Focus Article

Stretching the limits of visual attention: the case of action video games

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Visual attention is the set of mechanisms by which relevant visual information is selected while irrelevant information is suppressed, thus allowing the observer to function in a world made up of nearly infinite visual information. Recently, those who habitually play video games have been documented to outperform novices in a variety of visual attentional capabilities, including attention in space, in time, and to objects. Training studies have established similar improvements in groups of nongamers given experience playing these video games. Critically, not all video games seem to have such a beneficial effect on attention; it seems that fast-paced, embodied visuo-motor tasks that require divided attention (tasks commonly found in popular action games like *Halo*) have the greatest effect. At the core of these action video game-induced improvements appears to be a remarkable enhancement in the ability to efficiently deploy endogenous attention. The implications of such an enhancement are relevant to a variety of real-world applications, such as work force training, rehabilitation of clinical populations, and improvement of traditional educational approaches. © 2010 John Wiley & Sons, Ltd.

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INTRODUCTION

Through visual selective attention, certain chunks of information deemed relevant to the observer are selected for further processing, while others are ignored. It is generally thought that the purpose of this universal mechanism is to prevent sensory overload and promote effective functioning in the face of the overwhelming amount of stimulation we constantly receive from the external world. Visual attention is multifaceted and may be directed to specific retinal locations, objects, or even to certain moments in time. Regardless of what exactly is being attended to, the attended stimulus benefits from enhanced processing throughout the visual stream, allowing for faster reaction times and lower detection thresholds, while unattended information is suppressed.[1–4] In many cases, the allocation of attention can be the difference between seeing and reacting appropriately versus missing the event of interest, with all the negative consequences that entails.

Given its crucial function in determining the visual percept that we experience when we look around the world, it is not surprising that scientists have long been interested in ways to modify, extend, and enhance the different facets of visual attention. Early studies of college athletes demonstrated marked improvements in perceptual and cognitive abilities (attention-related and otherwise) that were linked to their years of playing fast-paced action sports,[5–8] suggesting that these skills might be augmented through visual experience. Another potential avenue that investigators have hypothesized might produce these enhancements is video game playing. While earlier scattered studies showed differences in tasks related to vision and visual cognition between those who regularly played video games and those who did not, it was Greenfield et al.[9] who first used a training study to illustrate the causal link between playing a primitive action video game and improvements in tests of visual attention, showing that as little as 5 h of training on a video game had a beneficial

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effect on strategies for dividing attention between two possible target locations.

In the last decade, video games have made considerable progress both technically and culturally; according to the Entertainment Software Association, over 68% of American households play computer or video games.[10] Modern video games often provide the player graphically realistic and attentionally demanding environments, and so perhaps it is fitting that scientific interest in the medium, especially its effects on aspects of visual attention, has renewed in recent years. Here we review much of the work that has been conducted on video games and visual attention, discussing both the established and hypothesized effects of video game experience, current controversies, and future directions for research.

We should note that in this review we will be focusing particularly on studies investigating the effect of *action* video games, games where the player must often respond quickly to sudden appearances of stimuli among distractors, track and act on many fast moving objects, and manage multiple tasks at once. Popular examples of action video games include the *Halo*, *Call of Duty*, and *Unreal Tournament* series. Other genres of video games, such as turn-based strategy or role-playing, due to their overall slower pace and more static visual environments, are not generally thought to lead to the changes in attention many attribute to action video game experience. Studies have shown, for example, that visual attention remains unchanged after training on strategy games like *Rise of Nations*, theme games like *Harry Potter: Quidditch World Cup*, or simple visuo-motor games like *Tetris* or *Solitaire*.[11,12] Of course, we do not suggest that other types of games should have no cognitive effect at all; in fact, the opposite seems likely, as exemplified by the beneficial effect of *Rise of Nations* on task switching.[11] Again, however, we focus on the effect of action games in this review.

