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REVIEW

A new look at the cognitive neuroscience of video game play

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A growing body of literature has investigated the effects of playing video games on brain function and behavior. One key takeaway from this literature has been that not all entertainment video games are created equal with respect to their effects on cognitive functioning. The majority of the research to date has contrasted the cognitive impact of playing first- or third-person shooter games (together dubbed "action video games") against the effects of playing other game types. Indeed, when the research began in the late 1990s, action video games placed a load upon the perceptual, attentional, and cognitive systems in a manner not seen in other video games. However, the video game industry has shifted dramatically over the intervening years. In particular, first- and third-person shooter games are no longer unique in the extent to which they load upon cognitive abilities. Instead, a host of other game genres appear to place similar degrees of load upon these systems. This state of affairs calls for a paradigm shift in the way that the cognitive neuroscience field examines the impact of video game play on cognitive skills and their neural mediators—a shift that is only just now slowly occurring.

Keywords: video games; action video games; cognitive enhancement; behavioral intervention studies

Over the past 25 years, commercial video games have become increasingly prevalent in society. Currently, there are an estimated 2.5 billion video game players worldwide,[1] with 166 million gamers in the United States alone.[2] By 2021, these numbers are expected to dramatically increase, partially due to the growing emphasis on easily accessible (and often free) cloud and mobile video games designed for casual play.[2]

In parallel with the development of the gaming industry, a growing body of research has emerged investigating the impact of video game play on cognitive and brain functions. One key takeaway from this literature is that not all entertainment video games are created equal with respect to their effects on brain and cognition. Indeed, nearly all theories of how cognitive abilities could be altered by experience emphasize the need for sustained heavy load to be placed upon the very cognitive systems of interest. As such, research in cognitive neuroscience to date has heavily focused on the "action" genre, mainly defined as first- or third-person shooter games. Such games require quick and accurate decisions to be made in the context of rapidly changing and highly cluttered visual scenes—demands that should heavily load upon attentional and executive processes. Other video games, such as turn-based strategy games or life-simulation games, do not necessitate extraction of information under time constraints, constant scanning of one's surroundings, or suppression of a wide variety of distractors. As such, these other game genres should load less strongly upon attentional and executive systems.

We consider here existing research so far in the cognitive neuroscience of video games as well as future outlooks. In particular, we note that the gaming industry has dramatically changed over the past two decades, and the nature of both game genres and gamers themselves has likewise evolved in a concomitant fashion. For example, many of the

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game mechanics that, in the late 1990s–2000s, were largely only found in action games are also now found in many other types of games, such as certain racing games,[3] 3D platformers,[4] multiplayer online battle arena (MOBA) games,[5] role-playing games (RPGs),[6] and real-time strategy (RTS) games.[7] This, together with many changes in the commercial game sphere, has resulted in significant methodological challenges in evaluating video game play and its associations with cognitive skills and brain functions. If we are to understand how to leverage video games as a medium for studies of brain and cognitive functions, many of these changes will require a meaningful modification in approach as compared with the types of methodologies that have been dominant for the past 20 years in the field.

Previous methodological approaches

Research on the possible associations between video game play and cognitive performance began essentially in concert with the rise in popularity of video games as an entertainment medium in the mid-1980s. In terms of basic methodology, this early work utilized the same two basic methodological approaches that continue to dominate the literature today. The first is a quasiexperimental approach, wherein individuals who regularly play games are contrasted in terms of their cognitive abilities against individuals who rarely or never play video games. For instance, one of the first empirical reports on the associations between playing video games and cognitive performance was a quasiexperimental study that demonstrated that regular video game players (defined as individuals who played games for 2–59 h per week) had superior hand-eye coordination as compared with nonvideo game players (NVGPs) (i.e., individuals who played no games).[8]

Although this type of quasiexperimental study is easy to conduct, such methodology cannot be used to identify a causal relation between game play and differences in cognitive skill. As such, the second main approach that is utilized in the field is a true experimental (intervention) approach, wherein individuals are specifically trained on a given video game and the causal impact of this training on cognitive skills is assessed (with their performance usually being contrasted against a control group). For example, in one early study, a group of participants were asked to play two different video games for 5 h: a 2D game called *Targ*™, or a 3D game called *Battlezone*®.[9] Participants from both training groups showed improvements in both spatial rotation and visualization following training relative to a no-contact control group, providing the first evidence that the link between playing video games and cognitive performance may be causal.

