Competitive eSports as a New Paradigm for Cognitive Science: Current State and Future Directions

Noah Phillips (philln2@rpi.edu)
Department of Cognitive Science, Rensselaer Polytechnic Institute
Troy, NY 12180 USA

Abstract

Video games represent a complex, engaging task domain that has shown great promise as an experimental paradigm for the study of cognition and skill acquisition. The methods that have thus far been used to study video games, however, have been sub-optimal, and will likely become more outdated as the video gaming landscape continues to change. In this work, I first give a brief overview of the previous literature surrounding video games and cognition. I next address the critical methodological problems such as measuring expertise based solely through time-on-task as a heuristic of expertise rather than true metrics of skilled performance itself. I then suggest how the burgeoning sub-domain of competitive video gaming, or "eSports," provides an elegant solution to these problems. Finally, I discuss the current and future directions of eSports cognition research.

Keywords: eSports; video games; expertise; cognition; skill acquisition; experimental paradigm

Background and Motivation

One of the most foundational pillars of human cognition lies within our ability to learn and acquire complex skills. Arguably the best method we have for understanding the process of skill acquisition is through the analysis of experts within their given task domain. By identifying the key components of expert-level performance, we isolate the factors that separate experts from less skilled performers. This understanding allows us to begin designing training methods which facilitate the acquisition of further expertise.

While many components of skill acquisition will necessarily be task-specific, a great deal of the overall learning process can be transferable between domains (Bavelier, Bediou, & Green, 2018). Therefore, one of the best approaches we have is to learn as much as possible about an ideal task domain, then use this knowledge to begin generalizing to new tasks, building an overarching theory of skill acquisition. As Allen Newell suggested in 1973, Cognitive Science can be advanced by "accepting a single complex task and do[ing] all of it," in order to fully understand "a genuine slab of human behavior" (Newell, 1973). It is a primary challenge for us as researchers to find such a single complex task, so that we may allocate our full resources into studying it. I argue in this paper that the most ideal task domain we have at our disposal to accomplish this goal is a subdomain of modern video gaming, namely competitive eSports.

Action Video Games and Cognition

The modern era of video games cognition research was kicked off by a landmark paper from 2003, where Green and Bavelier examined the effects of video game play on various measures of cognition. Habitual video game players and non-players completed a series of cognitive tests, and their results were compared, showing that video game players exhibited better visual selective attention than non-players (Green & Bavelier, 2003). This effect persisted when implementing a follow-up, interventional experiment involving 10 hours of training on an action video game, suggesting a causal relationship between gameplay and cognitive ability.

Since 2003, a multitude of studies have attempted to provide further evidence for the relationship between video games and cognitive enhancement. Although meta-analyses on the literature have yielded varying results (see Bediou et al., 2018; Hilgard et al., 2019; Sala et al., 2018), the most recent and comprehensive meta-analysis published on this topic strongly reinforces the position that action video game play does indeed impart measurable effects on cognition (Bediou et al., 2023). The authors used predefined keywords and inclusion criteria to synthesize the most up-to-date literature available, examining 312 effects extracted from 133 independent studies (105 cross-sectional, 28 intervention studies). They found that action video game players did indeed outperform non-video game players, with a large effect (g = .64) for correlational studies as well as a small (g = .30) but significant effect causally linking interventional designs with improvements in cognitive skills. Among correlational studies, the largest effect sizes were observed for the domains of perception, spatial reasoning, top-down attention, and multitasking. For the available intervention studies (all of which employed "active control" groups where participants trained for the same amount of time on a non-action game), the largest effect sizes were observed for top-down attention and multitasking, of which top-down attention exhibited the strongest causal link (g = .52).

As the landscape of video gaming is extremely varied, with every game and genre having its own unique set of characteristics and gameplay mechanics, it is important to establish the precise type of video game being studied.