BODY

Visuo-Spatial Selective Attention

Many situations in everyday life, such as driving a car or searching for a friend in a crowd, require us to willfully distribute our attentional resources to particular areas in the visual field in order to detect specific target items, often while ignoring distractor items. In the case of driving, for instance, the driver must be able to detect the introduction of pedestrians or animals into a visual scene regularly crowded with distractor items such as other cars, mailboxes, telephone poles, and the like. In order to navigate safely, the driver must deploy his or her attention in visual space in such a way as to optimally monitor the scene for these relevant items. Modern action video games place similar heavy spatial and divided attention demands on players, requiring that they aim and shoot accurately in the center of the screen while continuously tracking other enemies and monitoring the periphery for novel threats.

One commonly used task to investigate spatial attention abilities is the Useful Field of View task (UFOV), originally developed by researchers interested in vision and driving performance in older adults.[13] In this task subjects localize a small, very briefly presented peripheral stimulus among distractors (see Figure 1(a)). The target may appear radially at a variety of eccentricities, typically 10°, 20°, and 30°. Since standard measures of visual acuity are poor predictors of performance in this task,[14] it is generally accepted that the UFOV measures the subject's ability to distribute attentional resources throughout the visual field rather than aspects of lower level vision.

Green and Bavelier[15] initially adapted the UFOV task for use on groups of expert gamers and nongamers and in a subsequent training study where groups of nongamers played an action or a nonaction video game for 10 h. They found that habitual action video game play significantly improved performance on the UFOV at all target eccentricities. Notably, action game experience produced benefits that generalized to portions of the visual field beyond the extent of normal game play. By adding a central task to the paradigm, an extension of this study established that gamers are not reaping these greater peripheral benefits at the cost of central vision, as they matched the nongamer performance on the central task while again outperforming them on the peripheral one.[16] Interestingly, this result also suggests greater multi-tasking ability in gamers. Introduction of an additional task typically results in decreased performance on the original task. It did so for nongamers, but gamers' performance remained unchanged by the additional task, indicating that they may possess abilities similar to the 'super-tasking' described by Watson and Strayer.[17]

In their own study, Feng et al.[18] confirmed this finding of enhanced spatial attention in gamers, observing the same beneficial effect of action video game play on UFOV performance. Interestingly, this group also noted that though females performed worse than males before training, they closed this performance gap with 10 h of action game play. It may therefore be possible that populations less likely to seek out the fast and demanding environment of action games could show greater benefits of training on such games. As these games currently draw a predominantly male audience, young girls are at

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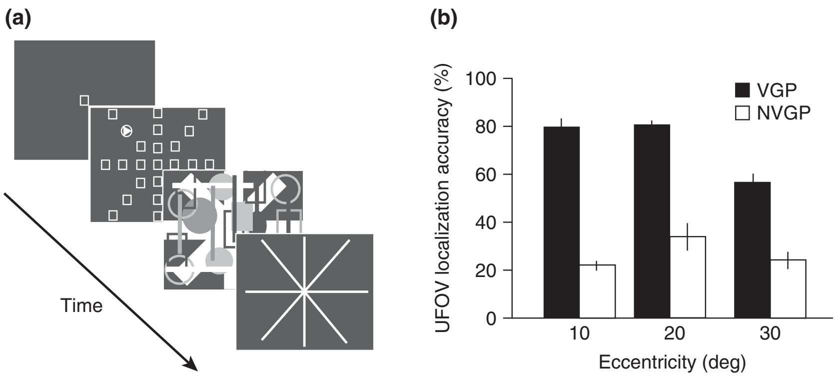

FIGURE 1 | UFOV method and results adapted from Green and Bavelier.[16] (a) The peripheral target could appear along eight radial axes at either 10°, 20°, or 30° from the center, where subjects were asked to fixate throughout the experiment. A Mondrian-style mask followed stimulus presentation to eliminate use of afterimages to help localize the target. (b) Localization accuracy data for expert action gamers compared to nongamers. Gamers significantly outperformed nongamers at all three eccentricities, while matching their performance on the concurrent center identification task.

risk of underperforming on tests of spatial attention, indicating a need for careful control of video game usage when assessing gender differences in attentional tasks. Indeed, children who report playing action video games have been observed to outperform their peers on this skill by middle school age.[19]

