Video game experience improves sustained and divided attention but does not affect resistance to cognitive fatigue

James Brooks, Craig P Speelman, Guillermo Campitelli

An increasing number of occupations involve tasks requiring sustained and divided attention skills. These tasks are often susceptible to the effects of cognitive fatigue, resulting in poorer performance and increasing the likelihood of human error. Previous research indicates that those who regularly play action video games have superior performance on cognitive tests that are related to sustained attention and divided attention performance. Few studies, however, have investigated how performance on these tasks change as time-on-task increases. The current study compared the performance of 18 video game players (VGPs) and 24 non-video game players (NVGPs) on the NASA Multi-Attribute Task Battery (version 2; MATB-II) before and after completing a 60-minute sustained attention task. Results indicated that at the multivariate level, VGPs demonstrated superior sustained attention compared to NVGPs, however both groups experienced similar levels of cognitive fatigue with an increasing number of errors and greater reaction time variability as time-on-task increased. In addition, at the multivariate level, VGPs demonstrated superior divided attention performance compared to NVGPs, however univariate analyses revealed a more complex relationship. Further, the performance of both groups improved in the second session compared to the first, indicating a learning effect rather than a fatigue effect. Whilst the current results demonstrate VGP superiority in sustained and divided attention tasks, there was no evidence that these abilities assist with resisting the effects of cognitive fatigue.

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Abstract

An increasing number of occupations involve tasks requiring sustained and divided attention skills. These tasks are often susceptible to the effects of cognitive fatigue, resulting in poorer performance and increasing the likelihood of human error. Previous research indicates that those who regularly play action video games have superior performance on cognitive tests that are related to sustained attention and divided attention performance. Few studies, however, have investigated how performance on these tasks change as time-on-task increases. The current study compared the performance of 18 video game players (VGPs) and 24 non-video game players (NVGPs) on the NASA Multi-Attribute Task Battery (version 2; MATB-II) before and after completing a 60-minute sustained attention task. Results indicated that at the multivariate level, VGPs demonstrated superior sustained attention compared to NVGPs, however both groups experienced similar levels of cognitive fatigue with an increasing number of errors and greater reaction time variability as time-on-task increased. In addition, at the multivariate level, VGPs demonstrated superior divided attention performance compared to NVGPs, however univariate analyses revealed a more complex relationship. Further, the performance of both groups improved in the second session compared to the first, indicating a learning effect rather than a fatigue effect. Whilst the current results demonstrate VGP superiority in sustained and divided attention tasks, there was no evidence that these abilities assist with resisting the effects of cognitive fatigue.

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Sustained attention, the ability to maintain attentional focus and remain alert for long periods of time, and divided attention, the ability to perform two or more tasks simultaneously (Matthews, 2000), play crucial roles in human performance in a range of occupations (e.g., pilots, unmanned vehicle operators, air traffic controllers, power plant operators, long-distance drivers, and security surveillance operators) (Chiappe, Conger, Liao, Caldwell, & Vu, 2013; Durso & Sethumadhavan, 2008; Finomore, Matthews, Shaw, & Warm, 2009; Gartenberg, Breslow, McCurry, & Trafton, 2013; Hubal, Mitroff, Cain, Scott, & DeWitt, 2010; Warm, Matthews, & Finomore, 2008; Warm, Parasuraman, & Matthews, 2008). Performing such complex cognitive tasks for long periods of time can result in cognitive/mental fatigue, which can lead to reduced task performance and an increased likelihood of error (Ackerman, 2011; Guastello et al., 2013; Lal & Craig, 2001; Van Dongen, Belenky, & Krueger, 2011). This decline in task performance over time is known as the fatigue effect or the time-on-task effect (Van Dongen et al., 2011).

Previous research has found that those who regularly play (or those who are trained on) action video games, and in particular first-person shooter (FPS) video games, demonstrate improved performance in a range of cognitive areas, including those areas that are most often used when performing sustained attention tasks (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Castel, Pratt, & Drummond, 2005; Dye, Green, & Bavelier, 2009b; Green & Bavelier, 2003, 2006, 2007; Hubert-Wallander, Green, Sugarman, & Bavelier, 2011; Schmidt, Teo, Szalma, Hancock, & Hancock, 2012), and divided attention tasks (Chiappe et al., 2013; Dye, Green, & Bavelier, 2009a; Gaspar et al., 2013; Hambrick, Oswald, Darowski, Rench, & Brou, 2010; Kearney, 2005). Action video games contain features that relate closely to well-known training principles (Chiappe et al., 2013). For example, instant feedback of performance, variability of training (Healy, Schneider, & Bourne Jr, 2012), motivated and focused learning, and increasing levels of difficulty (Green, Li, & Bavelier, 2009). Together, these features provide a possible medium through which to improve people's divided and sustained attention performance (Pavlas, Rosen, Fiore, & Salas, 2008). However, whilst there is a theoretical basis for the hypothesis that playing action video games can improve sustained attention and divided attention performance, there is currently little research on the topic, and none that explicitly focuses on cognitive fatigue. Thus, the purpose of this research study was to investigate whether action video game players (VGPs) were more resilient to the effects of cognitive fatigue compared to non-video game players (NVGPs), as measured by sustained attention and divided attention task performance.

Cognitive fatigue was initially thought to be the result of depleted cognitive resources. However, after a review of the literature, Hockey (2013) proposed that cognitive fatigue is rather an adaptive mechanism, with the function of controlling and managing motivation and behaviour, and is therefore connected to executive functions. Executive functions are higher-order cognitive control processes that organise and control lower-level cognitive functions according to the individual's goals (van der Linden, 2011). They are used when irrelevant stimuli need to be ignored, when automatic responses need to be overruled, and when information needs to remain active in memory for extended durations (van der Linden, 2011). Over time, the amount of mental effort required in using executive control to perform these tasks increases, resulting in a reduction in the efficiency of these functions, and thus the occurrence of the fatigue effect (Earle, Hockey, Earle, & Clough, 2015; Lorist & Faber, 2011; Lorist et al., 2000; van der Linden, 2011; van der Linden, Frese, & Meijman, 2003).