This early work in the field was situated within a gaming industry that did not have a clear hierarchical organization. Video games at the time were very commonly produced by small independent companies, teams, or even individuals, and thus were not particularly yoked to one another in any fashion. The literature on the cognitive impact of games thus mirrored this lack of structure. Quasiexperimental designs commonly aggregated across all video game players, irrespective of the particular games the individuals played. Additionally, experimental designs typically examined the impact of what might be called "one-off" games (i.e., games where no other similar game was ever produced).

This state of affairs shifted in the early to mid-1990s as video games became increasingly big business. One consequence of the increasing economic pressure was that games tended to settle into a set of reasonably discrete genres, under which games shared mechanics, dynamics, narrative structure, and so on. This practice made games easier to market and also ensured that developers and publishers could more easily predict the likelihood of success. Critically, with respect to cognitive psychology, it led to categories with very distinct perceptual, attentional, and other cognitive demands from one another. This resulted in a shift in methodological approach, in which researchers focused on the impact of playing certain genres of video games. In particular, one genre category, known as first- and third-person shooter games (popular examples are the *Call of Duty*® and *Gears of War* series, respectively), which together came to be known as "action video games" in the cognitive psychology literature, presents a unique set of characteristics: (1) a fast pace, meaning that players are constantly put under the constraint to react under time pressure, (2) the need for players to distribute their attention across the peripheral visual field to monitor for potential incoming threats, (3) the need for players to focus their attention when required, such as when shooting at an opponent, (4) the need to switch between these two states of attention (distributed/focused) upon demand, and (5) enough variability in the game, such as in the behavior of the opponents, to prevent full task automatization. Succeeding in these games requires heightened skills in a variety of cognitive abilities, such as attention, working memory, task switching, and cognitive flexibility. Importantly, and contrary to what is sometimes stated, this category does not include just "any physically challenging video game in which reaction time plays a crucial role"[10] as many games requiring fast and accurate responding (such as the *World's Hardest Game*) do not fit the above definition of action video games. Below, we first examine the literature contrasting the impact of action video games as compared with other genres of games before addressing why this methodological approach will need updating in the coming years.

The influence of video game play on cognition and its neural bases

In the perceptual domain, action video game players (AVGPs) have been shown to outperform NVGPs on tasks that require fine perceptual discriminations in the visual (and occasionally auditory) modality.[11–16] For example, AVGPs exhibit a lower (i.e., better) contrast threshold in tasks where participants have to detect low-contrast targets[15] and they perform better when identifying small stimuli (such as letters) in a crowded visual space.[12] They show a higher degree of precision on multisensory temporal processing tasks, such as tasks where they are asked to determine which of a visual or an auditory stimulus came first.[11] AVGPs also have larger useful perceptual fields, and they are generally better able to extract visual and/or auditory information.[17,18]

In terms of general speed of processing, AVGPs show consistently faster reaction times[19–21] relative to NVGPs. This finding has held across a wide variety of stimuli and response methods, including manual, vocal, and saccadic responses.[22–25] Importantly, this decrease in reaction time does not come with a degraded accuracy, suggesting that it is not the result of a speed–accuracy trade-off, but an actual improvement in processing speed.

