Research Report

The effects of an action video game on visual and affective information processing

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Abstract
Playing action video games can have beneficial effects on visuospatial cognition and negative effects on social information processing. However, these two effects have not been demonstrated in the same individuals in a single study. The current study used event-related brain potentials (ERPs) to examine the effects of playing an action or non-action video game on the processing of emotion in facial expression. The data revealed that 10 h of playing an action or non-action video game had differential effects on the ERPs relative to a no-contact control group. Playing an action game resulted in two effects: one that reflected an increase in the amplitude of the ERPs following training over the right frontal and posterior regions that was similar for angry, happy, and neutral faces; and one that reflected a reduction in the allocation of attention to happy faces. In contrast, playing a non-action game resulted in changes in slow wave activity over the central–parietal and frontal regions that were greater for targets (i.e., angry and happy faces) than for non-targets (i.e., neutral faces). These data demonstrate that the contrasting effects of action video games on visuospatial and emotion processing occur in the same individuals following the same level of gaming experience. This observation leads to the suggestion that caution should be exercised when using action video games to modify visual processing, as this experience could also have unintended effects on emotion processing.

1. Introduction

Sixty-seven percent of American households play PC or console based video games (Entertainment Software Rating Board, 2011; Entertainment Software Association, 2010). Given the popularity of video games, it is critically important to understanding of how this medium affects cognition and emotion. A substantial body of evidence reveals that playing action video games can have beneficial effects on visuospatial cognition (cf. Green et al., 2010a, 2010b) and negative effects on social information processing and behavior (cf. Anderson et al., 2010). The current study was designed to address two limitations of the existing literature. First, studies examining video game effects have tended to focus on a single domain (e.g., visuospatial or social cognition) making it difficult to determine whether the same level and type of experience produces effects in each domain in the same individuals. Second, relatively few studies have examined the neural basis of video game effects on cognition and emotion (Bailey et al., 2010, 2011; Bartholow et al., 2006; Mathews et al., 2005; Montag et al., 2012; Wu et al., 2012). The current

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study addressed these limitations by using event-related brain potentials (ERPs) to examining the effects of 10 h of action or non-action video game experience on visuospatial and emotion processing within a single task. Determining whether or not changes in these domains occur simultaneously may serve to inform the use of action video games as a platform for interventions designed to enhance visuospatial cognition (Feng et al., 2007; Green and Bavelier, 2008).

1.1. Positive and negative effects of action video games

A number of studies have demonstrated that playing action video games has beneficial effects on visuospatial processing (Dye et al., 2009; Feng et al., 2007; Green and Bavelier, 2003; but see Boot et al., 2011). Studies of chronic video game players reveal positive correlations between individual differences in action gaming and hand-eye coordination (Griffith et al., 1983), speed of visual search (Castel et al., 2005), and tracking in a flight simulator (Lintern and Kennedy, 1984). Additionally, training experience and visuospatial processing has been demonstrated a causal effect of action video games in these and other tasks (Dye et al., 2009; Green and Bavelier, 2003, 2007) that may persist for five or more months after training (Feng et al., 2007).

The positive association between action video game experience and visuospatial processing has been demonstrated in a number of studies examining visual search. Castel et al. (2005) reported that gamers displayed faster overall reaction times relative to non-gamers. Consistent with this finding, Green and Bavelier (2003) have reported that action video game experience was associated with an enhancement of the spatial distribution of attention in the useful field of view task. Importantly, these authors have also demonstrated a causal effect between video game experience and visuospatial processing. Specifically, the useful field of view is expanded in non-gamers with as little as 10 h of training on an action video game. Based upon these and other findings it seems clear that action gaming can enhance visuospatial cognition (Green et al., 2010a, 2010b).

There are numerous studies documenting the effects of action, or violent, video games on social information processing and behavior (cf. Anderson et al., 2010; although see Ferguson, 2007). Perhaps most relevant to the current study, two studies using ERPs have revealed desensitization (i.e., a reduced neural response) among chronic action gamers to images portraying violent content. Bartholow et al. (2006) examined differences in the amplitude of the P3 – an index of the allocation of attention to a stimulus during categorization (Ito et al., 1998) – elicited by neutral, negative violent, and negative nonviolent pictures in gamers who primarily played violent or nonviolent games. The investigators predicted that desensitization to violence would result in an attenuation of the amplitude of the P3 for violent pictures in the violent gamers. Consistent with this prediction, the amplitude of the P3 for negative violent pictures, but not negative nonviolent pictures, was attenuated in violent gamers relative to nonviolent gamers.

