping strategies to relieve the negative effects of stress on esports performance are emotion-focused, problem-focused, avoidance-focused, approach-focused, and appraisal-focused [68, 70]. The benefits of applying reappraisal, an appraisal-focused stress-coping skill that guide people to perceive stress differently, were found in two included articles [44, 54]. Moreover, in Nesseler's study [52], the geopolitical turmoil might also be perceived differently by Russian and Ukrainian Counter-Strike athletes, which might explain the contrary effects as reported in the study. *Future studies in esports psychology could dig deeper by exploring the effects of each stressor, finding its related physiological responses, and arranging suitable coping strategies* ***(Agenda 4)***.

The 21 articles included in this review covered research participants specializing in four game genres and eight titles. Because of the difference in game mechanics, each game genre and even games under the same genre might require different skills. For example, most first-person shooting (FPS) games are played in a three-dimensional view, but most multiplayer online battle arena (MOBA) games are played in a two-dimensional view. In the study by Toth et al., [71], FPS gamers rated visual-spatial awareness as one of the decisive factors but MOBA gamers did not. Only the study by Sainz et al. [14] recruited participants from more than one game title, but cross-title comparison was not analyzed by the authors. The performance indicators in the rest articles were not the same, which limits the chance of conducting cross-genre/title comparisons. *By further studying the performance predictors across game genres and titles, it is possible to develop a new player-centered categorization system based on the skills involved* ***(Agenda 5)***. This new system will help esports teams in talent scouting and training, and help game developers form new marketing strategies.

4.3. Methodological agenda

Only four included articles were conducted in real esports events [41, 43, 47, 48]. As Nolla et al. mentioned in their study, real esports competition is more complicated than a controlled laboratory setting and might bring unique performance-influencing factors such as a tight tournament schedule [47]. Therefore*, more field studies are encouraged to test the effects of performance-influencing factors on the outcomes of real-life esports matches* ***(Agenda 6.1)***. 10 of the included articles adopted interventional design, mostly conducted in laboratory settings via cognitive/training tasks, while the rest adopted non-interventional design via mostly analyzing esports match records. Compared with non-interventional designs that focus on revealing potential cause-effect relations, interventional studies evaluate impacts more directly [72]. *Future studies could consider mixed-method study designs to find the links between training tasks and actual esports match records, and design comprehensive training tasks* ***(Agenda 6.2)***.

It can be noted that quite a few studies used task finishing time as the performance indicator (see Table 5). We argue that any improvements in task finishing time should be taken and discussed carefully, even without statistical significance. In the 2020s, many esports events always offer the most advanced technical setups with a system latency of about 10 ms [73]. In Li's study [29], the 4-ms improvement in the movement time was not statistically significant but it might generate a big difference when compared to the system latency, especially in high-level competition. None of the 11 articles in Table 5 mentioned the system latency and only five offered the computer setups in their studies [29, 31, 39, 44, 45]. *When task finishing time is adopted as the*

performance indicator in future studies, researchers should consider recording the computer setups and using the system input latency as a benchmark ***(Agenda 7)****.*

5. Limitation

Though this literature review study was conducted by following the guideline of PRISMA, there are still a few limitations. Firstly, only one database (Scopus) was used for the literature search. While it is acceptable in literature review studies (e.g. [74, 75]), future research could benefit from incorporating additional databases, such as the AIS Library, ACM Digital Library and Web of Science, to enrich the findings. Second, only English-written articles were included in this study. Thus, some esports studies from non-English regions might be missed, especially from top esports countries like China and South Korea. Third, in most included articles, the research participants specialized in PC game titles played via mice and keyboards, such as Counter-Strike. However, one study was conducted on professionals who specialized in games mainly played by controllers [47]. Because of the inconsistency in input devices, findings from mouse-and-keyboard game titles may not apply to all game titles. Fourth, to provide a more objective analysis of the extant literature and reliable research evidence, this review was limited to studies based on quantitative approaches. By considering the qualitative studies, we could develop a more comprehensive understanding and gain new insights into esports performance.

6. Conclusion

This study reviewed 21 empirical quantitative studies on esports performance and extracted seven categories of performance-influencing factors. This study makes several contributions to the esports academia. First, to our best knowledge, this study is one of the first few attempts to systematically review performance-influencing factors in esports. To date, an esports performance framework that suits the HCI nature of esports is still missing and is needed urgently. The findings of this study provide a solid base for developing an esports performance model. Second, several key future research agendas and suggestions are proposed. Moreover, other esports stakeholders, such as esports teams and game developers, may also benefit from this study. As such, this study systematizes current research on performance in esports, allows future studies to refine and expand upon these findings, and contributes to both academic progress and practical applications in the esports industry.

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