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DOI 10.1007/s41465-017-0015-6

OPINION

The Changing Face of Video Games and Video Gamers: Future Directions in the Scientific Study of Video Game Play and Cognitive Performance

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Received: 4 October 2016 / Accepted: 15 March 2017

Abstract Research into the perceptual, attentional, and cognitive benefits of playing video games has exploded over the past several decades. However, the methodologies in use today are becoming outdated, as both video games and the gamers themselves are constantly evolving. The purpose of this commentary is to highlight some of the ongoing changes that are occurring in the video game industry, as well as to discuss how these changes may affect research into the effects of gaming on perception, attention, and cognition going forward. The commentary focuses on two main areas: (1) the ways in which video games themselves have changed since the early 2000s, including the rise of various "hybrid" genres, the emergence of distinct new genres, and the increasing push toward online/open-world games, and (2) how video game players have changed since the early 2000s, including shifts in demographics, the decreasing specialization of gamers, and the fact that gamers today now have a long gaming history. In all cases, we discuss possible changes in the methods used to study the impact of video games on cognitive performance that these shifts in the gaming landscape necessitate.

Keywords Video games · Cognition · Methodology

Introduction

Video games, in some form or another, have existed for over 50 years. However, it was not until the late 1970s and early 1980s, when home systems became available, that they truly entered popular culture. The rising commercial popularity of video games during this period was mirrored by increasing scientific interest in exploring the effects of playing video games on a number of facets of behavior. For example, over the past few decades, numerous studies have been conducted to examine the possible link between gaming and aggression (Anderson and Bushman 2001; Sherry 2001), how gaming affects motivation and emotion (e.g., Granic et al. 2014; McGonigal 2011; Russoniello et al. 2009; Ryan et al. 2006), how playing video games can enhance learning in educational settings (e.g., Gee 2003; Prensky 2003), and on video game addiction (e.g., Gentile et al. 2011; Gentile 2009; Lemmens et al. 2011). Additionally, video games have been investigated as potential tools in rehabilitation settings, such as in the treatment of dyslexia (e.g., Franceschini et al. 2013) and amblyopia (Li et al. 2011), as well as in job-related settings, such as for training pilots (Gopher et al. 1994; McKinley et al. 2011) or laparoscopic surgeons (e.g., Kennedy et al. 2011; Schlickum et al. 2009). Of particular importance to the current paper, however, is the ever-growing body of research that has explored how playing video games can affect the perceptual, attentional, cognitive, and motor systems.

Early studies that examined the effects of gaming on perceptual, attentional, and cognitive functioning outlined a number of positive outcomes associated with video game play. For instance, regular video game players outperformed non-gamers in a variety of abilities including hand-eye coordination, spatial skills, and divided attention (Greenfield et al. 1994a, b; Griffith et al. 1983). Furthermore, intervention studies demonstrated that non-gamers who were trained on certain video games showed improvements in various cognitive, attentional, and/or motor skills, suggesting that the relationship between gaming and enhanced performance was indeed causal (Dorval and Pepin 1986; Gagnon 1985; Greenfield et al.

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1994a, b; Okagaki and Frensch 1994; Subrahmanyam and Greenfield 1994).

It was not until the early 2000s, however, that scientific interest in the potentially beneficial effects of playing video games on perceptual, attentional, and cognitive performance began to accelerate. In an influential study, Green and Bavelier (2003) first demonstrated that individuals who avidly played one particular video game sub-genre, "action video games," outperformed individuals who did not play that sub-genre of game on several different tasks of selective attention. The authors then showed that this effect was causal via a well-controlled intervention study. Participants who were trained for 10 h on an action video game, Medal of Honor: Allied Assault (2002), showed significantly greater improvements on several measures of selective attention following training as compared to individuals who were trained for the same length of time on the non-action puzzle game, Tetris (1984).

One key point from this study is that not all video games equally benefit perception, attention, and cognition. Instead, playing action video games leads to significantly larger effects than playing other types of video games. This finding is consistent with the types of perceptual, attentional, and cognitive processes engaged by the various types of games. Indeed, games from the action genre require players to attend to information that is rapidly presented both centrally and peripherally and to make quick and accurate decisions based on this information. As such, these games place processes related to selective attention, spatial attention, and task switching under significant load. From this, it follows that playing these games regularly can enhance cognitive processing, whereas playing games from non-action categories that do not rely heavily on these processes should not influence cognition.

In the more than 10 years that have passed since this study, a vast amount of work has been published on the potential use of action video games to enhance various processes such as perception (Donohue et al. 2010; Dye et al. 2009; Li et al. 2010b), attention (e.g., Dye et al. 2009; Dye and Bavelier 2010; Green and Bavelier 2003, 2006, 2007; Hubert-Wallander et al. 2011; Li et al. 2010a, b; Wu and Spence 2013; Wu et al. 2012), and higher-level cognition including task switching (Chiappe et al. 2013; Colzato et al. 2010; Green et al. 2012; Strobach et al. 2012), multi-tasking (Strobach et al. 2012), and some aspects of short-term/working memory (Blacker and Curby 2013; Blacker et al. 2014; Colzato et al. 2013; McDermott et al. 2014; Sungur and Boduroglu 2012; Wilms et al. 2013). Indeed, the literature on the relationship between video game play and cognitive and perceptual performance is now sufficiently large enough to allow for meta-analyses to be conducted (Bediou et al. under review; Powers et al. 2013). Critically, in nearly every case above, the main finding was that playing action games was associated with larger effects than playing other types of video games (although see a recent paper by Unsworth et al. 2015, as well as a response by Green et al. 2017).

However, while the above papers nicely illustrate the impact of action video game play on human performance, the video game landscape of today is immensely different from the landscape of 2003. Indeed, none of the games listed as commonly played by participants in the cross-sectional study in Green and Bavelier (2003) would make the top-100, top-1000, or potentially even top-10,000 games played today. Instead, as is typical of cultural systems, the video game industry is in a constant state of change, with both games and gamers ceaselessly co-evolving. This means that the methodological techniques utilized to study the impact of video games on performance must similarly adapt or run the risk of becoming antiquated and potentially producing misleading results.

Because not all scientists who study the impact of video games on cognitive processing are themselves gamers, the purpose of this commentary is to illustrate and discuss some of the key ways in which the gaming world has changed since the publication of Green and Bavelier (2003) and how these differences will affect the study of gaming and its effect on cognition/perception going forward. Although the gaming literature is vast, and researchers from many areas of psychology study the impact of games on behavior, the current paper is designed specifically for those researchers who study the impact of video games on perceptual, attentional, and cognitive processing.