Bailey et al. (2011) extended the work of Bartholow et al. (2006) by including positive pictures in the stimulus set and having low and high action gamers rate the pictures on different dimensions (e.g., colorfulness, threat, pleasantness). The three orienting tasks were used to determine whether the nature of the appraisal made by participants (i.e., emotion relevant or irrelevant) influenced the association between video game experience and picture processing. The data revealed desensitization to violent, but not nonviolent, negative images among high gamers in the colorfulness block. In contrast, there was no evidence for desensitization in the threat block. This finding led to the suggestion that the association between video game experience and emotion may depend upon how individuals appraise the content of the pictures. Additionally, gaming experience was not related to processing positive images in this study. Together these findings indicate that action gaming experience can be associated with desensitization to violence in some cases. One limitation of these studies is that video game experience was measured as an individual difference variable rather than being experimentally manipulated. This limitation was addressed in the current study by training non-gamers on an action or non-action video game for 10 h.

Studies using individual difference (Kirsh et al., 2006) and experimental (Kirsh and Mounts, 2007) approaches reveal that action gaming can alter the processing of facial expression related to emotion. Kirsh et al. (2006) found that individuals low in media violence exposure were faster to identify a neutral face morphing into a happy face than a neutral face morphing into an angry face, demonstrating the happy-face advantage (Billings et al., 1993). In contrast, individuals high in media violence exposure did not demonstrate this effect. Furthermore, Kirsh and Mounts (2007) found that playing a violent video game for 15 min resulted in individuals being slower to identify a neutral face morphing to a happy expression than individuals who played a nonviolent video game. Based on this work, it appears that action video game experience is associated with changes in the processing of positive social information when the stimuli are faces.

1.2. Emotion search task

The emotion search task has been used to study the sensitivity to threatening and negatively valenced stimuli compared to positive and neutral stimuli in a number of studies (Mather and Knight, 2006; Öhman et al., 2001; Schupp et al., 2004). In the emotion search task, individuals view an array of nine schematic faces and decide whether there is a discrepant face in the array, or all nine faces have the same expression (e.g., neutral, happy, or angry). Öhman et al. (2001) found that when the discrepant face was angry, reaction time was faster and accuracy was higher than when the discrepant face was happy or neutral, a finding that was replicated by Mather and Knight (2006). This task is particularly well-suited to the goals of the current study as it allows one to assess visual (target) processing and differential sensitivity to positive and negative facial expressions simultaneously within the same task, thereby making it ideal for examining the concurrent effects of video game experience on visuospatial and social information processing.

1.3. ERPs and target processing

Studies examining the neural correlates of target processing in visual search tasks using ERPs have consistently
demonstrated that the amplitude of the N2 and P3 components are greater for targets than non-targets (Bledowski et al., 2004; Luck and Hillyard, 1990, 1994). The N2 is a negative going deflection in the ERPs that peaks between 180 and 300 ms after onset of the visual display over the parietal-occipital regions of the scalp. The N2 is considered an index of processes involved in stimulus identification (Patel and Azzam, 2005). The P3 is a positive going wave in the ERPs that is typically greatest in amplitude between 300 and 600 ms after stimulus onset over the central and parietal regions of the scalp (Donchin and Coles, 1988). The P3 is thought to reflect processes underlying categorization of stimuli as targets (Kok, 2001; Polich, 2007) or the allocation of attention to these stimuli (Ito et al., 1998). Within the context of emotion processing, the amplitude of the P3 has been found to be greater for positively and negatively valenced stimuli compared to neutral stimuli in several paradigms, including the oddball task (Delplanque et al., 2006; Foti et al., 2009; Keil et al., 2002) wherein individuals are asked to detect a target or deviant stimulus.

1.4. The current study

The current study was designed to examine the neural correlates of the effects of action gaming experience on visuospatial cognition and emotion processing in the same individuals following the same level of gaming experience. This demonstration is important as experimental studies of the effects of action gaming have tended to observe changes in visuospatial processing after several hours of game play, while effects on social cognition and behavior are often examined after a brief gaming experience (i.e., 15–20 min of game play). In the current study, individuals performed the emotion search task (Mather and Knight, 2006) in pre- and post-test sessions while ERPs were recorded. In this task, individuals viewed an array of nine schematic faces and were asked to detect a target or deviant stimulus. Based on previous work in the visuospatial processing domain (Green and Bavelier, 2006, 2007) and social information processing domains (Bailey et al., 2011; Bartholow et al., 2006; Kirsh and Mounts, 2007) several hypotheses were considered. For response time, we expected that individuals would be faster to identify angry faces than happy faces (Ohman et al., 2001), and that the magnitude of this effect would differ between the action game group and the non-action game and no-contact groups following training. For the ERP data, we expected that the amplitude of the N2 and P3 would be greater for target (happy or angry face present) displays than neutral displays. If action gaming results in desensitization to positive or negative emotion related to facial expression (Kirsh and Mounts, 2007), then we expected that the amplitude of the N2 and P3 for targets would be attenuated in the action gaming group relative to non-action gaming or no-contact group following training. In contrast, if action gaming serves to enhance information integration (Green et al., 2010b), then we expected that the amplitude of the N2 and P3, or other components of the ERPs, would be greater in the action gaming group than in the other two groups following training.