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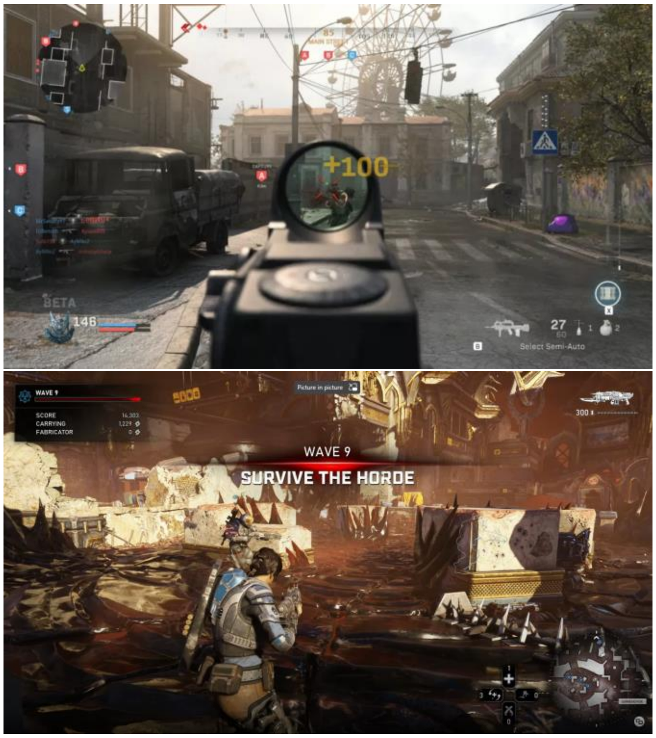

Figure 1: Examples of two popular action video games: *Call of Duty* (top) and *Gears of War* (bottom).

Within most of the literature, an "action video game" is defined as a first-person or third-person shooting game, such as *Call of Duty* or *Gears of War* (see Figure 1). This style of game has historically been chosen because it tasks players with visually attending to many dynamically changing elements of the game environment, requiring them to parse through an abundance of visual stimuli to make decisions under time pressure. These gameplay elements constitute the cognitive demands that are placed on a player. Since various genres of games contain different gameplay elements, the cognitive demands among games will differ, therefore so will the cognitive effects gained through gameplay. In this sense, a game that requires a player to engage a particular cognitive faculty should preferentially train that specific ability.

Within recent years, genres have begun substantial intermingling. Dale and Green describe the rise of "hybridization" of game genres, with sub-genres such as "Action-RTS" combining many gameplay elements and mechanics from multiple preexisting genres, with this crossover between genres further increasing as games become more technically complex over time (Dale & Green, 2017b). Another conclusion based on survey data from Dale and Green is that there exists less "specialization" in gamers of today. In the past, a video game player might have stuck to one individual gaming genre due to its distinct characteristics, but as genres become more hybridized, players tend to branch out into more than one type of game. This lessening of genre specialization could prove challenging for studying the cognitive effects of gameplay, as it may be more difficult to know which specific games or game mechanics are contributing to any systemic cognitive enhancements. This problem requires us to reconsider the way we look at the interactions between video games and players, updating our experimental paradigms to reflect the modern gaming landscape.

Defining Video Game Experts: Time vs Performance

To date, the majority of video game research relies on survey data to classify participants into groups of video game players and non-players based on the time spent playing games per week. It is a general assumption that the more time an individual spends playing a video game, the more cognitive engagement they will have with the game, and therefore the more likely that any possible cognitive enhancements will be observed. This may be true by and large, although I will argue that this methodology serves only as a heuristic, and there does exist a much better option.

If we wish to categorize players based on their cognitive engagement with a task, the ideal metric is not merely time spent doing the task, but rather an individual's level of performance on said task. We know that not all practice is created equal: according to Ericsson, deliberate, structured practice will nearly always achieve greater task learning than the same amount of chaotic, unstructured practice (Ericsson, Krampe, & Tesch-Römer, 1993). In a subsequent paper, Ericsson states that, "it is not the total number of hours of practice that matters, but a particular type of practice that predicts the difference between elite and sub-elite athletes" (Ericsson, 2014, p. 14), further suggesting that the gap in performance outcome based on type of practice only widens as one reaches the highest levels of expertise.