Next, there is evidence that action video game play is positively associated with a number of visuospatial memory and mental rotation skills. For instance, researchers have demonstrated that AVGPs outperform NVGPs on visual short-term memory tasks.[26–31] Visuospatial working memory has also been shown to potentially be influenced by action gaming, such that AVGPs are better able to monitor and continually update their working memory stores.[32] AVGPs also more rapidly switch from one task or goal to another[22,31,33–38] and are better general multitaskers.[3,34]

Finally, in the attention domain, a number of groups have demonstrated that action video game experience is linked with enhanced attentional capabilities. AVGPs possess better visual search capabilities,[39–41] as measured by manual response times or oculomotor abilities,[21,42,43] for example. They also show enhancements relative to NVGP performance in terms of the ability to flexibly distribute attention over space,[6,44–48] monitor and track objects (i.e., both in foveal and peripheral vision),[6,31,44,46,49,50] and monitor and select information in time.[21,45,51–53] Although researchers initially hypothesized that such differences may be the result of better attentional selection in early sensory processing, a series of electroencephalography studies have instead suggested that these behavioral differences are more likely the result of changes in "attentional control." Evidence in favor of this latter view includes both cross-sectional[54,55] and experimental[48] works showing that action gaming is associated with changes in parietal activity (yoked to attentional control), rather than occipital activity (yoked to early visual processing).

Support for this view has also been provided by a series of studies utilizing the steady-state visually evoked potentials technique, which have found that action gaming is associated with a particularly large change in the extent to which distracting (i.e., task-irrelevant) information is suppressed at the neural level.[51,56] Finally, the same basic trend has been seen in functional magnetic resonance imaging. For instance, in one study, irrelevant moving stimuli led to comparatively lower MT/MST (medial temporal and medial superior temporal cortex) activation in AVGPs as compared with NVGPs,[57] while in other work AVGPs have been seen to display enhanced intra- and internetwork connectivity in two networks: (1) the central executive network, which is linked with working memory, planning, and readiness toward an incoming stimulus, and (2) the salient network, which is associated with the integration of sensory, emotional, and interoceptive signals, as well salient stimulus detection.[58,59]

Together, these results point toward the idea that the behavioral enhancements noted as a result of action video game play arise from more efficient late attention selection. In this view, AVGPs may initially process most available information, and only late in processing do they more efficiently select the relevant parts.

However, we do note that not all studies have replicated the positive link between action gaming and improved cognitive skills[31,60–62] (but see Ref. 63). Attempts to systematically determine whether playing AVGs benefits cognitive performance via meta-analytic approaches have documented a consistent cognitive benefit in quasiexperimental studies.[60,64–70] In short, individuals who report playing 3 or more hours per week of action video games, and having done so for at least the past 6 months, outperform individuals classified as NVGPs on a wide variety of cognitive tasks. However, as discussed above, whether AVGPs perform better on these cognitive tasks because they play action video games, or whether they chose to play action video games because they excel at this type of game play from the get-go, can only be answered through intervention studies.

A recent meta-analysis[64] aggregated all intervention studies that compared a group trained on AVGs with a group trained on a control video game. This meta-analysis found a small-to-medium effect size of action video game experience above and beyond control video game experience on cognition (Hedge's $g = 0.34$). The most significant positive effects of AVG play were on attentional control and spatial cognition, with encouraging signs for perception. Importantly, this and other meta-analyses of intervention studies have all converged to highlight the need for more intervention studies with larger *n*'s and longer training durations. In this debate, it is also important to note that the discrepancy between the available meta-analytic works may also come down to the ways in which researchers have differentiated games and gamers. As we will see below, how to best differentiate games and gamers is a major current issue in the field and one where the difficulty of that differentiation task is accelerating.

Changes in games and gamers

For the most part, the system differentiating between action and nonaction video games has been quite successful for more than 15 years. Yet, the game industry over this period has been far from stable. It is thus worth considering some of the recent major changes in games and gamers that together have combined to make the currently standard methodological approach an increasingly poor match with the game ecosystem of today. We take below the case of action video games to illustrate our point.