Partial Least Squares analysis (PLS; Lobaugh et al., 2001) was used to examine the effects of gaming on the full time course and topography of the ERPs elicited during the emotion search task. This method offered two advantages for the current study: first, it allowed us to identify effects of action video games that may be difficult to identify in univariate analyses of ERPs data given the temporal and spatial overlap of components that may be differentially sensitive to stimulus type and gaming experience. Recent work from our laboratory demonstrates the utility of PLS analysis in addressing this concern in a study examining the association between action gaming experience and components of the ERPs sensitive to positive and negative emotion (Bailey et al., 2011). Second, it allowed us to explore effects of video game experience where the time course and topography of task-related differences in the ERPs could not be predicted in an a priori manner given the limited number of studies using ERPs to examine the neural basis of the effects of video games on visuospatial and affective information processing.

2. Results

2.1. Video game performance data

For the action game group, the mean level of difficulty increased from pre-test (M=1.0, SD=0) to post-test (M=3.3, SD=7), t(9)=10.78, p<.001. For the non-action game group, the mean level of difficulty also increased from pre-test (M=8.0, SD=2.18) to post-test (M=11.9, SD=1.1), t(8)=7.59, p<.001.

2.2. Behavioral data

To examine the effects of gaming experience on accuracy and response time a pair of 3 (group: no-contact, non-action, action) × 3 (stimulus: happy, angry, non-target) ANCOVAs were performed using performance on the post-test as the dependent variable and performance on the pre-test as the covariate. For response accuracy, the covariate was significant, F(1, 24)=5.67, p=.03, η²=.19, and the main effects (group F<1.00, stimulus F(2, 48)=1.05, p=.36, η²=.04) and interaction, F<1.00, were not significant (proportion correct no-control M=.94, non-action M=.92, action M=.91).

For response time, the covariate was significant, F(1, 24)=16.32, p<.001, η²=.41, and the main effects of group and stimulus were not significant, F's<1.00, η²'s<.06. The group × stimulus interaction was significant (Fig. 1), F(4, 48)=2.58, p=.04, η²=.18. This interaction reflected the fact that the effect of stimulus was significantly greater for the no-contact group than the non-action group, F(2, 30)=3.70, p=.04, η²=.19, and was not significantly different between the non-action group and the action group, F<1.00, η²=.06, or the action group and the no-contact group, F(2, 30)=1.18,
None of the main effects or interactions were significant, the amplitude of the P3 did not differ from the pre-test to the post-test over the left hemisphere or the midline, \( F_s<3.83, p's>.10, \eta_p^2's<.30 \). Over the right hemisphere, the amplitude of the P3 was greater at the post-test than at the pre-test, \( F(1, B)=11.01, p=.01, \eta_p^2=.58, \epsilon=1.0 \). This effect may be related to enhanced processing in the right hemisphere related to experience with visual transformation (i.e., mental rotation) required in Tetris (Harris et al., 2000).

The latency of the P3 was analyzed in a 3 (group)\( \times 2 \) (occasion) ANOVA. The main effects of stimulus, occasion, and group were not significant, \( F_s<1.13, p's>.34, \eta_p^2's<.08 \). The group \( \times \) occasion interaction was significant, \( F(2, 25)=4.31, p=.03, \eta_p^2=.26 \). Further analysis revealed that for the no-contact and non-action group, the main effect of occasion was not significant, \( F_s<1.68, p's>.23, \eta_p^2's<.17 \). For the action group, the latency of the P3 was shorter for the post-test (\( M=547 \) ms, \( SE=.22 \)) than for the pre-test (\( M=614 \) ms, \( SE=.33 \), \( F(1, 9)=7.09, p=.03, \eta_p^2=.44 \), consistent with what one might expect based upon the existing literature (Dye et al., 2009; Green et al., 2010a, 2010b).

2.3. ERP data

The grand-averaged ERP data at nine electrodes for the three groups are presented in Fig. 2 and the pre-test minus post-test difference wave are presented in Fig. 3. At a descriptive level, the amplitude of the N2 and P3 appear to be greater for trials where a happy and angry face was present (i.e., targets) than when all the faces were neutral (i.e., non-targets). The amplitude of the P3 appears to be greater in the post-test than in the pre-test, particularly for the two gaming groups.