An even more salient example lies within academic studies. A pupil may spend countless hours reading and rereading their science or mathematics textbook in the days before an exam, but they are likely to perform worse on the test than someone who spaced out their study over weeks, even if the latter student spent an overall less amount of time studying. In this example particularly, level of performance aside, we would not say that the first student was more intellectually and cognitively engaged with the learning content as a result of their study habits. We would likely agree that the latter student achieved a higher level of cognitive ability in this particular task domain, which in turn translated into a higher exam score. This same framework can apply to any cognitive task domain. If we are most interested in the level of cognitive engagement with video games as a task domain, we should be concerned with performance in-game rather than time spent playing, which will more accurately allow us to study how this cognitive engagement is associated with enduring cognitive enhancements that may transfer outside of the specific task. This approach has not been widely adopted thus far because it can be difficult to measure video game skill level objectively and systematically. Thankfully, however, the modern era of gaming affords us a great opportunity for just such a methodology.

Video Games as Experimental Paradigm

Video games uniquely provide cognitive science researchers with an endless number of complex, dynamic tasks in which our study participants will gladly partake for hundreds of hours. Gray describes the value of action games as an experimental paradigm for cognitive science, citing key components such as manageable complexity, well-defined goals, and participant engagement (Gray, 2017). On the logistical side, the use of action video games allows us to sample from a large distribution of skill levels, access large naturalistic sources of gameplay data (Huang et al., 2017), and it even affords the opportunity to conduct longitudinal studies of single individuals improving at their task domain across many years (Allen et al., 2023). These advantages are quite significant compared to training participants on standard laboratory tasks, as it is unreasonable to expect anyone to spend as much time practicing a visual perception task as they may spend playing an engaging video game. Even if time spent performing each task could be equated, another unparalleled benefit is that video games contain inherent motivators to perform well. Since our key research interest lies within the study of expertise, it should be a priority to utilize task paradigms in which individuals actually desire to increase their expertise and performance level, such that their learning trajectories can more closely resemble the trajectories of real-world experts who consciously choose to acquire expertise in their given domain.

Games as experimental paradigms also foster *learning to learn*. By providing complex training environments, action video games may promote brain plasticity, with the potential to augment an individual's learning capacity by enabling greater asymptotic performance at faster learning rates (Bavelier, Green, Pouget, & Schrater, 2012). This would not only support one's ability to gain expertise at a given task, but also allow them to acquire skill in new task domains faster and easier. If achieved, this could jump-start our subsequent research into the generalization of expertise, providing a framework for future skill development – coined here as "acquisitional scaffolding" – that can be utilized to develop further expertise and skilled performance in other task domains.

One potential shortcoming of the study of video games, however, lies within player motivation. Although many video game players desire to get better at their games, this motivator is not universal to all players. Just as some may watch a film not for sake of critically analyzing the underlying themes and commentaries but rather just to relax and enjoy a piece of media, some video gamers also may play primarily for recreation – not with a particular eye for improvement. This confounding factor can be somewhat mitigated through the choice of video game genre (i.e., studying action video games rather than life simulation games), although recreational players will still exist for any game or genre. To isolate individuals who are driven primarily to achieve high levels of performance, we must examine a sub-domain of gaming that has seen unprecedented growth in recent years: eSports.

Figure 2: Examples of two popular eSports: *Super Smash Bros. Melee* (top) and *League of Legends* (bottom) of the fighting game and MOBA game genres, respectively.

eSports as an Ideal Task Paradigm

Competitive video gaming, also known as *eSports*, is a form of gaming in which players compete against one another, either one-on-one or in teams, in tournaments and competitions similar to those of traditional sports. In recent years, the eSports industry has ballooned from a niche group of dedicated gamers to a multibillion-dollar industry and spectator sport, projected to reach a valuation as high as 12 billion by 2030 (Grand View Market Research, 2022).