One major shift that has occurred is in terms of individual histories of game play. Twenty years ago, most of the individuals recruited as action gamers had a quite short history of playing action video games. Individuals could be categorized as AVGPs or NVGPs based on their last year of gameplay. By contrast, action games have been available for the entire lifespan of young adults today. It is thus possible that individuals who report having played no action games over the past year would have played (perhaps even heavily) in their past. Ideally, one could simply assess gaming over a longer history (i.e., more than just the past year). Unfortunately, surveys asking individuals to report their activities years in the past are known to be quite unreliable. Given that total time is one of the best predictors of the impact of an experience, the fact that self-report is an increasingly poor indicator of previous experience is a significant issue for cognitive neuroscientists interested in the impact of video games on brain and cognition.

A second major shift is in terms of the mass prevalence of video games in mainstream culture today. Although video games were certainly popular in the early 2000s, it was nevertheless possible to find individuals who played essentially no games. This was partially because video games at that time still required some dedicated hardware to play (e.g., a gaming console). The accessibility (e.g., via mobile devices and tablets) and general mass appeal of video games today means it is increasingly more difficult to find individuals who fit the NVGP criteria. Most research studies on the cognitive neuroscience of game play necessarily rely on contrasts (e.g., comparing one type of experience with another). Therefore, the increasing lack of true nongamers puts additional stress on the need to separate out specific types of gamers.

Third, gamers themselves are increasingly unwedded to particular genres of games. Again, this is likely partially due to accessibility. Previously, purchasing and playing a game was a significant investment. Thus, individuals mainly chose to play games that they already knew they would enjoy. Today, with thousands of often heavily discounted, or even free games, available, there is a tendency to explore a greater variety of game types. This trend is further exacerbated by video game streaming (i.e., where individuals watch other individuals play games), which exposes gamers to a wide variety of different games. In our own research group, we have seen a huge expansion of what we refer to as "tweeners" (i.e., individuals who do not meet criteria for AVGPs or NVGPs because they play a substantial mixture of game types).[71] Therefore, when considering possible contrasts (e.g., contrasting players of one game genre versus players of another game genre), it is critical to consider the fact that individuals increasingly do not fit neatly into such categories.

Finally, the game space itself has changed dramatically over the past decades such that today's genres less aptly differentiate between game mechanics.[71] When research first focused on action games in the early 2000s, they primarily contained high intensity, fast-paced warfare situations that required gamers to rapidly attend to a broad visual field and quickly execute relatively complex actions to complete a mission/survive a battle. The storyline of these games, however, was fixed, and largely irrelevant. Strategy games, on the other hand, often contained little-to-no real-time action, were primarily slow paced, and used a turn-based mechanic whereby players had the time to carefully plan and execute their next move. Finally, RPGs typically had limited to no action and were heavily storyline based, allowing players the freedom to alter the course of the story based on their choices.

Fast-forward to today and many of the game mechanics that, in the late 1990s–2000s, were largely only found in action games are also now found in many other types of games. Indeed, many games today are, in essence, mixtures of action game mechanics with mechanics from at least one other classic genre. This state of affairs has resulted in a host of what are known as hybrid genres. For example, the widely played games *The Elder Scrolls® V: Skyrim* and *Mass Effect™: Andromeda* each contain elements of both classic RPGs and classic shooter games and thus are commonly referred to as "action-RPGs." The same is true of the adventure genre, which now nearly always includes third-person shooter mechanics (thus, these games are called "action-adventure" games). The strategy genre, which formerly tended to use turn-based mechanics (which were quite slow), has come to involve almost uniformly real-time, temporally demanding mechanics in a manner similar to action video games, and now has a genre label of its own (RTS genre). There is even a hybrid of the RTS genre with the action genre—most commonly referred to as the MOBA genre. Adding to the problem, there are now several games on the market that combine three or more genres, and thus fit even more poorly into traditional genre-based structures. These include games, such as *Valkyria Chronicles™ 3*, which combine elements of RPGs, strategy games, and third-person shooters; or *Fortnite*, which combines elements of FPS, battle-royale (i.e., where every player acts as an individual and the goal is to kill every other player); and open-world building games (such as *Minecraft*).[71]