We will examine two key topics in this paper. The first topic will focus on the ways in which video games themselves have changed since the early 2000s. This includes (a) the rise of various "hybrid" genres that contain elements from multiple previously distinct genres, (b) the emergence of many distinct new genres, (c) the increasing push toward predominantly online (versus single player) games, and (d) the growth of games that allow for many different play styles within the same basic game framework (e.g., "open-world" games).

The second topic will focus on the ways in which video game players have changed since the early 2000s. This includes (e) shifts in demographics (such as gender and age), (f) the decreasing specialization of gamers with individuals now playing games from many different genres, and (g) the fact that gamers today have a very different history of gaming than those of 2003. In all cases, we will discuss how these shifts in the gaming landscape can influence studies of perception, attention, and cognition going forward and possible changes in methodology that these shifts necessitate. Ultimately, our goal is to provide those researchers who study the effects of gaming on these behavioral processes with the knowledge and tools to produce research that is relevant, accurate, and generalizable.

The Changing Face of Video Games

Most of the research on video game play and cognitive performance to date has been genre-based. Specifically, as discussed above, this literature has focused almost exclusively on games that traditionally belong to the "action" genre, and has generally contrasted the effects of playing the action genre with all other genres (see Table 1 for a breakdown of various gaming genres). This work has, as its foundation, two implicit assumptions. The first assumption is that video games can be classified into exclusive genres that are indicative of the core mechanics in the games (as it is the mechanics of a game that drive changes in abilities, not the fact that a game nominally belongs to a certain genre). The term "mechanics" essentially refers to those core elements or characteristics of a given game that determine how players interact with the game. For example, in a typical shooter/action game, the elements of aiming at an enemy, accurately shooting the enemy before they can hide or disappear, being aware of surrounding threats by attending to the periphery, and avoiding said threats by either eliminating them or by strategically taking cover, would all be common game mechanics (see Table 1 for a description of various genres and their core game mechanics).

The second assumption is that only games that traditionally belong to the action genre (e.g., first- and third-person shooters; see Table 1) have the type of mechanics that will drive changes in cognitive performance. Specifically, it is hypothesized that there is something unique about action games that leads to improvements in a host of cognitive abilities, such as attention, cognitive control, and perception. One prominent theory suggests that the complex environment of action video games that requires players to effectively divide their cognitive resources and rapidly perceive and respond to threats, and the varied demands that these games place on the system, ultimately increase the player's capacity to learn, which in turn transfers to other non-video game tasks (i.e., "learning to learn"; see Bavelier et al. 2012 for a review).

While it may have been true a decade ago that only traditional action games (e.g., first- or third-person shooter games) contained the appropriate combination of game mechanics that can lead to changes in cognition, the popular video games of today increasingly contain mechanics from a variety of genres, including the action genre, and it is becoming far less common to find games that could be classified as genre-pure (see Spence and Feng 2010 for a review). Indeed, as can be seen in Table 1, there are several genres that would traditionally be classified as non-action, such as the real-time strategy (RTS) genre, that contain mechanics that significantly overlap with the traditional action genres (e.g., first-person shooters). One result of the presence of action mechanics (such as the requirement to rapidly respond to threats or constantly scan the periphery for danger) in previously non-action genres is that beneficial effects have been seen from playing games that were not traditionally defined as action games. For example, a recent study demonstrated that non-gamers who were trained on a traditional RTS game, StarCraft II (2010), showed greater improvements on a cognitive flexibility task after training as compared to controls who were trained on a non-action game (Glass et al. 2013). Similarly, Basak and colleagues demonstrated that older adults who trained on the RTS game, Rise of Nations (2003), showed greater improvements on tasks of mental rotation, short-term memory, and task switching as compared to controls (Basak et al. 2008). Finally, a recent study demonstrated that participants who played 20 h of mini-games (e.g., hidden object game and life simulation game) significantly improved on measures of visual search and working memory following training (Oei and Patterson 2013). Together, the above results demonstrate that the evolution of games may have serious implications for research. The following section will focus on how game genres and structure have changed since 2003, as well as how these changes could influence gaming research.

The Melding of Distinct Genres into New Hybrid Genres

Although the literature examining the cognitive effects of video games has often treated the various genres of video games as fully separable, in practice, the lines separating game genres have some degree of uncertainty (see Table 1). As such, there have always been games that fell into the gray areas where the borders between genres overlapped. Take, for example, the game Tomb Raider (1996). This game is alternately classified as a third-person shooter (TPS) or a puzzle platformer, depending on the source, as it contains elements of both of these genres. A more modern example might be Valkyria Chronicles 3 (2011), which has elements of turn-based strategy (TBS) games, role-playing games (RPGs), and TPS games (see Table 1). However, while any video game classification scheme will always involve some exemplar games that fit into multiple genres, of greater importance is the rise in popularity of full-hybrid genres. Games in hybrid genres involve a mixture of characteristics from two (or more) distinct genres, and importantly, there are enough games that include the same basic mixtures to qualify as full genres in and of themselves. While there are many such hybrids, we will focus here on two specific hybrid genres that involve an action component, which are action-role-playing games (action-RPGs) and action-adventure games.

As is clear from the name, action-RPGs involve a mixture of characteristics from the classic RPG genre and from the classic action game genre (see Table 1). RPGs typically include a well-defined story involving exploration of a broad fantasy world in the service of some specific quest or quests. The player controls either a single character or a small number of characters within a "party," who interact with the environment. Successful interactions with the environment build "experience points" which can be used to "level up" the

Table 1 Breakdown of game genres, abbreviations, common characteristics/mechanics, and cognitive functions that may be positively influenced by playing the game