The rapid rise of eSports popularity provides a fantastic opportunity to study expertise in a complex task domain where individuals are primarily concerned with improvement, often driven by internal motivations to succeed rather than external motivators such as being paid to perform a laboratory task. Not only are players at all levels of expertise available to sample, but also their skill levels are easily identifiable, as competitive gaming naturally categorizes players into different echelons of skill based on their in-game rankings, tournament results, and other objective factors. The empirical study of eSports expertise will build upon the notion of video games as an experimental paradigm, significantly amplifying its power for numerous methods of analysis. For instance, by virtue of existing within a digital environment, eSports gameplay can naturally provide troves of telemetry data for all players and game events at the millisecond level, a feat that has been long sought out (with limited success) by traditional sports analytics (Goes et al., 2021; Kovalchik, 2023). Through combining all the established advantages of video games with the crucial additions concerning player motivation, objective skill quantification, and data analytics laid out here, eSports addresses all major shortcomings of studying video games in a non-competitive environment.

Additionally, from the perspective of cognition, the level of engagement a player achieves with the cognitive demands of a video game is likely heavily influenced by the manner in which the individual plays. That is to say, two different players could beget vastly different experiences even from playing the same game. A competitive player aims to focus all their cognitive resources on optimizing performance, while a casual player is much less likely to maximize their cognitive output. If we do wish to investigate cognitive effects of video games, then it logically follows that studying those who most deeply engage their cognitive abilities are the most likely to show observable effects in their cognition. This factor, along with the prior mentioned advantages of eSports as a concentrated form of video gaming synergize to make competitive eSports a truly ideal task paradigm to study skill acquisition.

Studies of eSports and Cognition

Before discussing studies on eSports and cognition, it is important to first establish how even a singular game played casually can be functionally different than the same video game played competitively as an eSport by virtue of elective game mechanics themselves. Some games, such as a subset of action video games known as tactical shooters (e.g., *Counter Strike*) are played very similarly by both casual players and professional players since the format of the game naturally lends itself to competitive play. Other games, however, exhibit marked differences between play at the casual and competitive level. *Super Smash Bros.*, for instance, is a popular party-style fighting game with many random elements designed to level the playing field so that players of all skill levels are able to play together. When this game is played competitively as an eSport, however, rigid rulesets and gameplay formats are implemented to remove as many non-skill-based mechanisms as possible. Since the demands of the game differ when considering casual versus competitive play, when it comes to understanding the relationship between video games and cognition, it is paramount that we discuss studies not merely recruiting casual players of various games, but rather studies that specifically seek out competitive players who engage with these games at the level of eSports.

As mentioned, many competitive shooting games fit the standard definition of action video game, therefore the findings on enhanced top-down attention and multitasking (Bediou et al., 2023) carry over to these games as eSports. One study investigating links between expertise in first-person shooting games and cognition found significant associations between *Counter Strike* skill level and choice reaction time performance (Toth et al., 2019).

After action video games, the next most well-studied eSports genre is multiplayer online battle arena (MOBA) games, with the research centered around the largest competitive games in the genre, such as *League of Legends* and *Dota 2*. Studies on MOBA experts have shown similar positive correlations with processing speed and attentional abilities (Ding et al., 2018; Large et al., 2019; Qiu et al., 2018), working memory (Chang et al., 2017; Valls-Serrano, De Francisco, Vélez-Coto, & Caracuel, 2022; Yao et al., 2020), cognitive flexibility and impulse control (Li et al., 2020), decision making ability (Sörman et al., 2022), and even connections between fluid intelligence and game expertise (Kokkinakis, Cowling, Drachen, & Wade, 2017).

A moderate amount of research has also been conducted on games within the real-time strategy (RTS) genre. Expertise in RTS games such as *StarCraft 2* has also been associated with greater motor dexterity and lower response times (Dale & Green, 2017a; Thompson, Blair, Chen, & Henrey, 2013), as well as greater white matter volume in brain regions associated with visual perceptual learning (Kim et al., 2015).

Less popular eSports genres have yet to see much empirical study. One recent paper by Phillips and Green examined experts of the fighting game genre in contrast to experts of the rhythm game genre (Phillips & Green, 2023). Top-level experts of various games in both genres completed a series of cognitive tasks, finding that both expert groups exhibited faster measures of processing speed when compared to a non-expert control, while fighting game experts exhibited better sustained attention and rhythm game experts exhibited better paced motor timing in a rhythm maintenance task. Another study on world-class experts of the fighting game genre found game expertise to be positively correlated with larger gray matter volume in the right posterior parietal cortex, as well as enhanced performance in a visual working memory task (Tanaka et al., 2013). It seems clear that although action video games have received the most empirical attention due to their reliably measurable cognitive effects, multiple other game genres contain gameplay elements that place sufficient cognitive load upon the player to produce generalizable cognitive improvement. Therefore, a more granular and comprehensive approach is warranted as further research examines differing genres within eSports.