In the early 2000s, players of RPGs and strategy games would have been considered nonaction game players. However, as these genres have shifted in terms of their mechanics (i.e., adding in more and more action mechanics), research has similarly shown a shift in the impact of these games. Quasi-experimental, intervention, and correlational studies have linked action-RPGs, RTS and racing games, and MOBAs with some cognitive skill enhancement, akin to what has previously been observed to arise via action video game play.[3,7,41,72,73]

Crucially, the specific mechanics implemented in the game, rather than the genre or the content of the game, appear to drive the changes in brain and cognition. For instance, Glass *et al.*[7] conducted a study wherein 72 women were tested on a battery of cognitive tasks before and after playing 40 h of either a control game (*The Sims™*) or one of two versions of an RTS game (*StarCraft®*) that differed in the amount of information the players had to track simultaneously. The results showed that playing *StarCraft* improved cognitive flexibility more than playing *The Sims*. More importantly, perhaps, the positive effects on cognitive function were strongest for those trained on the *StarCraft* game version with higher load on cognitive flexibility.

Similarly, Franceschini and collaborators[73] took advantage of the fact that the video game *Rayman's Raving Rabbids™* is composed of a series of separate minigames that differ in terms of their action mechanics. They thus trained one group of children on a set of minigames that incorporated mechanics similar to those found in AVGs (high pacing; necessity to shift between focused and divided attention; and variability in target, distractors, or their context). A separate group of children was trained on a different set of minigames that did not have strong action mechanics, but rather required very fast, repetitive responding. After the training, the group that played the AVG-like minigames showed improved reading and attentional skills compared with the control group.

One final, and substantial, level of complication in assessing the impact of video game play on cognitive function stems from the fact that games now allow an increasing amount of freedom in terms of how a gamer interacts with the game world. As players tailor their gaming experience to suit their taste, the cognitive load associated with the game play becomes highly idiosyncratic to each player rather than the game title per se. For example, one individual playing the game *Skyrim* may treat the game primarily as what is known as a "tactical shooter game" (where the player watches enemies from afar and attempts to shoot them from a distance while under cover). A second player may play the game as a "hack-n-slash" (where the player runs directly into combat with a melee weapon and engages enemies face-to-face). A third player might avoid most of the combat elements and instead play the game largely as an RPG (i.e., focusing on the dialog, interpersonal relationships, etc.).[71] As such, not only is it the case that a single game may mix elements of classic genres, but players themselves may differ in the extent to which they experience those elements. Such individual-level variety has already been shown to impact the outcome of game play. For example, West and collaborators[74] found differential impact of action video game training on the hippocampus depending on the extent to which individuals adopted spatial or nonspatial strategies for navigation.[74]

All of the studies mentioned in the above section are part of a young and promising effort to better understand the impact that playing video games has on the brain. However, most of the evidence is correlational in nature and, although hypotheses are being refined, more studies are needed in order to confirm them. In that regard, with the increasing evidence that game mechanics, more than game genre, drive the observed cognitive changes, and as the differentiation of game genres driven by the industry is less and less consistent with a differentiation along the cognitive demands of game play, a shift in methodology appears needed in order to (1) better sort video games with regard to their effect on cognition, and (2) more accurately assess gamers' past experience with different video game genres. Although cognitive neuroscientists are often not games experts, it is increasingly the case that a certain degree of sophistication around the topic of games is necessary to ask questions regarding their impact on brain and cognition.

Existing classification systems

One of the most common ways in which gamers are classified is by asking participants to report their gaming by genre via a self-reported questionnaire similar to that used by Green and Bavelier in 2003.[45,a] Using a genre-based approach, these questionnaires typically ask participants to indicate (1) the average number of hours per week that were spent playing each of several game genres within the past 12 months, (2) the average number of hours per week that were spent playing each of several game genres before the past 12 months, (3) perceived expertise for playing each game genre, and (4) provide examples of their most frequently played games for each genre over the past 12 months. There are numerous variations on this standard questionnaire, with some researchers omitting game genres entirely and simply asking about general gaming hours, and others asking about different time frames. Furthermore, given the changing state of the game industry, researchers have attempted to adapt their genre labels by, for instance, expanding the number of potential genres (e.g., the latest version of the Bavelier lab questionnaire separates FPS and TPS games from action-RPGs and action-adventure games).