2.3.1. Mean amplitude and latency

The amplitude of the N2 was analyzed in a 3 (group) \( \times 2 \) (occasion) \( \times 3 \) (stimulus) \( \times 2 \) (electrode: PO9, PO10) ANOVA. None of the main effects or interactions were significant, \( F_s<4.12, p's>.06, \eta_p^2's<.14 \).

The amplitude of the P3 was analyzed in a 3 (group) \( \times 2 \) (occasion) \( \times 3 \) (stimulus) \( \times 3 \) (electrode: P3, Pz, P4) ANOVA. The main effect of stimulus was significant, \( F(2, 50)=60.92, p<.001, \eta_p^2=.71, \epsilon=1.0 \). Further analyses revealed that the amplitude of the P3 was not significantly different between angry targets (\( M=3.38 \) \( \mu V \), \( SE=.34 \)) and happy targets (\( M=3.04 \) \( \mu V \), \( SE=.33 \)), \( F(1, 25)=2.31, p=.14, \eta_p^2=.08 \). The amplitude of the P3 was greater for angry and happy targets combined (\( M=3.21 \) \( \mu V \), \( SE=.32 \)) than for non-targets (\( M=1.12 \) \( \mu V \), \( SE=.24 \)), \( F(1, 25)=124.04, p<.001, \eta_p^2=.83 \). These data indicate that the amplitude of the P3 was greater for targets than non-targets consistent with the findings of previous research (Bledowski et al., 2004; Luck and Hillyard, 1994).

The group \( \times \) occasion \( \times \) electrode interaction was significant, \( F(4, 50)=2.85, p=.03, \eta_p^2=.19, \epsilon=1.0 \) (Table 2). Post hoc analyses revealed that the occasion \( \times \) electrode interaction was not significant for the no-contact or action groups, \( F_s<2.72, p's>.12, \eta_p^2's<.25 \). The occasion \( \times \) electrode interaction was marginally significant for the non-action group, \( F(2, 16)=3.47, p=.06, \eta_p^2=.30, \epsilon=1.0 \). In the non-action group, the amplitude of the P3 did not differ from the pre-test to the post-test.
reduction in the happy face advantage reported by Kirsh and Mounts (2007).

The second latent variable revealed an effect of non-action gaming experience (Fig. 4b). In the non-action gaming group, the contrast differentiated angry and happy targets in the post-test from stimuli in the pre-test. In contrast, in the no-contact and action gaming groups all of the confidence intervals for the brain scores included zero. The electrode saliences revealed that this effect reflected a sustained modulation of the ERPs representing a negativity over the
left central-parietal region and a positivity over the frontal region. Previous work has found that Tetris produces either no effect on task performance (Green and Bavelier, 2003, 2006) or a decrease in mental rotation time for Tetris-like shapes (Sims and Mayer, 2002), suggesting limited and highly specific transfer of skill. Here, the results indicate that 10 h of training on Tetris may produce changes in target processing for non-Tetris stimuli.

The third latent variable captured an effect of action gaming (Fig. 4c). In the action gaming group, the contrast differentiated the pre-test trials from the post-test trials for targets (happy and angry), and non-targets. In contrast, for the no-contact and non-action gaming groups all of the confidence intervals for the brain scores included zero. The electrode saliences revealed a transient negativity over the parietal-occipital region around 300 ms and a more

Fig. 3 – Grand-averaged ERP difference waves for pre-test minus post-test demonstrating the effect of occasion for target (happy and angry) and neutral displays on the N2 (black arrows) and P3 (white arrows). The tall bars reflect stimulus onset and 1 µV and the short bars reflect 250 increments.
Fig. 4 - Results of the PLS analysis: (a) Brain scores (left), and the time course (middle) and topography (right) of the electrode saliences, for the first latent variable that captures the effects of training on the amplitude of the N2 (upper map) and P3 (lower map) components. The brain score for happy targets is non-significant after training on the action game, (b) brain scores, and the time course and topography of the electrode saliences for the second latent variable that captures the effect of training on a non-action game; the upper map portrays the topography of the early transient modulation and the lower map portrays the topography of the sustained modulation. (c) Brain scores, and the time course and topography of the electrode saliences, for the third latent variable that captures the effect of training on the action video game; the upper map portrays the topography of the early transient effect and the lower map portrays the topography of the right hemisphere effect. The error bars for the brain scores represent the 95% confidence interval derived from the bootstrap distribution and the symbols above the x-axis mark electrode saliences where the bootstrap ratio exceeded 2.5.
sustained modulation over the right hemisphere that extended from the frontal to posterior regions beginning around 500 ms after stimulus onset. The similarity of this effect for target and non-target displays is consistent with the general facilitation of response time resulting from action gaming experience observed for visuospatial processing (Dye et al., 2009) that may be associated with enhanced stimulus integration (Green et al., 2010b).