Another task that measures the ability to spatially distribute attention in order to search for a target among distractors is the 'Swimmer Task' recently developed by West et al.[20] Subjects in this task view a wide-field array of schematic swimming figures as they move throughout the display (see Figure 2 for an illustration). Subjects attempt to detect the presence or absence of a nonswimmer target, distinguishable from the regular swimmers by its lack of motion and rapidly waving arms. Although this task is less well characterized than the UFOV, like the UFOV it requires effective distribution of attention across the scene in order to quickly and reliably detect the target. In their study, West et al. reported that expert action gamers recorded higher hit rates, lower miss rates, and better performance on rare catch trials than nongamers across three target eccentricities and under both high and low distractor load, indicating that gamers are better able to spread their attention across the whole visual scene. Further evidence for this claim comes from a kinetic perimetry study in which gamers were found to have larger Goldmann fields than nongamers.[21]

One notable failure to replicate these changes in visuo-spatial attention can be found in a study conducted by Boot et al.[22] Gamers and nongamers were compared on a version of the UFOV and although the effects were in the expected direction, with gamers being more accurate than nongamers, they did not reach statistical significance. The more

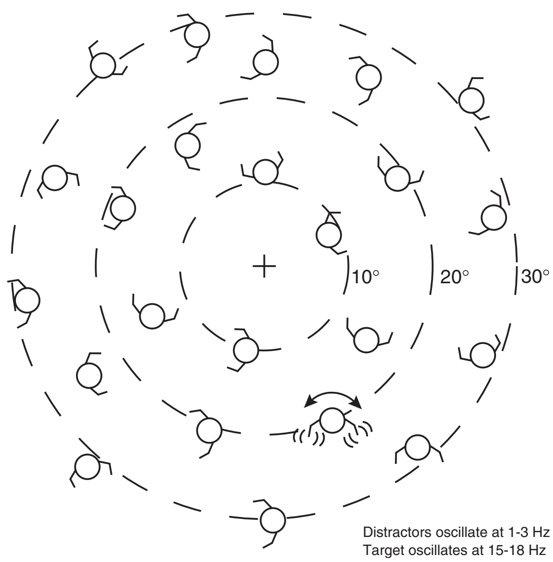

FIGURE 2 | Schematic illustration of the Swimmer Task method, adapted from Ref 20. Subjects fixated at the center of the display and viewed a wide-field array of randomly moving 'swimmer' targets while monitoring the scene for the abrupt onset of a 'nonswimmer' target, defined by its sudden lack of motion and rapidly waving arms. Nonswimmer targets occurred on 50% of trials and could appear at 10°, 20°, or 30° of eccentricity.

lenient subject inclusion criteria in regards to amount of action video game play required may explain, at least in part, the lack of significance. The authors reported that their subjects were required to have played seven or more hours per week of *any* video games and had 'expertise' with action games, whereas previous UFOV studies included only individuals who explicitly reported playing at least 5 h per week of action games specifically.

While the UFOV and the Swimmer task both employ relatively high-salience targets to test spatial

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attributes of attention, some groups have investigated those same attributes using tasks where the targets are relatively low-salience and do not 'pop out' as much at the viewer. In such tasks, the subject must conduct a more exhaustive serial search through many stimuli. Castel et al.[23] found that action video game players showed significantly faster reaction times in all conditions for a paradigm where subjects searched for a target letter among an array of varied distractor letters. However, whether gamers actually possess faster search rates remains unclear. The authors initially note a group by set size interaction in their reaction time data, indicative of faster search rate in gamers. However, they then show that the interaction does not persist when data from the smallest set size are removed. Faster reaction times across groups in the absence of an interaction between group and set size could result, they argue, from more effective motor execution or post-decisional processes in gamers. This explanation seems less likely now, as more recent work indicates that a mere additive change in reaction times (what would be predicted by more efficient motor execution) cannot account for the general speeding of processing observed in gamers.[24,25] Yet, it remains that further study is needed to clarify if and how the rate of visual search might be altered by action gaming.

Objects of Attention

Just as one may attend to spatial locations, observers may also direct their attention to specific objects in the visual field. Most people can only attend to about four objects at once, suggesting that a capacity-limited process is at work.[26,27] This limit can, however, be increased by action video game training.