Game genre	Abbreviation	Game example	Key characteristics/mechanisms	Cognitive processes affected
First/third-person shooter	FPS/TPS	Call of Duty	Aim, shoot, run, hide, little storyline, first- or third-person perspective, control single character, real-time action	Perception, attention, reaction time, cognitive control, executive functions, memory
Sports/driving	–	FIFA	Aim, shoot, run, little storyline, first- or third-person perspective, typically control single character, real-time action	Likely similar as FPS, as often included with those games in "action" category
Real-time strategy	RTS	StarCraft II	Gather resources, build, defend base, attack enemies, control army of characters, real-time action	Reaction time, cognitive control
Multi-player online battle arena	MOBA	League of Legends	Similar to RTS but no building/resource gathering, control single character, play in teams, attack/defense, real-time action	Unknown, possibly similar benefits to RTS and/or FPS
Turn-based strategy	TBS	Civilization	Similar to RTS (above), but action is turn-based (not real-time), allows for extensive analysis/strategizing	Unknown, possibly planning, problem solving, and/or memory
Role-playing game	RPG	Fallout II	Play a single character, emphasis on storyline, dialog trees, action plays secondary role, can be turn-based, but most now real-time	Unknown, perhaps similar to RTS
Action-role-playing game	Action-RPG	Mass Effect 3	Combination of FPS/TBS and RPG	Unknown, perhaps similar to RTS
Adventure	–	Life is Strange	Compelling story, dialog trees, exploration, puzzle solving, no shooting/attacking	Unknown, possibly planning, problem solving, and/or memory
Action-adventure	–	Assassin's Creed	Combination of FPS/TPS and adventure	Unknown, possibly similar to RTS
Mini-games	–	Angry Birds	Short, little storyline, simplistic graphics, drag-and-drop, problem solving/puzzle, several genres	Depends on game
Puzzle	–	Portal 2	Point and click, drag-and-drop, problem solving, extensive planning required	Problem solving, spatial skills, persistence, executive control
Music	–	Guitar Hero	Timing, rapid finger or foot movements, rhythm	Unknown, possible manual dexterity/reaction time/time perception

[a] Aside from the shooter/action genre, the influence of most other genres on cognition is unknown/speculative

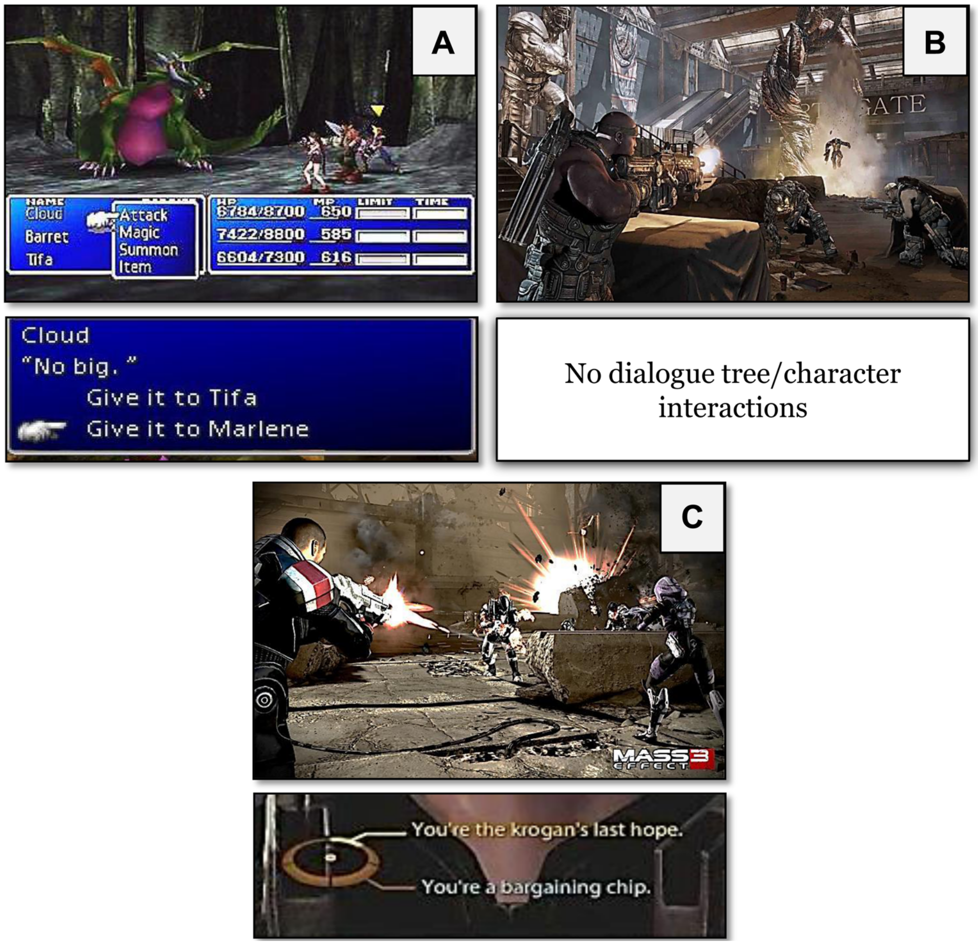

Fig. 1 The rise of "hybrid" genres such as action-RPGs. **a** RPG: example of the classic RPG, Final Fantasy VII (1997). Combat in this, and similar classic RPGs, is turn-based, such that players have time to select which attack they will use on the enemy. Here (*top panel*), a player is viewing the available combat options to determine which to employ. In general, action in RPGs plays a very minor role as compared to aspects such as story development. For instance, the *bottom panel* shows an example of the type of dialog trees that allow players to choose how the storyline will proceed. **b** Action: example of a popular third-person shooter, Gears of War 2 (2008). Gameplay is mainly centered on combat (i.e., killing enemies) that proceeds in real time (i.e., under significant time constraints). Here (*top panel*), the player (through their avatar on the *left*) is firing at an enemy who has just sprung through the floor. Although there is a storyline in such games, it is generally secondary to the action, and players cannot influence its direction (as indicated in the *bottom panel*). **c** Action-RPG: example of the action-RPG, Mass Effect 3 (2012). This game uses the same third-person combat mechanisms as Gears of War (*top panel*) but contains a rich storyline that progresses differently depending on the options players select from the dialog wheel (*bottom panel*), like Final Fantasy VII. Thus, it combines action combat mechanics with storyline/character development mechanics from RPGs

character (i.e., gain new abilities or make existing abilities more powerful) (see Fig. 1a). As these games partly evolved from tabletop role-playing games (e.g., Dungeons and Dragons 1974), combat in RPGs is often turn-based. The player selects an "attack" from among a number of options, and the success of the attack is then determined (either explicitly or implicitly) by a dice roll that takes into account the relative abilities of the attacker and defender. Prototypical examples of the RPG genre include Elder Scrolls: Arena (1994), Final Fantasy VII (1997), and Fallout 2 (1998).

The defining feature of the action video game genre largely centers on the method of combat. Players use projectile-based weapons (e.g., gun, laser, and bow and arrow) to engage with enemies either in a first-person view (i.e., looking directly through the character's eyes) or in a third-person view (i.e., looking at the character from behind; see Fig. 1b). Because the challenge of these games is based on the difficulty of the combat, it is common for enemies to move very quickly, to first appear in the far edges of the screen, and for multiple enemies to be presented simultaneously (i.e., the aspects that are believed to drive the changes in cognitive abilities). The storyline and characters in these genres usually take a secondary role to the shooting mechanics (e.g., the character is usually pre-defined along with the character's traits). A hybrid action-RPG is thus one that combines first-person or third-person shooter-based combat mechanics with story, exploration, experience, and leveling characteristics of RPGs (see Fig. 1c and Table 1). To some extent, most RPGs made today are actually better characterized as action-RPGs. This includes some of the most popular games of the past 5 years such as The Elder Scrolls V: Skyrim (2011), Borderlands 2 (2012), Mass Effect 3 (2012), Dragon Age: Inquisition (2014), The Witcher 3: Wild Hunt (2015), and Fallout 4 (2015).