3. Discussion

The current study examined the effects of playing an action and non-action video game on visuospatial and affective information processing. The response accuracy data revealed that task performance was quite high for all groups. The response time data revealed that the difference in response time between targets and non-targets was reduced in the two video game groups relative to the no-contact group after training; however, this difference was only significant for the comparison of the no-contact and non-action groups. The analyses of mean voltage and latency of the P3 revealed that the amplitude of the P3 was enhanced in the non-action gamers after training and that the latency of the P3 was shorter in action gamers after training. The PLS analysis revealed three patterns of neural activity (i.e., latent variables) that distinguished the no-contact control group from the video game groups following 10 h of game play. The two games were associated with distinct effects on the ERPs that reflected components commonly associated with target detection (i.e., N2 and P3), as well as, transient and sustained modulations of the neurophysiology that were broadly distributed across the scalp. These findings demonstrate that effects of action video games on visual and affective information processing can arise from the same level and type of gaming experience.

Action gaming appeared to result in a reduction in the amplitude of ERPs related to the allocation of attention to positive facial expression represented in the happy faces during stimulus categorization. This finding is consistent with the findings of Kirsh and Mounts (2007) and Kirsh et al. (2006) in studies using a change detection task. In contrast to the results of the PLS analysis, there were not significant differences in RT or accuracy to happy face targets between the groups. This discrepancy may reflect the fact that the competing effects of the action video game revealed in the PLS analysis (i.e., reduced response to happy faces in the first latent variable and the general effect on visual processing in the third latent variable) serve to obscure the effects of video games in the behavioral and mean voltage data. Together, the current findings and existing evidence may indicate that action gaming has an effect on the processing of positive facial expression that transcends the specific stimulus (i.e., real vs. schematic faces) and task demands (i.e., change detection or target detection) used to examine the effect.

In contrast to the effect on positive facial expression, action gaming did not influence the processing of negative facial expression represented in the angry faces. This finding is interesting in the context of other recent work from our laboratory (Bailey et al., 2011). In this study, the negativity bias for pictures depicting interpersonal violence was attenuated in high action gamers relative to low action gamers when emotion was not relevant to task performance; in contrast, differences in the expression of the negativity bias between high and low gamers were eliminated when individuals evaluated the level of threat engendered in the picture. Given these findings, the failure to find an effect of action gaming for the angry faces may have resulted from the relevance of facial expression for task performance in the emotion search task.

The effect of action gaming seen for the third latent variable of the PLS analysis was similar for the target and non-target trials and was broadly distributed over the right hemisphere. The distribution of this effect is consistent with the widely documented role of the right hemisphere in visuospatial cognition (Kolb and Whishaw, 1996). The tendency for the effect to be similar for targets and non-targets converges with the effect of action video games seen in behavioral studies reflecting a general speeding of response time across a range of tasks (Dye et al., 2009). The pattern of stable electrode saliences for the third latent variable may provide some insight into the locus of this effect. There were very few stable time points between 0 and 300 ms after stimulus onset for the third latent variable. This may indicate that action gaming had relatively little effect on early visual processing (Wu et al., 2012). In contrast, there was sustained activity over the right occipital-parietal and lateral frontal regions. This finding is interesting given recent work demonstrating that the locus of the effect of action video games may reflect a general increase in the efficiency of information integration within neural circuits that underpin task performance rather than an enhancement of early perceptual processing (Green et al., 2010a, 2010b).