Subitizing and Enumeration

When asked to apprehend the exact number of objects presented in a visual scene, normal observers demonstrate two distinct behaviors. When the number of items is small, a fast, accurate, parallel, and largely automatic process termed subitizing is used. In contrast, a slower serial process termed enumeration is employed for larger numbers of items. In their work, Green and Bavelier[15,28] measured the speed and accuracy of item counting using these two distinct processes in action gamers and in nongamers and found that gamers' enumeration performance for increasing numbers of items outstripped the nongamers' performance, while subitization performance as measured by reaction times was equivalent in the two groups (as a sidenote, subitization performance as measured by percent correct was higher in action gamers, which suggests enhanced visual short-term memory; for a further discussion see Ref 28). Importantly, the investigators established the causal role of action game play through an accompanying training study. Using a comparable paradigm, Boot et al.[22] reported a similar but nonsignificant result whereby expert gamers seemed to enumerate more quickly and more accurately than nongamers, but their effects did not reach statistical significance ($p = 0.084$ using a one-tailed hypothesis). Again, the lack of findings in this case could be due to the investigators not enforcing enough separation between the two groups in terms of how much action game experience each had.

Multiple object tracking

Action gamers also show enhancements in their ability to attend to several objects continuously over time, especially in the presence of nontarget distractors. A standard task to measure this skill is the multiple object tracking (MOT) task, where the subject is presented with an initially stationary array of many identical items and then asked to visually track a designated subset of them. Once a given trial starts, this target set and the accompanying distractors move randomly through the display (see Figure 3(a)). After several seconds of motion, the items are halted and the subject must indicate whether a probed object belonged to the target set or the distractor set. Most healthy normal observers can successfully track three to four objects in these paradigms. Using this task in gamer versus nongamer comparisons and in training studies, several groups have found that this ability to split attention among moving objects is enhanced by action game play in both adults[12,22,28] and children.[19,29]

In their work, Green and Bavelier[28] suggest that these enhanced enumeration and tracking capabilities that action gaming elicits are mediated by improvements in visual working memory. They propose that action gaming experience augments the speed at which gamers can 'cycle' through and update memory traces corresponding to the tracked or counted items. By updating more traces per unit time, gamers would be able to maintain a higher number of items in visual working memory without sustaining significant leakage. This account, while unconfirmed, would be able to explain the benefits in tracking and enumeration evinced in the findings reviewed above.

Attention in Time

Just as visual attention may be allocated spatially to retinal locations or objects, it may also be allocated to particular moments in time so that several successive targets may be quickly and accurately processed.

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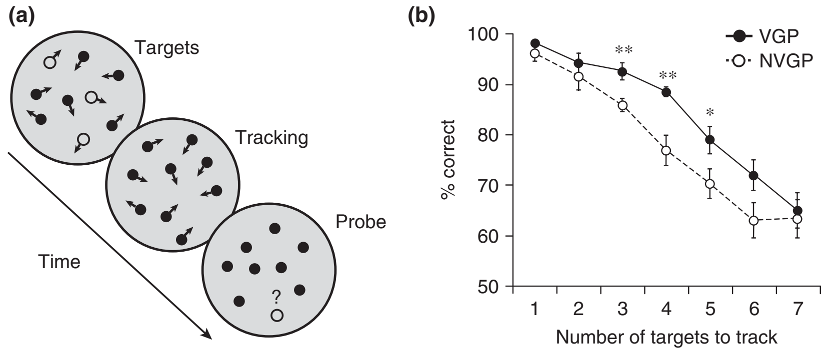

FIGURE 3 | MOT method and results adapted from Green and Bavelier.[28] (a) Subjects tracked up to seven pre-identified target dots as they and a set of identical distractor dots moved randomly through a circular field. Motion stopped after 5 s, when one of the dots was probed. Subjects responded indicating whether the dot was a target dot or not. (b) Task performance in action gamers and nongamers. Gamers were able to reliably track one to two more items than nongamers, with the most prominent performance differences observed when subjects were asked to track three to five targets.