Action-adventure games, on the other hand, combine elements of action games and adventure games (see Table 1). The modern adventure game genre evolved from both board- and text-based video games from the 1970s and 1980s, such as the game Adventure (1999). The defining characteristics of adventure games are typically exploration and puzzle solving. There is usually a lesser focus on experience and leveling of one's character (the character's abilities are often fully predefined), and combat in adventure games is usually either entirely absent, or else is highly limited and secondary to the goals of the game. Prototypical examples of the adventure genre include King's Quest V (1992), Myst (1993), Riven (1997), and Machinarium (1999). Action-adventure games thus involve a significant amount of exploration and puzzle solving but also use the same action combat mechanics as discussed in the context of action-RPGs (i.e., first-person shooter (FPS) or third-person shooter (TPS) mechanics).

Similar to action-RPGs, nearly all games that might be classified as adventure games today are likely better characterized as action-adventure games. This includes popular games such as The Legend of Zelda: Ocarina of Time (1998), Metroid Prime (2002), Grand Theft Auto V (2013), Far Cry 4 (2014), Assassin's Creed: Syndicate (2015), and Batman: Arkham Knight (2015).

Thus, because the games in the action-RPG genre and the action-adventure genre have, in many respects, very similar action combat mechanics as are found in prototypical action games, they will need to be treated appropriately by research teams going forward. Indeed, it is possible that training on these games will also improve cognitive performance, just as with more traditional action games like first-person shooters. We will discuss this in greater detail after considering a number of other key changes that have occurred in the video game landscape below.

New Genres: Music/Rhythm, Real-Time Strategy, and "Mobile Games" In addition to the rise in hybrid genres, a number of new genres have also been created over the past decade. For instance, one genre that essentially did not exist at the time of Green and Bavelier (2003) is the Music/Rhythm genre. Games in this genre often involve hitting buttons in time with music and visual cues on the screen. While there were a few such games in the late 1990s and early 2000s (e.g., PaRappa the Rapper (1998), Dance Dance Revolution (1999), and Karaoke Revolution (2003)), it was not until the musical rhythm game, Guitar Hero (2005), was released that the music/rhythm genre saw real growth. Eventually, a host of games using the music/rhythm format emerged, such as Rock Band (2007) and Just Dance (2009).

While the cognitive effects of playing games from the music/rhythm genre have largely been unexplored, a second genre that emerged over the same time frame—the RTS genre—has been the focus of some experimental work. As described earlier, this work suggests that playing games from this genre may result in beneficial effects similar to action video games (see Table 1). RTS games are similar to TBS games (see Fig. 2a); in that, players must strategically maneuver an army around a map in order to defeat an enemy. The player's army usually consists of a great many sub-units of different types, each with different strengths and weaknesses (e.g., archers that can attack from afar but are themselves vulnerable to attack, cavalry that can move great distances quickly but are also vulnerable to some types of attack, and infantry that usually move more slowly but are less vulnerable to attack). Thus, these games involve significant planning and abstract thinking, as the player not only must decide how to use the various units but also must plan which units to create in the first place. The biggest difference between TBS and RTS games is that while TBS games allow for pauses between the action, RTS games move in real time (see Table 1). Thus, while in TBS games the players can stop and carefully consider actions and their possible consequences, RTS games are very fast-paced and require rapid thinking (see Fig. 2b). Examples of RTS games include WarCraft II (2002), Rise of Nations (2003), Warhammer 40,000: Dawn of War II (2009), and StarCraft II (2010).

While the RTS genre is a relatively recent genre, it has already spawned a hybrid genre that is variously called action-RTS or multi-player online battle arena (MOBA). In this genre, players typically control a single character and compete with teams to defeat the enemy. Games from this genre include League of Legends (2009), Dota 2 (2013), and Heroes of the Storm (2015). Both RTS and action-RTS/MOBA games tax a number of the same cognitive systems as more traditional action games and are one of the main genres of games played in e-sport competitions (indeed, the largest e-sport tournament purse ever was for Dota 2's *The International 2016* at $20,770,640.00). As such, playing these games regularly may also lead to cognitive benefits that are similar to those seen with more traditional action games.

Finally, one of the more popular groups of games today belongs to a genre that is extremely ill defined, specifically mobile games. In this case, the classification is based largely on the device that is being used to play the game (i.e., a smartphone or tablet) rather than the actual mechanics of the games themselves. This is problematic not only because there is little to no evidence

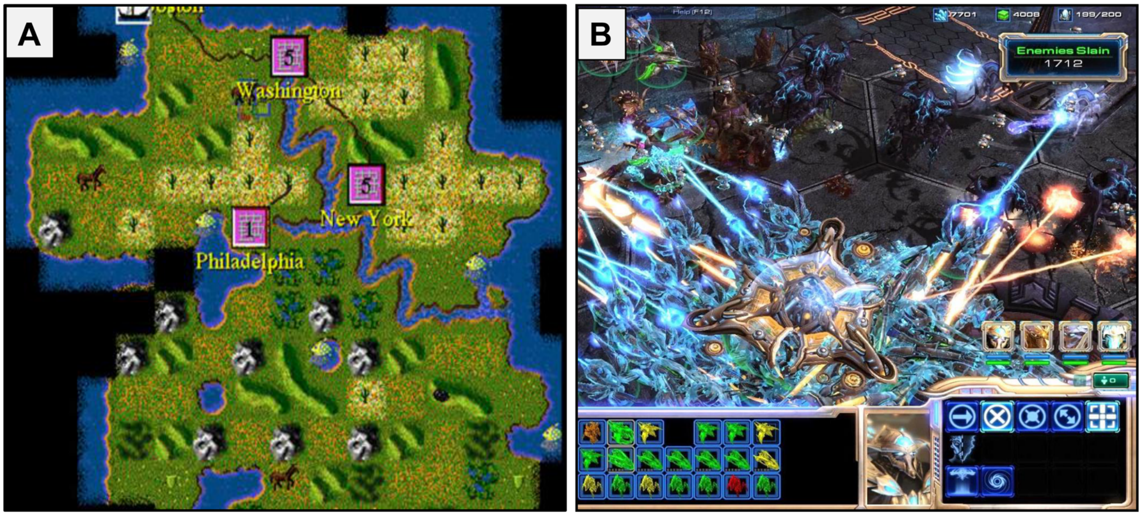

Fig. 2 **a** Example of the classic TBS game, Civilization (1991). Players gather resources and build structures and armies, and then eventually attempt to conquer new lands. Gameplay is turn-based, such that players receive a limited number of actions that they can take in each turn. After they have taken all available actions, they must wait for all other players to act before it once again becomes their turn to act. **b** An example of the RTS game, StarCraft II (2010). Like Civilization, players control units or armies and strategically gather resources, build new units, and attack the enemy, all while defending their own base from attacks. However, the action is real time. Thus, there are no pauses in game play or limits in the amount of moves they can make. This results in a much faster-paced experience, wherein players must make decisions under considerable time pressure (much like in action video games) and are forced to effectively monitor the entire screen (again, very much like in action video games)