Non-action gaming resulted in two effects on target processing, one that reflected an increase in the amplitude of the N2 and P3 (LV1), and one that reflected a sustained modulation of the ERPs over the left central-parietal and frontal regions (LV2). This suggests that playing the non-action game was associated with changes in the efficiency of neural networks underlying target processing. These findings diverge from those of Green and Bavelier (2003, 2006) who have used Tetris as a control game, and are consistent with other research demonstrating that playing Tetris can effect spatial (Sims and Mayer, 2002) and social (Sestir and Bartholow, 2010) information processing. One explanation for this discrepancy is that the current study incremented the difficulty level of Tetris in a similar manner to the action video game, whereas this does not appear to be the case in the studies by Green and Bavelier (2003, 2006). An important feature of successful training protocols is incrementally increasing the difficulty of the task as the individual's skill level improves (Gentile and Gentile, 2008). This feature of training is likely a necessary component for effects of Tetris to be realized. Regardless of the reason for the differences between our findings and those of Green and Bavelier, the current findings demonstrate that non-action games, like Tetris, that include a visual component may facilitate aspects of visual processing related to target identification that differ from those modified by action games.
Given previous work finding no effect (Green and Bavelier, 2003, 2006) or limited transfer (Sims and Mayer, 2002) of Tetris training, the results of the PLS analysis for the non-action group were unexpected. The increased F3 (LV1) may represent an enhancement of visual processing, particularly in the right hemisphere, related to experience with visual transformation gained from playing Tetris (Harris et al., 2000). Successful Tetris performance requires close and continuous monitoring of the game, particularly as the pieces begin to move faster; therefore one interpretation of the prolonged activity following Tetris training (LV2) is that it may represent an enhancement of sustained attention that develops with experience and transfers to the emotion search task. Further examination of this and other unexpected effects of non-action video games may be a fruitful avenue for future research.

There are a few limitations of the study that must be acknowledged. First, the differences in response time between the action and non-action game players in the post-test were not significant, although average performance was in the expected direction. This is inconsistent with the general finding that action gamers are typically faster than non-action gamers across a number of tasks (Dye et al., 2009). However, we recently failed to replicate the findings of Dye et al. in an analysis including data for 66 experimental conditions from our laboratory (West and Bailey, 2013). Given this, it may be that the relationship between action gaming and response time is sensitive to the information processing demands of the tasks and the training as discussed in the previous paragraph, rather than representing a ubiquitous speeding of response time. Second, given the nature of the task one might argue that it is difficult to distinguish between processes related to target processing and affective processing since neutral stimuli were not tested as targets. However, the differential effects of the action game observed for the first latent variable for happy and angry faces converge nicely with the findings of Kirsh and Mounts (2007), and together with the general effect of this game on the third latent variable, demonstrate both general and specific effects of an action game. Therefore, even in the context of this limitation we believe that the current data provide a valuable contribution to our understanding of the effects of action video games.

Finally, the small sample size may lead one to question the robustness of the effects, particularly as related to the general lack of significant differences in the analyses of the behavioral and manifest ERP data. Our sample size is similar to that of many of the previous studies of video game training effects (e.g., Feng et al., 2007; Green and Bavelier, 2003, 2006; Li et al., 2009; Sims and Mayer, 2002) and was sufficient to support reliable statistical inferences in the PLS analysis. As mentioned previously, spatiotemporal overlap of the effects of the action and non-action games could have obscured the ability of the mean voltage analyses to detect the effects of the video games. However, we acknowledge that further larger scale studies should be undertaken to gain a more complete picture of the effects of video games on cognition and emotion, and some more recent studies have made efforts to increase sample size (e.g., Green et al., 2010a, 2010b, 2012). A related issue is the amount of time spent training on the respective video games which across studies ranges widely from 10–50 h (Green and Bavelier, 2003; Feng et al., 2007; Li et al., 2009). The sample size and length of training in the current study were similar to those used in recently published work that also used ERPs (Wu et al., 2012). Consistent with studies using a similar duration of training, the current study demonstrated differences in visuospatial cognition and emotion processing after just 10 h. One avenue for future research will be to determine the amount of training required to establish the various effects of video games on cognition and emotion, the robustness of these effects over time, and whether the amount of exposure influences the magnitude of the effects.

In summary, the current study revealed differential effects of playing an action or non-action video game for 10 h on neural activity related to target processing and the perception of emotion in facial expression. The most salient finding was that the effects of an action game on visual and affective information processing occurred in the same individuals following the same amount of game play. It is worth noting; that 10 h of experience is not that much greater than the amount of time the average gamer spends playing in a typical week (Entertainment Software Association, 2010). Our findings may suggest that caution should be exercised when using action games as a platform for interventions designed to enhance visuospatial processing, as it seems that one would need to weigh the beneficial effects of these game on visuospatial processing (Dye et al., 2009; Green and Bavelier, 2007) against the potential negative, and likely unintended, effects on affective and social information processing (Anderson et al., 2010).