A common paradigm designed to measure one's ability to orient attention in time is the attentional blink task. During the attentional blink, a short period a few hundred milliseconds after the presentation and apprehension of a primary target, detection performance for a second target is significantly reduced. Purported to represent a bottleneck in attentional processing, depressed performance during the attentional blink has been measured in expert gamers and normal controls by several groups. Green and Bavelier[15] and Dye and Bavelier[19] have found that the magnitude and extent of the blink are reduced in action gamers, both in adults and children. They also showed that training on action games produces the same result in adults (Refs 12, 15, but again, see Ref 22 for a failure to find statistically significant differences).

The extent to which these results reflect better attention in time, faster sensory processing, or possibly a combination of both remains unknown. Complicating matters, critical duration studies have shown that action gaming changes the temporal dynamics of sensory integration.[30] Thus, while action game training clearly changes the dynamics of visual processing, the levels of processing at which such changes happen require further characterization.

Attentional Resources and Executive Control

Several studies measuring attentional differences between gamers and nongamers have included experimental tasks designed to measure the effect of distracting flanker items near a central target on the ability to process that target. On some trials the flankers share characteristics with the target item (compatible flankers), but on other trials the flankers have characteristics opposite the target item (incompatible flankers). A variant of these flanker compatibility tasks was used by Green and Bavelier[15] as well as Dye et al.,[31] with both groups finding that action video game players (both adults and children) experience a high interference effect due to incompatible flankers in certain conditions where normal controls show reduced interference.

Rather than suggesting that this reflects poorer processing abilities or lack of executive control in gamers, Green and Bavelier posit that it actually demonstrates that gamers have *higher* amounts of attentional resources available compared to controls. The perceptual load theory of attention[32] predicts that subjects with more attentional resources will have more resources left over from the target processing. These extra resources 'spill over' into the distractor items, causing them to be processed, which then results in response interference if the flankers are incompatible with the target. As the perceptual load of a task increases, this view predicts that compatibility effects in gamers will be more substantial than in nongamers. Indeed, in the nongamer group perceptual load increases will more quickly exhaust processing resources, leaving no spare resources to process the flankers.

This research raises the crucial issue of whether all interference effects should be interpreted as a lack of control or greater attentional resources. We would argue that the interference effect (also termed executive score in paradigms like the Attentional Network Test (ANT), discussed below) cannot be interpreted on its own. As with any measures relying on differences of reaction times, baseline reaction times also need to be taken into account. In the case of action gamers, greater interference effects are accompanied by much faster reaction times in all conditions. In fact, gamers are faster in the most difficult conditions than

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nongamers are in the easiest conditions. Thus despite experiencing greater interference from the distractor items, the reaction of gamers to a given target is still overall more efficient (faster) than that of nongamers. Measuring reaction time differences between two conditions may be less telling than a more theoretically motivated measure of optimal performance, such as the rate of correct responses per units of time.[33] Although such an explanation is in need of further confirmation, a possible working hypothesis given the data available so far is that gamers' performance may be best described as the result of a greater flexibility in their ability to allocate their attention through space and time. Indeed, this account seems supported by a recent study by Chisholm et al.,[34] wherein the investigators find evidence that while action gamers are susceptible to distracting items just as nongamers are, they also seem to discard them and reorient their attention to relevant items more quickly or more efficiently than nongamers.

Exogenous Cueing

Unlike in the case of the more endogenous aspects of attention discussed above, there is a comparative lack of published findings concerning the effect of action video game play on the exogenous processes of attention. This is likely due to the general consensus in the visual attention literature that exogenous attention, as a more automatic process, is governed by subcortical structures thought to be minimally plastic. However, some investigators have tested these muddy waters, so we discuss their findings here.