demonstrating that the gaming platform itself influences performance, but also because mobile games include a variety of genres including puzzle, RPG, action, and music/rhythm. In addition, several of the games that can be played on a smartphone can be played on other platforms including tablets, PCs, and even consoles. As such, the current practice of classifying all mobile games into a single category is problematic. However, there is evidence suggesting that playing mini-games, which have largely been developed for use on smartphones and tablets, have positive effects on cognitive processing (e.g., Oei and Patterson 2013). These games are typically shorter than traditional console/PC games, have simple graphics and controls, and are often puzzle-based (e.g., Bejeweled, Angry Birds; see Table 1). As such, although the category of mobile games is too broad and largely useless, certain games from within this overlarge genre are worthy of investigation. Again, sorting games based on their mechanics may be more beneficial than lumping games together based on the gaming platform (e.g., Bejeweled uses a simple drag-and-drop interface with an emphasis on speed of processing and response, whereas Angry Birds utilizes a similar drag-and-drop interface with an emphasis on accuracy).

Overall, because several of these new genres involve similar cognitive processes as action video games, they will need to be treated appropriately by research teams going forward as they are almost certainly not inert with respect to changing cognitive functions (see Basak et al. 2008; Glass et al. 2013). Given the significant overlap between these new genres and games that are traditionally classified as action games, it follows that regularly playing games from these new genres may also enhance cognitive performance.

The Rise of Online and Open-World Play Beyond the development of new genres and hybrid genres, two other major changes to the structure of games that have occurred since 2003 are (1) the dramatic increase in games where the majority of the gameplay occurs online and (2) the growing push toward so-called open-world games. As we will see below, both of these trends have a similar impact on the study of games.

Traditionally, video games were single player with a linear storyline. The games allowed for very little deviation from its linear path; thus, all gamers would encounter the same obstacles and challenges at the same point in time and would need to develop the same skills in order to succeed. For example, the FPS video game utilized in Green and Bavelier (2003), Medal of Honor: Allied Assault (2002), is what is commonly known as a "corridor shooter." Although the game gave the visual impression of being very open, players were in fact linearly shunted via a well-defined corridor (i.e., although it appeared that the player could move in any direction, directions other than along the pre-defined path were actually blocked). This meant that all players had essentially the same basic experience in the game. They encountered enemies at roughly the same point, from roughly the same position, and with roughly the same items at their disposal. Although there were differences at the edges (e.g., if player A took more bullets to kill the first enemy than player B, player A would have fewer bullets than player B to engage with the second enemy), it was a reasonably well-controlled experience.

While some modern FPS games retain a linear corridor-style, single-player component (often called "campaign mode"), this is often a minor part of the gameplay experience. Instead, the dominant forms of FPS gameplay today are usually online multi-player. These online sub-games may, for example, take rough forms such as "Deathmatch" (i.e., players simply attempt to kill as many members of an opposing team as quickly as possible, with the first team to reach a set number of kills winning the match), "Capture the Flag" (i.e., members of one team attempt to capture the flag or base of the opposing team and vice versa), and "Survival" (i.e., waves of enemies advance on a cooperative team and the goal is to survive as many such waves as possible), among many possible distinct online sub-games. Critically, because all of these modes involve playing with tens or even hundreds of other human users, the experience that each individual player has is largely unique. Not only will each individual player encounter a completely distinct set of other players (each with their own individual abilities and weaknesses), human players learn and adapt through time. This in turn means that an individual who plays a new online map during the first week that it is released (when players are still determining optimal strategies) will almost certainly have a completely different experience than an individual who plays the same map a month later. In addition, many of these games contain a strong social component that may also influence cognition. For instance, it has also been demonstrated that playing social games can lead to greater stimulation of the brain's reward centers than playing solitary games (e.g., Kätsyri et al. 2013), which in turn facilitates learning (Bao et al. 2001; see also Granic et al. 2014 for a review on the social benefits of gaming). As such, playing games that contain a social aspect may also influence cognition for reasons that are not necessarily related to the actual game mechanics.

Beyond online play, which is poorly controlled due to the complex interactions that occur between large numbers of human players, it is also the case that an ever-growing number of single-player games fall under the broad label of open-world games. In open-world games, rather than being forced down a highly restricted corridor with clearly defined and completely mandatory goals, players are instead given a great deal of freedom to choose where to go, which objectives to take on, and how to approach the various events that arise (see Fig. 3). While such games often retain a coherent story presented in the form of "main story missions," these missions are often highly branching and thus many distinct parts of the "main story" might be available for the player to choose to engage with at any given time. Moreover, even the main story missions are not necessarily linear in nature, but instead often allow the player significant autonomy to determine for him or herself how best to complete the various objectives. For example, in the action-adventure game, Metal Gear Solid V: The Phantom Pain (2015), if the objective is to rescue a prisoner in a small village populated heavily with armed guards, one player may choose to complete the mission by rushing directly into the village and engaging with the guards in close combat, a second player may choose to circle the village, sniping guards from afar and only moving in to rescue the prisoner once all of the guards have been killed, while a third player may choose to infiltrate the village stealthily, rescuing the prisoner without ever being seen by (let alone engaging with) the guards. All of these players will have "completed the same mission," but their actual experiences will have been different.

Additionally, such open-world games usually include a substantial number of optional "side quests" that may or may not alter the path that the main story takes, as well as any number of smaller side objectives (which often involve collecting various types of items from throughout the world). Thus, it is completely possible for two individuals who have both played the same action-adventure game for 30 h to be in different parts of the game. Indeed, it is even possible for two individuals to have played the same action-adventure game for 30 h without having had essentially any of the same experiences. As we will discuss below, because our hypotheses regarding the impact of games are rooted in individuals' actual experiences (i.e., the cognitive demands they face), the fact that the game-label provides increasingly less information regarding those experiences will be of critical importance for researchers going forward.