4. Experimental procedure

4.1. Participants

Thirty-one men from Iowa State University between the ages of 18 and 45 years participated in the study. Participants were recruited based on their responses to a media usage questionnaire (Bailey et al., 2011) completed at least 2 weeks prior to participating in the study. All participants reported playing 0 h of video games per week currently (based on responses to two questions asking the individual to indicate the number of hours spent playing video games on a typical weekday (Question 1) or weekend (Question 2) for each of four time periods: 6 am to noon, noon to 6 pm, 6 pm to midnight, and midnight to 6 am). Participants also reported low levels of experience with 11 popular video game titles (M=1.64, SD=.36), rated on a scale of 1 (never played) to 5 (play frequently). Participants were randomly assigned to one of three groups (final sample, no-contact control 9, non-action 9, action 10), and received course credit or $15 for the pre- and post-test sessions and $5 for the video game sessions. Two participants withdrew from the study early (non-action 1, action 1). Another participant’s data from the non-action group were excluded due to excessive artifacts in the EEG data. The groups were similar in age, handedness (Oldfield, 1971), verbal ability, and working memory (Table 1).
4.2. Materials

4.2.1. Verbal ability and working memory

The Mill Hill vocabulary test was used to assess verbal ability (Raven, 1965) and the letter-number sequencing test was used to assess working memory (Wechsler, 1997).

4.2.2. Emotion search task

The stimuli for the emotion search task were similar to those used by Mather and Knight (2006). Stimulus displays consisted of nine schematic faces arranged in a three by three matrix that was 200 by 267 pixels with a visual angle of \( 4^\circ \). Participants were seated 100 cm from the monitor. Non-target trials were composed of nine neutral faces. Target trials were composed of 8 neutral faces and either one angry or one happy face. The happy and angry faces appeared in each of the nine positions 5 times, for a total of 45 happy target and 45 angry target trials. There were 90 non-target trials.

4.3. Procedure

All stimuli were presented using the E-Prime 1.2 Software (Psychology Software Tools, Pittsburgh, PA). Participants were instructed to press the ‘n’ key if all of the faces in the display were the same and the ‘m’ key if one of the faces was different using the index and middle finger of their right hand. Participants completed 9 practice trials, three of each trial type, followed by two experimental blocks of 90 trials. Each trial began with a fixation cross for 500 ms and then the stimulus display until the participant responded. Participants were instructed to limit their eye movements during the task.

All participants completed two laboratory sessions. In the pre-test participants gave informed consent and completed the Edinburgh Handedness Inventory, the media usage questionnaire, the psychometric measures, and the emotion search task, as part of a larger battery of tasks, which included the following: Stroop, n-back, enumeration, emotion search, visual short-term memory, and affective picture processing. Half the participants performed the tasks in the order listed above, and the other half performed the tasks in the reverse order. In the post-test, participants performed the tasks a second time while the EEG was recorded. Data for the enumeration and affective picture processing tasks were generally consistent with the current findings and previous work (Bailey et al., 2011; Green and Bavelier, 2003). However, as the data for these tasks do not make a unique contribution to the question under investigation the results are not reported here. The remaining tasks (Stroop, n-back, and visual short-term memory) measure executive functioning and will be reported elsewhere. For the EEG recording participants were asked to limit eye and head movements.

Participants in the no-contact group only completed the pre- and post-test sessions that were scheduled at least 10 days apart. Participants in the gaming groups completed 10 sessions in between the pre- and post-test wherein they played either Tetris (TetrisZone, Tetris Holding, LLC) or Unreal Tournament 3 (Epic Games, Midway Games) for 1 h each day. The gaming sessions were scheduled across 10 consecutive days excluding weekends.

4.4. Electrophysiological recording and analysis

The electroencephalogram (EEG) was recorded from an array of 68 tin electrodes based on a modified 10-10 system with a bandpass of 0.2–150 Hz, digitized at 500 Hz, gain 1000, 16-bit A/D conversion. Data were filtered using a zero-lag, semi-orthogonal, dual-pass filter (Butterworth, order 4) with cut-off frequencies of 0.5 and 40 Hz. Data were analyzed using Brain Vision Analysis 2.0 software (Brain Products). The EEG data were filtered with a notch filter at 50 Hz and high-pass filtered at 1 Hz. The data were segmented into epochs of 1000 ms centered on the onset of each trial and baseline corrected at 200 ms pre-stimulus. The EEG data were averaged separately for target and non-target trials and collapsed across participants. The data were then subjected to a 2 (Group) x 6 (Electrode) x 2 (Occasion) x 10 (Trial Type) repeated measures ANOVA. The results are presented in Table 2.

Table 1 – Age, handedness, verbal intelligence, and working memory by Group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>Handedness</th>
<th>Verbal intelligence</th>
<th>Working memory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>No-contact</td>
<td>24.22</td>
<td>8.43</td>
<td>16.67</td>
<td>3.04</td>
</tr>
<tr>
<td>Non-action</td>
<td>21.77</td>
<td>4.02</td>
<td>15.56</td>
<td>4.56</td>
</tr>
<tr>
<td>Action</td>
<td>20.40</td>
<td>2.01</td>
<td>16.40</td>
<td>3.31</td>
</tr>
</tbody>
</table>

Table 2 – Mean amplitude (µV) of the P3 for Group x Electrode x Occasion interaction.