These studies provide a promising first look at eSports cognition research using objective skill as a marker of true domain expertise. This key contribution, combined with the fact that eSports competitors play these games with the primary intent of increasing their skill level and outperforming others in competition, thereby amplifying their cognitive engagement with the task domain, more than justifies the pursuit of competitive eSports as an ideal task domain for the study of complex skill acquisition.

Table 1: Overview of the studies on players of video games addressed in this review, including whether the given studies measured expertise via time-on-task (hours played) or through direct metrics of in-game skill (e.g., Elo ratings).

Game Genre	Game	Studies	Cognitive Measures	Expertise Measurement
Action Video Game	*Counter Strike*	Toth et al. (2019)	Cognitive inhibition, RT accuracy & speed	In-game skill
	Various action games	Green and Bavelier (2003)	Visual selective attention	Time-on-task
	Various action games	Bediou et al. (2023)	Multitasking, top-down attention, spatial perception	Both
MOBA	*League of Legends*	Large et al. (2019)	Processing speed, attention	In-game skill
		Ding et al. (2018)	Multitasking, visuospatial attention	Both
		Qiu et al. (2018)	Visual selective attention	Both
		Valls-Serrano et al. (2022)	Working memory, attention	In-game skill
		Chang et al. (2017)	Multitasking, working memory	Time-on-task
	Dota 2	Sörman et al. (2022)	Decision-making ability	In-game skill
		Kokkinakis et al. (2017)	Fluid intelligence	In-game skill
Real-time strategy	*StarCraft 2*	Kim et al. (2015)	Visual perceptual learning	Time-on-task
		Dale & Green (2017a)	Motor dexterity, processing speed	Time-on-task
		Thompson et al. (2013)	Motor dexterity, processing speed	In-game skill
Fighting game	*Super Smash Bros.*	Phillips & Green (2023)	Sustained attention, processing speed	In-game skill
	Street Fighter	Phillips & Green (2023)	Sustained attention, processing speed	In-game skill
	Guilty Gear	Tanaka et al. (2013)	Visual working memory	In-game skill
Rhythm/music games	*Guitar Hero*	Phillips & Green (2023)	Paced motor timing, processing speed	In-game skill
	osu!	Phillips & Green (2023)	Paced motor timing, processing speed	In-game skill

Future Directions of Study

Future work on complex skill acquisition should take a more granular approach to analyzing specific types of competitive eSports from various genres, assessing the individual gameplay elements that may be shared among games which are likely to influence overall cognition. A fine-grained understanding of these competitive games must be held in order to properly analyze not only these intrinsic game mechanics, but also features of gameplay that are necessary to achieve high levels of skilled performance.

A recent paper by Gray and Banerjee (2021) adopted just such an approach as described above, for what may be one of the most rudimentary games that can be considered a legitimate eSport: *Classic Tetris*. This paper established a list of 35 features of *Tetris* gameplay, such as pile height, decision latency, and number of piece rotations, and employed a principal component analysis to reduce the dimensionality down to a list of 6 factors, to which experimenters assigned intuitively understandable labels such as "planning efficiency" and "pile management." These 6 factors were then used to analyze a large group of *Tetris* gameplay data taken from players along the spectrum of skill to determine which factors were most important to performance outcomes at any given skill level. Notably, the most predictive factors were not uniform across the skill distribution, such that the skills needed to rise from a novice player to an intermediate are different than those needed to rise from an intermediate to an expert, supporting the notion that variable importance is not static across levels of expertise in a rich, dynamic context (Thompson et al., 2013). This methodological framework established by Gray and Banerjee can be translated to a variety of other task domains, such as other competitive eSports, and is planned to soon be applied to a large source of gameplay data from *Super Smash Bros. Melee*, a popular fighting game and competitive eSport.