Castel et al.[23] employed a version of the classic Posner cueing paradigm[35] in which an uninformative exogenous cue is presented in one of two possible target locations shortly before the presentation of the target itself in either the cued location (a validly cued trial) or the uncued location (an invalidly cued trial). If gamers possess enhanced bottom-up orienting mechanisms, we should expect to see them reap a greater (or earlier) reaction time benefit at short cue-target stimulus-onset-asynchronies (SOAs), but the results indicated that the gamer and nongamer group benefited similarly from the valid cue compared to the invalid cue at early SOAs. Furthermore, both gamers and nongamers showed similar inhibition of return at later SOAs, where reaction times for cued locations are typically *higher* than for uncued ones. Though the gamers' reaction times were once again lower than those of the nongamers overall, the similar within-group pattern of reaction times at both early and late SOAs seems to indicate that exogenous orienting processes operate similarly in gamers and nongamers. As a caveat though, the SOAs tested here were long (with only one SOA under 200 ms), which still allows for the possibility of group differences at early cue-target SOAs.

A similar study conducted by Dye et al.[31] used the ANT to obtain a measure of spatial orienting in response to an exogenous cue in child, adolescent, and adult gamers and nongamers. Like in the results of Castel et al., the researchers found no significant effect of action video game play on orienting ability across the four age groups tested. The fact that the ANT uses a single SOA (500 ms, relatively long for measuring exogenous orienting) across its wide variety of conditions, however, limits our ability to infer much about the differences in exogenous orienting between the gamer and nongamer groups.

In opposition to the previous two studies, findings from West et al.[20] do in fact demonstrate a difference between gamers and nongamers on a task involving exogenous cues. Using a temporal order judgment task, these authors quantified the degree of visual prior entry one of two present targets undergoes when its location is cued shortly before both appear. A significantly larger prior entry effect for the cued stimulus was found in the gamer group as compared to the nongamer group, ostensibly the result of greater attentional allocation to the cued target's location in gamers. In other words, the cue may automatically draw a greater amount of attentional resources to its location in gamers, which in turn could indicate an increased sensitivity to exogenous stimuli in that group.

As one may see, the small collection of results on action video games and exogenous cueing is anything but conclusive. Despite the results in West et al. above, the body of evidence indicates that the neural mechanisms controlling the exogenous processes of attention, processes thought to operate reflexively and outside of the observer's control, may be less amenable to change following altered experience. This idea falls in line with reports that exogenous orienting in sports athletes does not differ between those with extensive experience in fast-paced, attentionally demanding sports and those in slower-paced, nonaction sports (for an example, see Ref 6). However, these findings could benefit from further exploration.

The Causal Effect of Action Video Games

As shown above, many aspects of attention appear to be enhanced in action video game players. Whether game play itself led to the benefits can only be addressed by training studies, however. Indeed, those with high pre-existing visual or attentional capabilities may be more likely to develop into habitual

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action game players, allowing for a selection bias when comparing gamers and nongamers. Thus, only well-controlled training studies can establish the causal effect of game playing. Action gamer effects observed on the UFOV, enumeration tasks, attentional blink tasks, and the MOT have all been supported by paradigms where groups of nongamers are tested initially on the variables of interest, randomized into experimental training and control training groups, given experience playing action or nonaction games, and then tested again on the same variables a few days to a few months later.[12,15,16,18,28] In each of these cases, the action game groups improved significantly more from pre- to posttest than the control game group. Only greater improvement in the action trainees as compared to control trainees can establish the causal effect of action game play in the attentional enhancements noted and rule out explanations involving differences in genetic endowment between those that play action games and those who do not. Furthermore, only by separating the end of training and posttesting temporally can investigators convincingly show that observed effects were not due to transient factors caused by the training, such as arousal or priming.[36]

The use of a control group is critical in training studies, as it accounts for the well-established fact that performance on a test typically improves the more times one takes it. In addition, the inclusion of a control group that is asked to engage in an engrossing activity controls for factors such as subject motivation, arousal, and the Hawthorne Effect (where subjects improve their task performance simply because they know they are being observed). Another caveat regarding training studies is that the initial pretest measurements should always be finely tuned to avoid floor, ceiling, and unexpected test–retest effects that can complicate analyses. As an example, several of the tasks used in Boot et al. (Ref 22, discussed above) produced considerable test–retest effects between pre- and posttest, including a doubling of accuracy performance in some UFOV conditions. Unfortunately, these effects can mask genuine training-induced improvements, and thus can make it difficult to detect any between-group differences that might be present.