Considerations for How the Changes in Games Will Affect Research

As a result of the changes in both the mechanics and structure of many modern video games, there are two key considerations that should be made. First, we need to reevaluate traditional genre classifications. As discussed above, most cognitive researchers today exclusively focus on action video game players and compare these action gamers to non-action gamers. Similarly, most training studies will compare the results of training on an action game to the results of training on a non-action game. However, as was highlighted above, using simplistic genre labels is becoming increasingly problematic as, for example, most RPGs are now more accurately classified as action-RPGs, most adventure games are action-adventure, and most strategy games are RTS or action-RTS/MOBAs. In other words, many distinct genres now have action components (see Table 1). As such, it is problematic to categorize gamers from these genres as non-action gamers and to ignore the potentially beneficial effects of playing these

Fig. 3 An example of some of the ways in which a player can interact with the open-world action-RPG, Elder Scrolls V: Skyrim (2011). The *top two panels* depict the player engaging in typical RPG activities to develop their character, such as creating new weapons and armor in the blacksmith forge (*top left*) or learning new magical spells at the College of Winterhold (*top right*). The *middle two panels* depict combat in the game. Combat can either use a third-person (*middle left*) or first-person (*middle right*) view. Furthermore, independent of the viewpoint, combat can either be what is often known as "hack-and-slash" in the video game industry (i.e., where the player uses a melee weapon such as a sword to engage in close combat with enemies; *middle left*), or combat can be identical to either FPS or TPS games (i.e., engaging with enemies from afar using projectile weapons, such as a bow and arrow; *middle right*). Lastly, the *bottom two panels* depict how players can interact with the game, including embarking on a solo quest to discover new areas (*bottom left*) and interacting with other characters in the game (*bottom right*) to receive quests and advance the storyline. These are but a few of the many ways in which a player can spend time in the game. Because of this variety in permitted play styles, it is increasingly possible that two individuals will have nominally played the same "game" without having had any of the same experiences

games. Given these issues with genre classifications, it is essential that perceptual, attentional, and cognitive researchers begin to examine the actual mechanics of games, and create classifications based on this information, rather than attempt to utilize increasingly imprecise genre classifications. Under such a classification scheme if, for example, action components are of interest, it would make little sense to pit action games against action-RPGs and/or action-adventure games as all three categories include the same basic action components. One initial step that could be taken for cross-sectional studies might be to have players list the games that they most often play and to then classify the players into various gamer groups depending on the mechanics of their chosen game. To begin to address this issue, some research groups are currently developing game taxonomies that break down games based on their components, rather than the genre to which they have been assigned (e.g., King et al. 2010). Using such taxonomies would allow researchers to better separate different categories of gamers in order to understand why some games lead to cognitive benefits, whereas others do not.

The second consideration is that we need to better evaluate how individuals actually play their games. While there is certainly some value in knowing the broad genre of games that individuals have played, and slightly more value in knowing the actual games that individuals have played, the level that would be best predictive of cognitive outcomes is discerning exactly *how* individuals have engaged with the given games and, through this, what cognitive processes have been placed under load. For example, an individual who plays the action-RPG, The Elder Scrolls V: Skyrim (2011), as an FPS game will have a completely different set of experiences than an individual who plays the game as an RPG. Furthermore, even knowing that the game is played as an FPS is likely an insufficient level of description, as within the FPS category, there are several clear sub-types of behaviors, including stealth, ranged combat, and melee combat. This in turn will likely create significant differences in what the individuals learn from the game, and the kinds of cognitive abilities that are affected by playing the game. For example, gamers who mainly rely on stealth develop more advanced timing and planning abilities, whereas gamers who play as an up-close, fast-paced melee fighter may develop enhanced manual reaction time. As such, we feel that it would be prudent to start understanding not only what games people play, but how they play as well.

The Changing Face of Video Game Players

In addition to changes in the video games themselves, video game players are also quite different from how they were a decade ago. Gamer demographics have shifted significantly over the past years. Most notable is the increase in the number of female gamers, older gamers, and the number of people in general who have experience with video games (Entertainment Software Association 2015). In addition, fewer gamers today stick to playing games from within the same genre, leading to issues with recruiting single game or genre-pure gamers. Lastly, one simple consequence of the long-term popularity of video games is that today's gamers often have extensive histories of game play. In the following section, each of these issues are discussed in detail, along with some suggestions for how we can mitigate some of the research challenges associated with these changes.

Shifts in Demographics While video game players in the past were often males in their teens or early 20s, there has been a steady rise over the past decade in the number of both female gamers and older gamers. For example, a recent (2015) survey showed that 44% of all gamers are female, and of the entire population of gamers, more are females over age 18 (33%) than males under age 18 (15%; Entertainment Software Association 2015). In addition, the average gamer is 35 years old, with 27% of all gamers being over the age of 50 (up from only 9% in 1999; Entertainment Software Association 2015).

These shifts in gamer demographics are important to take into consideration for at least two key reasons. First, while there has been an increase in the number of female gamers and older gamers, these individuals are not distributed evenly across game genres. For example, a 2012 survey found that female gamers are far more likely to play simulation, puzzle, and dance/music games, whereas males are more drawn to FPS and RTS games (Phan et al. 2012; see also Hartmann and Klimmt 2006). Indeed, a recent survey estimated that while 57% of gamers who play The Sims (2000; simulation/adventure game) are female, only 28% of Call of Duty (2003; FPS) gamers are female (Harwell 2014). Similarly, older adults are less likely to play action games and are more likely to engage in casual social games (De Schutter 2010; Souders et al. 2015). These gender and age disparities can lead to problems when comparing performance across various games or genres, as there are known pre-existing differences in cognitive abilities between older and younger adults (e.g., van Hooren et al. 2007) and, to a lesser extent, between males and females (e.g., Voyer et al. 1995).

In addition to the increase in female and older gamers, there has been an increase in the number of individuals in general who play video games. Indeed, far more people self-identify as gamers than ever before. It is estimated that over 155 million adults in the USA play video games (Entertainment Software Association 2015). One reason for this increase could be that most individuals (an estimated four out of five households) now have access to a computer or console on which to play games (Entertainment Software Association 2015). In addition, with the introduction of smartphones (which are now used by an estimated 2.6 billion people around the globe; Ericsson 2015), there has been an influx in the number of mobile games available for play (such as Candy Crush (2012)). These games are generally free either through mobile apps, or through websites like Facebook, and are often highly addictive (Kuss and Griffiths 2012). As such, it is becoming much more difficult to find individuals who do not play any sort of game at all.