Although this general approach is widely used, the specific ways in which gamers are then classified based on their responses can vary widely. Some experimenters, for instance, consider both past and current gaming, and only classify gamers

[a]The most recent version of this questionnaire can be accessed at https://www.unige.ch/fapse/brainlearning/vgq.

into a given genre if a strict set of criteria are met (e.g., 5+ h per week of a given genre, but no more than 3 h per week of any other genre). Others only consider current gaming habits, the games that individuals most frequently play, or even the games that gamers most prefer rather than probing play per se in order to separate gamers into categories that are contrasted against one another.

One of the most substantial issues with this type of approach lies in the set of genres presented to the participants and what games researchers typically include in each of them. Given the increasingly blurry boundaries between genres, finding an accurate classification of games that is also easily understandable by participants is an increasingly difficult challenge. In addition, individuals often over-report the number of hours during which they perform a given activity, particularly if they participate in numerous activities (or, in the case of video games, play multiple genres[63,71]). This is a common issue with quantity–frequency questionnaires (i.e., questionnaires that assess how often an individual engages in various activities), such that the more categories that are presented to individuals, the more categories they are likely to endorse.[75] Moreover, with the increasing prevalence of video games in popular media, more and more individuals will have a long history of gaming, even if they have stopped playing over the past few years. Given that video game play may show long-term effects, it is important to probe distant gaming history, in which case these questionnaires are known to not be particularly reliable. A final issue lies in how to treat individuals who report playing multiple genres (a rapidly increasing percentage of individuals). While some groups continue to attempt to select only individuals whose game play is "genre pure" (i.e., only play games from a single genre), others have attempted to make use of participants who play multiple genres (which has a host of associated issues).[63]

Going forward

Given the limitations of the existing methods discussed above, it may be useful when moving forward as a field to consider various systems that have been used in the media studies literature to classify games. This literature includes a host of systems that differ based on the extent to which they use game experiences and motivations,[76–85] mechanics, or structure,[84,86–95] or a combination of gaming experiences and structure[96] to differentiate between game genres. Many of the approaches in the media studies domain use a combination of qualitative and quantitative methods in order to construct taxonomies. These methods have made use of facet analysis,[97] card-sort/q-sort methodologies,[79,87] and focus groups[98] to derive their data. For example, Bedwell *et al.*[87] recruited experienced gamers and game developers, and asked them to categorize 18 previously identified game attributes using a card-sort technique with an iterative process. This enabled them to develop a comprehensive taxonomy of learning outcomes from serious games.

A second type of approach typically consists of a first step wherein a questionnaire or a survey is administered to a large group of gamers and/or gaming experts, and then some form of dimension reduction is used to reveal the underlying game categories. In a second step, different categories of gamers are derived based on the game categories revealed in step one. For example, to create their taxonomy of game enjoyment, Quick *et al.*[99] administered a questionnaire about personality traits, game preferences, and gaming habits to 293 gamers, and then used factor analysis to reveal a six-factor solution of gameplay motivation. A cluster analysis was then used to identify different categories of gamer type.

Importantly, given the emphasis on players and not just games, these methods allow researchers to derive gamer profiles, which can be used to determine how individuals interact with a given game,[76,82,100] a crucial factor in how video game play influences brain and cognition. This is particularly relevant in open-world games where players have numerous options for how they play the game. However, the existing methods have primarily focused on content and motivations to play the game, rather than game mechanics. Because mechanics, rather than motivations, likely drive the beneficial cognitive effects demonstrated in the gaming literature, a model that focuses on mechanics that exert cognitive load would be more appropriate for the gaming and cognitive performance field (see Wood *et al.*[94] for an example).