Another very fruitful domain of application is the field of cognitive modeling. With the sheer amount of expert level data available from competitive eSports, the possibilities of various reinforcement/machine learning models and the development of expert-level cognitive architectures remain largely unexplored. Some work has attempted to map out this new territory, such as the framework of Stafford and Vaci (2022) which uses gaming data to fit formal learning curves, allowing the isolation of multiple factors such as learning rate and initial/asymptotic performance. Other exciting works have attempted to use deep reinforcement learning to train artificial players for competitive games such as *Super Smash Bros. Melee* (Bezerra et al., 2020; Firoiu et al., 2017, 2018).

The ultimate goal of skill acquisition research, of course, is not merely to make sense of expertise itself, but also to be able to apply our understanding to create training programs that can be used to facilitate the acquisition of future expertise. Once we create a solid model of the components of eSports expertise that account for variance in performance, we can attempt to directly train these gameplay elements and/or cognitive abilities to see if such an intervention would translate to enhanced performance outcomes. As we build out our understanding of the changing importance of variables at each step of the skill progression, we can tailor our training methods to emphasize the components most relevant to a particular individual at his/her current level of skill.

To successfully design and implement pragmatic methods of training any complex skill, a robust understanding of the goals and challenges to the performer must be attained. Within the context of eSports, a recent paper by Kleinman, Shergadwala, and Seif El-Nasr (2022) attempted to identify just such factors, with an eye towards the development of computational assistant technology in the future. They identified four key learning activities (practice, leveraging the knowledge of others, tracking performance, and reflecting on gameplay to set future goals) as well as four key challenges (coordinating with teammates, knowing what to do next, tracking game state, and tracking skill improvement) pertinent to competitive gaming. Each of these activities and challenges can be further analyzed to design interventions for improvement, either by traditional means or through the creation of next generation training tools such as the intelligent computational support proposed by Kleinman and colleagues. Future research should continue this logistical approach to identifying and understanding the hurdles to acquiring skill.

Much future research will be necessary to design optimal training programs that effectively augment not only individual skills but also overall performance. A promising line of future work may involve the creation of within-task practice modules, such as an in-game training mode that helps players practice specific skills in an engaging, gamified fashion. Through the creation of these dynamic training methods, we may build a stronger framework for skill acquisition that goes beyond video games, rather creating a learning system that could be applied to optimize skill acquisition in countless complex task environments.

Conclusion

The most impactful stepping stone for cognitive scientists researching complex skill acquisition would likely be to come to a consensus on an ideal task domain within which to invest our collective resources to fully understand. I argue that there exists no better such task paradigm than competitive eSports, the subgenre of video gaming specifically concerned with optimizing skill level and competitive performance. I also argue that the past methodological approach of categorizing video game players and non-players based primarily on play time is an outdated heuristic for task engagement, and should be replaced by video game skill level as a truer representation of an individual's degree of cognitive engagement. The deliberate focus on improvement present in eSports maximizes the players' cognitive loading within the task medium, which will amplify any fundamental effects on cognition. Moreover, eSports represents a complex task domain which millions of individuals are already practicing for collective billions of hours, and at any given time individuals exist along all points of the skill spectrum, easily identifiable and accessible based on objective measures such as public leaderboards and skill rankings.

As the continued growth of eSports drives itself further into the mainstream, its cultural relevance and influence is becoming undeniable. I wholeheartedly believe that we should allocate substantial resources to continuing lines of research investigating competitive video games, not just to examine the cognitive ramifications of prolonged engagement with this form of media, but also (and especially) because this task domain is uniquely suited to illuminate the underpinnings of complex skill acquisition. Once we achieve an adequate level of understanding of this "slab of human behavior," we may begin formulating optimal ways of training so as to produce the highest levels of expertise as quickly and efficiently as possible. Once we crack the code of "learning to learn," the resulting blueprint and acquisitional scaffolding could be applied to a vast number of domains, allowing individuals to gain many complex skillsets more easily. In this sense, what started out as studying video games will yield profound insight on the fundamental building blocks of all human learning.

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