Most Gamers Play More than One Genre One key consideration in sampling gamers is that most regular gamers tend to play multiple games from multiple genres, as opposed to largely playing games from a single or small number of game genres. To illustrate, at the beginning of each semester, we administer a video game experience survey to approximately 800–1000 undergraduate students enrolled in Introductory Psychology. Combining across the years 2012–2016, we have surveyed approximately 6650 undergraduate students. If we exclude those individuals who indicated that they play less than 1.5 h per week of gaming (genuine non-gamers and those individuals who chose not to engage with the survey), we are left with 5008 individuals who have indicated that they play video games at least 1.5 h per week. Participants can then be classified as either genre-pure, multi-genre, or casual. Genre-pure gamers are classified as those who play 5+ hours per week of either action (AVG), RTS, or RPGs but no more than 3 h per week of any other game genre. Multi-genre gamers are those who play 5+ hours per week of video games but who play more than 3 h per week of more than one genre. Finally, casual gamers are those who play games for at least 1.5 h per week but no more than 5 h per week. Using this classification criteria, we found that 6% of the 5008 gamers could be classified as genre-pure gamers (3% AVG, 2% RTS, and 1% RPG), whereas 48% were classified as multi-genre gamers (47% were classified as casual gamers; see Fig. 4).

One reason for the commonness of "tweener" gamers who regularly play multiple genres is that game genres have increasingly become less unique and well defined, such that

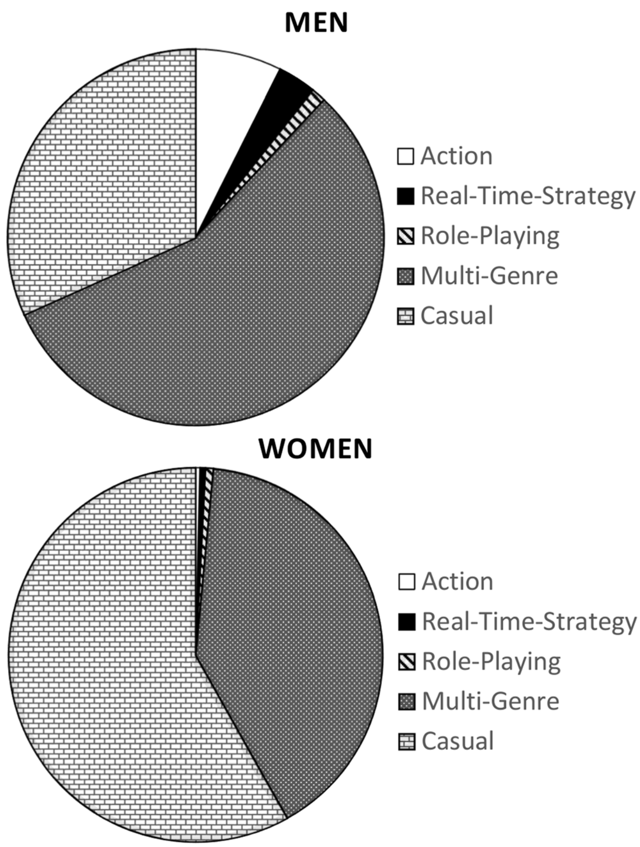

Fig. 4 The proportion of male (*top*) and female (*bottom*) gamers (more than 1.5 h of gaming per week) who were classified as **a** genre-pure gamers (action, real-time strategy, or role-playing), **b** multi-genre gamers, or **c** casual gamers from a sample of 5008 University of Wisconsin-Madison undergraduate students surveyed between 2012 and 2016

there is now significant overlap among the action/FPS/RTS/RPG genres (see Table 1). As such, games that once contained mechanics that were unappealing to certain groups of gamers are now becoming more accessible and attractive. For example, RPG players, who strongly valued the role of story, context, and the ability to explore new environments, may not have had any interest in corridor-style FPS games. However, they may enjoy the addition of FPS or TBS combat mechanics to games that retain the classic adventure/RPG story-based elements. In addition, many gaming systems have vast online communities (such as *Xbox Live* or *PlayStation Network*) where players can interact and compete in teams with gamers from all over the globe, which potentially leads to an increase in both the number of games played and the number of hours played. Lastly, many games are now purchased online either through the gaming console itself or through services like *Steam* that provide computer game content (Grubb 2015). Many of these games are relatively inexpensive, or even free, and have large online communities (it is estimated that *Steam* alone has over 125 million active users and has 781 million registered games; Te 2015). Furthermore, online streaming services like *Twitch* allow individuals to watch others play video games, which further increases their interest and knowledge of new games and genres. In general, gamers have access to a larger pool of games, larger online communities, and more information about the games themselves including guides and ratings, thus possibly leading to an increase in the number of games that individuals play.

Participants Now Have a Long Gaming History One final consideration is that individuals now have a much longer history of playing games, particularly action video games, than did participants in the early 2000s. While there are some participants who report that they do not currently play games, in our experience, a much smaller number will report that they have never played video games. Indeed, many individuals played extensively in elementary and high school, and even young children and babies are now introduced to games through tablets and smartphones (Kabali et al. 2015). Given that the effects of game training have been shown to be rather long-lasting (Feng et al. 2007; Li et al. 2010a), it is important to take this history into consideration. This is especially important when selecting non-gamers for a study, as there are likely large differences between an individual who has literally never played a video game before in their lifetime, and an individual who recently stopped gaming, but played extensively in the years prior to beginning college (e.g., if the individual was unable to bring their gaming console with them to college). Given the rise in gaming in the general population, and the advancement of various technologies that make gaming accessible even to very small children, this history should be taken into account, particularly when selecting specific populations of gamers for a study.

Considerations for How the Changes in Gamers Will Affect Research

Gamers have clearly evolved in myriad ways over the past decade. As a result, there are a several considerations that need to be made when examining the effects of gaming on perception, attention, and cognition. First, we need to better understand how to deal with individual differences that have arisen as a result of the changing demographics of gamers. This includes modeling individual difference factors that could affect how gaming influences cognition, as well as being cognizant of the pre-existing differences between these various demographic groups that could differentially affect performance.