An additional key aspect of training studies concerns the level of difficulty of the experimental and control training regimen. Since learning is maximized when the training task is neither too hard nor too easy (see the 'zone of proximal development', a phrase coined by Soviet psychologist Lev Vygotsky[37]), training study investigators should constantly strive to hit the 'sweet spot' of difficulty where the player is always pushed to achieve a goal just beyond their reach. This requires close monitoring of player performance and appropriate adjusting of training difficulty. Investigators that place control participants in an easy version of the experimental training regimen are at risk of interpreting differences between groups as due to improvements in the mental process of interest when in fact they could have resulted from differences in training difficulty. For example, perhaps in a hypothetical training study, an experimental group showed improved working memory skills after training on a challenging attentional task, while a control group trained on an easier, different training task did not. The investigators might be tempted to conclude that the attentional task improves working memory, when in fact it could simply be that any challenging task improves working memory. Without equalizing training task difficulty, the source of the experimental group improvements cannot be determined. So although training studies aim to characterize the training task components that lead to improved performance, they by their nature carry many experimental pitfalls that must be avoided if one is to obtain any useful interpretation of the resulting data.

Similarly, it is vitally important for future investigations into the effects reviewed here to control for the differential effects of different types of video games. The only genre of game that has been shown to induce visual attentional enhancements is the action genre. Thus, it is essential that investigators quantify precisely the amount of *action* video game play in each subject when sorting them into the gamer and nongamer groups, and not just video game play overall. Otherwise, it is impossible to determine whether any potential effect (or lack thereof) was truly the result of action gaming. Unfortunately, at least one study that has failed to replicate the results of Green and Bavelier seems to have this problem.[38]

CONCLUSION

Action video game-induced effects are notable for their generalization across varieties of attentional tasks and systems. Changes are noted not only when subjects have to select items in space, but also when they have to sustain attention over several objects or attend to specific events in time. As discussed above, it does not seem that a generic speeding of manual responses in gamers is a suitable account for the present body of findings. Rather, a more likely explanation is that the heart of the action game-induced improvements lies in an enhanced ability to flexibly allocate attentional resources along a variety of dimensions as a function of stimulus attributes and task demands. It may be that gamers or those trained on action games

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gain an advantage by optimizing the distribution of top-down resources across time and space to an extent that nongamers cannot achieve. In order to address this possibility, ongoing electrophysiological and fMRI work is testing the hypothesis that action gamers suppress unattended stimuli more readily than nongamers.[39,40] However, further work is needed to comprehensively evaluate this hypothesis.

Discussions of the theoretical basis aside, action video game training effects may be particularly useful for various real-world applications due to their remarkable generalization. Those in professions that demand 'super-normal' attentional function such as jet fighter pilots, ground soldiers, and many other military professionals would benefit enormously from enhanced visual attention, as their performance (and lives) depends crucially on their ability to rapidly pick out and act on relevant visual targets while filtering out irrelevant distractors. As a proof of concept, laparoscopic surgeons have already been reported to benefit from video game training.[41] In this case, attentional benefits seem to be accompanied by visuo-motor coordination benefits, as comparisons between surgeons who regularly play video games and surgeons who do not demonstrate shorter surgery completion times and fewer errors on a common laparoscopy performance diagnostic tool. Interestingly, past video game play experience appeared to be a more reliable predictor of surgery skill than traditional measures such as years of training and number of surgeries performed.

In another health-related application, recognition of the therapeutic potential of video games is already seen in the adoption of the Nintendo Wii (a popular and accessible gaming console) in many homes and communities for older adults, many of whom report increased mental and physical fitness as a result of the game playing.[42] Attentional training in this population would seem particularly beneficial.[43]

Here we have outlined a wide variety of benefits in visual attention that have been shown to result from action video game play, but there are certainly limits to the cognitive impact of video games. Video games should not be thought of as an elixir for all aspects of mental function, but their effects could be useful not only in themselves (see job skill training and therapeutic applications above), but also as a research tool for identifying the extent to which neural mechanisms governing different cognitive skills are malleable. By thus characterizing these mechanisms, we also characterize constraints on experience-dependent plasticity itself. Only once we understand this can we truly maximize the potential benefits of the remarkable adaptive power of the human brain.

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