Other possible future directions for the field investigating the cognitive impact of video game play include the use of a distance matrix, or a multidimensional scaling (MDS) technique, as a means to discriminate and categorize video games.[101] Similar to a factor analytic technique, MDS provides a visualization of the pairwise distances between elements of a set across multiple dimensions,[102] allowing for an examination of the degree of similarity between items. With respect to gaming, this technique would provide a meaningful clustering of game dimensions based on the degree to which various titles group together based on their cognitive demands (e.g., response pressure, divided attention load, and shifting attentional demands). With such a technique, a puzzle game like *Tetris*® that has high response pressure, low divided attentional load, and low demands for shifting attention would be reasonably distinct from a game like *Call of Duty* that has high response pressure, high divided attentional load, and high demands for shifting attention.

Another method of distinguishing game category may be to employ prototype theory.[103] With this technique, a prototypical or "complete" member of a given category is defined, and the relationship between other potential members of this category and the prototype is evaluated. Clarke *et al.*[89] raised the possibility of using this technique to distinguish games, although they primarily focus on using this technique to identify game genres. However, if instead of focusing on genre we defined a prototype containing elements that should influence cognitive performance (such as discussed above), we may be able to successfully and meaningfully categorize games based on whether or not they are expected to influence cognition, regardless of genre. Of course, both techniques require a thorough understanding of precisely how various aspects of video games influence cognitive performance, but both MDS and prototype theory may provide a promising way forward for game and gamer classification.

Better game classification systems, however, do not solve the inherent problem of self-report measures, especially in the face of having to recall activity schedules potentially dating back years. In that endeavor, the rise of digital game distribution over the last decade may be of help. Indeed, digital distribution of games is mostly done through platforms acting like digital game supermarkets where one can buy games that are then added to one's personal game library. Coincidentally, these platforms usually track a series of statistics linked to the games, such as total game time. Unlike self-report data, these values are objective, unbiased, and track performance far back into the past. If these data could be easily and ethically extracted for all games played by an individual, researchers could have access to much higher quality data. Although it is already possible to access these statistics for some games, it is not as convenient as simply browsing through one unified library. In addition, while some of these platforms were released more than a decade ago, only recently have they started to be the most prevalent form of game distribution. For instance, only about 400 games were released on *Steam*® in 2012 compared with the more than 9000 games released in 2018.[104] Thus, although it may be possible to have an accurate gaming history of players growing up with these technologies, it will not solve the problem of getting accurate data for people who avidly played video games in years before they were available.[104]

A different but equally important direction for future work will be to better consider possible similarities and/or differences between males and females in terms of video game play and its impact on brain and behavior. Previous cross-sectional research examining associations between action-video game playing and cognitive skills has typically utilized only (or mainly) male participants, due to the paucity of female first- or third-person shooter game players. Most intervention studies have, however, included both males and females. In such studies, males and females have shown roughly equivalent benefits of game playing (as long as performance at pretest is matched across gender).[105,106] Looking into the future, the discussed shifts in the game space may result in concomitant changes in the general demographics of action gamers. The addition of role-playing or strategy characteristics into such games may indeed serve to increase the percentage of females who play action-like games. This would be a welcome change as the disproportionate representation of males within this game genre so far could be a source of bias.

Conclusion

A growing body of the literature is unraveling the effects of playing action video games on brain and cognition. This is an important first step if we are to understand how to better use video games as tools to shape cognitive performance, whether for health- or education-related applications. However, as the game industry continues to evolve, the methodology of gaming researchers is fast becoming obsolete.

We thus urge researchers interested in the cognitive neuroscience of gaming to familiarize themselves with the ever-changing landscape of the gaming industry. A concerted effort is also urgently needed to select more appropriate methods than those we have relied on so far to move the field forward.

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Competing interests

The authors declare no competing interests.

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