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-contact</td>
<td>1.85</td>
<td>2.39</td>
<td>2.21</td>
<td>1.26</td>
<td>2.52</td>
<td>2.23</td>
</tr>
<tr>
<td>Post-test</td>
<td>2.19</td>
<td>2.95</td>
<td>2.57</td>
<td>1.23</td>
<td>3.48</td>
<td>1.37</td>
</tr>
<tr>
<td>Non-action</td>
<td>1.86</td>
<td>2.25</td>
<td>2.12</td>
<td>1.25</td>
<td>2.98</td>
<td>1.80</td>
</tr>
<tr>
<td>Pz</td>
<td>1.88</td>
<td>1.88</td>
<td>1.59</td>
<td>.81</td>
<td>3.34</td>
<td>2.08</td>
</tr>
<tr>
<td>Post-test</td>
<td>2.06</td>
<td>2.33</td>
<td>2.98</td>
<td>1.81</td>
<td>3.25</td>
<td>1.65</td>
</tr>
<tr>
<td>P4</td>
<td>1.93</td>
<td>1.75</td>
<td>2.72</td>
<td>1.38</td>
<td>3.37</td>
<td>2.21</td>
</tr>
</tbody>
</table>
using an Electro-cap (Electro-Cap International, Eaton, OH). Vertical and horizontal eye movements were recorded from electrodes placed beside and below the right and left eyes. During recording all electrodes were referenced to electrode Cz, then re-referenced to an average reference for data analysis. A 1–20 Hz zero-phase shift filter was applied before averaging. Ocular artifacts associated with blinks and saccades were corrected using the ocular artifact filter in the EMSE software (Source-Signal Imaging, San Diego). ERP analysis epochs included −200 ms of prestimulus activity and 1000 ms of poststimulus activity and included trials with correct responses. The average number of trials contributing to the ERPs were Happy (M = 41, SD = 4), (Angry M = 43, SD = 2), and Neutral (M = 85, SD = 7). Based on visual inspection of the data and past research (Folstein and Van Petten, 2008; Kok, 2001; Polich, 2007), peak amplitude of the N2 was measured from 180 to 200 ms at electrodes PO9 and PO10, and mean amplitude of the P3 was measured from 500 to 600 ms at electrodes P3, Pz, and P4. P3 latency was measured as the maximum voltage at electrode Pz between 200 and 800 ms after stimulus onset for the target trials.

4.5. Partial least squares analysis

The PLS analysis included data from 0 to 1000 ms after stimulus onset at 62 scalp electrodes excluding the four ocular channels and the mastoids electrodes since the left mastoid revealed a high level of artifact in a number of subjects. The input (deviation) matrix for the PLS analysis was obtained by mean-centering the columns of the data matrix with respect to the grand mean. Singular value decomposition (SVD) was performed on the deviation matrix to identify the structure of the latent variables. Three outputs were obtained from the SVD that were used to interpret the relationships between ERP amplitude, task design, and gamification. The first was a vector of singular values that are similar to eigenvalues and represent the unweighted magnitude of each latent variable. The singular values were used to calculate the percentage of task-related variance attributable to each latent variable. The second and third outputs represent the structure of the latent variables and are orthogonal pairs of vectors that are similar to component loadings in PCA. One vector defines the contrasts among conditions scaled for amplitude (brain scores) and the other vector represents the electrode saliences that reflect the spatial–temporal distribution of the latent variable across the scalp. The electrode saliences reflect components or modulations of the ERP waveforms that differ in amplitude across task conditions (e.g., an effect on the P3 might reflect stable saliences on the parietal region of the scalp between 400 and 600 ms).

The significance of the latent variables’ singular values was determined using a permutation test (500 replications) that provided the exact probability of observing the latent variable singular value by chance (e.g., p = .01); the stability of the electrode saliences at each time point and location on the scalp and the brain scores for the task conditions was established through bootstrap resampling (500 replications) that provides a standard error for each of the electrode saliences and brain scores. The ratio of the salience or brain score to its bootstrapped standard error is approximately equivalent to a z-score; therefore, bootstrap ratios greater than 2.5 can be taken to indicate saliences that differ from zero at the p < .01 level. Matlab code used to perform the PLS analyses was obtained at [http://www.rotman-baycrest.on.ca].

Acknowledgments

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References