Second, we need to better understand how to address gamers who play multiple genres. Researchers typically exclude multi-genre gamers from cross-sectional studies because their gaming habits, both with respect to number of hours played and the types of games that are played in a given week, tend to fluctuate dramatically not only between individuals but also within individuals. However, with the decline in genre-pure gamers, and the increase in multi-genre gamers, it is increasingly less viable to simply recruit those gamers who stick with a single game or genre, as this is no longer reflective of today's gamers. As such, researchers should start recruiting from this vast pool of tweeners in order to better understand the benefits/drawbacks of multi-genre gameplay. Preliminary cross-sectional research on multi-genre gamers suggests that the cognitive performance of tweeners falls somewhat in between that of genre-pure action gamers and non-gamers, such that they are numerically slower than action gamers on reaction time tasks but faster than non-gamers (Dale and Green, under review). This suggests that multi-genre gaming may also benefit cognitive performance. In addition to studying this large and diverse group of gamers ideally, as mentioned previously, we could begin moving toward classifying games on a mechanistic level. This would allow for regression models that were not previously possible (although such models would likely need to go far beyond simple linear models, as it is exceptionally unlikely that cognitive skills would be a linear function of hours of gaming over the past several months or year; see Green et al. 2017), and thus allow us to better understand how different game mechanics influence cognition.

Although some authors have attempted to perform such regressions using existing questionnaires (e.g., Unsworth et al. 2015), we have argued that one pressing methodological issue that will need to be addressed before such analyses are possible is the fact that individuals who play multiple genres tend to overestimate the total number of hours that they play (Green et al. 2017). This is a well-known issue with so-called quantity-frequency questionnaires (i.e., questionnaires designed to assess how often individuals engage in various activities), such that the more categories that are presented to participants, the more categories they will endorse (Sobell and Sobell 2003). For instance, consider an individual who has played on average 5 h of action games per week for the past year. If the questionnaire simply asks about action games, this individual may indicate their true number of hours with reasonable accuracy. However, if the questionnaire breaks the action category into FPS, TPS, action-RPG, action-adventure, and action-RTS, the same individual may indicate that they play 3–5 h of each of these sub-categories (presumably because, during those weeks when they happen to be playing one of those genres, that is the amount that they play). Thus, the same participant who indicates that they played 5 h of action games per week in the global questionnaire might indicate that they played 15–25 h of action games per week in the more fine-grained questionnaire. This in turn makes it impossible to attempt to model cognitive outcomes as a function of the amount of time spent playing different genres (Green et al. 2017). Consistent with this idea, although Unsworth et al. (2015) largely replicated the existing literature showing greater attentional task performance in pure AVGPs as compared to pure NVGPs (where the above issues are eliminated or minimized), multiple regression analyses attempting to model cognitive performance as a linear combination of reported hours of playing across all game genres (where the above issues are clearly at play) led to largely null effects.

A related issue is that we need to consider that gamers today have a much longer gaming history than in the past. Given the known long-lasting effects of game training, it is necessary to distinguish between individuals who have never gamed and those who have extensive previous game experience, but do not currently play games. Indeed, individuals who recently stopped playing video games, but have a long history of gaming, should potentially be excluded from the non-gamer category where they are so often placed, given that most gaming questionnaires only assess current gaming habits. Doing so, however, will effectively involve dealing with additional problems that arise when using self-report measures as an index of game play. As noted above, it is already difficult for participants (who are likely biased by recent play, etc.) to accurately indicate their gaming history across multiple genres for the past year (Green et al. 2017); attempting to quantify the average hours of gaming that occurred 5 years in the past may simply be impossible via current methods.

While fields that make use of quantity-frequency questionnaires (e.g., the study of alcohol consumption) have dealt with similar issues that affect reliability by using methods like requiring participants to keep daily diaries (e.g., Poikolainen et al. 2002), in the case of video games, a different way forward is possible and likely preferable. Specifically, the last several years have seen a significant rise in availability of objective gaming metrics, such as number of hours played, number of deaths versus kills, achievements, and a host of other information that is collected and stored on game consoles and online profiles (such as *Steam* or *PlayStation Network Account*). These data provide a more accurate measure of gaming history and will increasingly represent the entirety of an individual's gaming experience (i.e., for today's youngest gamers). These metrics could then be used without concern in advanced statistical models attempting to link gaming history to differences in perceptual, attentional, or cognitive performance, thus improving the overall quality of studies examining the effects of gaming experience on performance. As such, we recommend that researchers begin adopting these alternate measures of gaming history, particularly the diary method and extracting gaming information from game consoles/gamer profiles, in order to obtain more accurate estimates of actual gaming hours.

Conclusion and Future Directions

Video games, and video gamers, are constantly evolving. As such, the gaming landscape is vastly different than it was in 2003. In this commentary, we discussed a number of changes to the games themselves, including the increase in hybrid and multi-genre games, the development of new genres, the emergence of open-world online games, and how these changes can impact studies that are designed to examine the effects of gaming on perceptual, attentional, and cognitive performance. Furthermore, gamers/non-gamers themselves are no longer the same as they were a decade ago. Not only are gamers much more common but are also now more gender-balanced and more heterogeneous in terms of age. They are also more likely to play games from several genres and have a long, complex gaming history that may very well affect their cognitive performance. Because our theoretical models of the impact of games on cognition depend critically on the extent to which various cognitive processes are placed under load (Bavelier et al. 2012), the field will likely need to rethink whether previous methods continue to appropriately capture this variability. Indeed, given the rate at which research on the effects of gaming on perception, attention, and cognition is expanding, taking these changes to the gaming landscape into consideration is especially important because many researchers continue to use methodologies from papers that are over a decade old.

Of critical importance, much of the research on the effects of gaming provides a foundation for more applied research, such as training regimens to help ameliorate the effects of aging (e.g., Toril et al. 2014), rehabilitating amblyopia patients (e.g., Li et al. 2011), or treating children with dyslexia (e.g., Franceschini et al. 2013). As such, it is crucial that research in this field be both rigorous and generalizable.

Furthermore, while the issues discussed here represent the current state of affairs, the gaming field obviously continues to advance. For instance, products such as the Oculus Rift, HTC Vive, Sony Playstation VR, and the Google Daydream View all give the promise of a totally new set of virtual reality gaming experiences and have gained enormous popularity over the past few years. In addition, augmented reality games, such as Ingress and Pokémon Go which require participants to interact with their environment via their smartphone, have also seen a recent surge in popularity. It is currently unclear whether these innovative gaming experiences can influence cognitive performance, as most research suggests that it is the game itself, rather than the platform, that engages cognitive processes, but it certainly bears investigation, especially if these new modes of gaming become the norm. Thus, we would like to emphasize that researchers need to familiarize themselves with the current gaming climate, and update their knowledge on a continual basis, to produce research that is relevant, accurate, and generalizable in order to continue to expand the body of work on the effects of gaming on performance.

Compliance with Ethical Standards

Funding This research was supported by a grant from the Office of Naval Research N00014- 14-1-0512 to C.S.G.

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