Executive control is typically assessed using tasks that require attention to be switched between two or more different tasks (Boot et al., 2008; Cain, Landau, & Shimamura, 2012; Hambrick et al., 2010). Previous research has examined divided attention performance using multitasking paradigms (Chiappe et al., 2013; Hambrick et al., 2010), for example the Multi-Attribute Task Battery (MATB). The MATB was originally developed by researchers at the National Aeronautics and Space Administration (NASA, Comstock & Arnegard, 1992) to test human performance and human/automation interaction. It consists of two primary tasks (Tracking and Resource Management) that require constant monitoring, and two secondary tasks (System Monitoring and Communications) that are performed intermittently.

In one study that utilised the MATB to examine the effect of action video game training on divided attention performance (Chiappe et al., 2013), one group of NVGPs played a range of action video games for a minimum of 5 hours per week for 10 weeks, whilst the control group did not play any video games. It was found that action video game training resulted in improved performance (faster responses and fewer errors) on the secondary tasks, with no reduction in performance on the primary tasks. Although participants spent 90 minutes on the MATB, only the last 30 minutes were used in the analysis, and thus any effect of cognitive fatigue on divided attention performance could not be examined. However, this study does add to the existing evidence (Bavelier, Green, Pouget, & Schrater, 2012; Cain et al., 2012; Hambrick et al., 2010; Kearney, 2005) that video game playing can lead to improved multitasking abilities and thus superior executive functioning, compared to NVGPs.

The fatigue effect can also be measured through the vigilance decrement, which is characterised by increasing reaction times and/or decreasing detection accuracy on a vigilance task that typically occurs after 20 to 35 minutes performing the task (Buck, 1966; Hancock, 2013; Helton & Russell, 2012; Mackworth, 1948; See, Howe, Warm, & Dember, 1995). Currently, the resource theory (Fisk & Scerbo, 1987; Fisk & Schneider, 1981; Kahneman, 1973; Parasuraman & Davies, 1977; C. D. Wickens, 1984) is the dominant model used to explain the vigilance decrement (Helton & Russell, 2012). However, neither the resource theory view of vigilance, nor its opponents, the under-load (Frankmann & Adams, 1962; Heilman, 1995; Loeb & Alluisi, 1977; Welford, 1968) and mind-wandering theories (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), can adequately account for all findings related to the vigilance decrement. Instead, similar to cognitive fatigue, it has been proposed that the vigilance decrement is due to reduced executive functioning, rather than a lack of cognitive resources (Thomson, Besner, & Smilek, 2015).

Thomson et al. (2015) proposed that performing vigilance tasks taxes executive functions, as these functions control the ability to ignore irrelevant stimuli and inhibit automatic responses. Over time, as executive functions become taxed, an insufficient amount of attentional resources are allocated towards the task, resulting in deteriorating vigilance performance. It is therefore possible that individuals with greater executive control will be better able to direct the required attentional resources towards the vigilance task, resulting in improved performance over a longer period of time (Thomson et al., 2015).

Dye et al. (2009b) compared sustained attention (vigilance) performance of VGPs and NVGPs, using the Test of Variables of Attention. The test is 21.6 minutes long and requires participants to respond to shapes when they appear in target locations and withhold responses to shapes appearing in other locations. It includes two test conditions, one where targets are infrequent (test of sustained attention), and one where targets are more frequent that non-targets (test of impulsivity). The authors classified VGPs as people who played action video games 5 hours or more per week in the previous year. They found that, for both segments of the test, VGPs were significantly faster than NVGPs, and that there was no significant difference in accuracy between the two groups, indicating that VGPs did not make a speed/accuracy trade-off. This provides further evidence that VGPs may be more resistant to the effects of cognitive fatigue than NVGPs. However, performance over time was not analysed (Dye et al., 2009b), and the test is too short to induce fatigue or a vigilance decrement, thus the difference in the effect of cognitive fatigue on sustained attention performance between VGPs and NVGPs remains unexplored.

The present study

In the present study, cognitive fatigue was induced by time-on-task, with participants completing a gradual-onset Continuous Performance Task (gradCPT) for 60 minutes. Time-on-task is a common method of inducing fatigue (Lorist et al., 2000), and often involves completing continuous vigilance tasks (Xiao et al., 2015).

The continuous-performance design was chosen because it measures moment-to-moment fluctuations in reaction times and accuracy, requiring participants to respond to frequent non-target stimuli and to withhold responses to the rare target stimuli (Esterman, Noonan, Rosenberg, & DeGutis, 2012; Larue, Rakotonirainy, & Pettit, 2010; Rosenberg, Noonan, DeGutis, & Esterman, 2013). Although the vigilance decrement has not been consistently found using this design (Helton, Kern, & Walker, 2009; Rosenberg et al., 2013), Esterman et al. (2012) found that using gradual-onset stimuli in a continuous performance task, rather than abrupt-onset stimuli, successfully taxes the ability to sustain attention. In the present study, stimuli gradually transitioned from the inter-stimulus mask (‘X’) into the stimulus (a random number between 1 and 9) and back into the inter-stimulus mask.

Performance accuracy on the gradCPT was measured according to signal detection theory using sensitivity (d') and response criterion (c, also referred to as $\lambda_{centred}$) (T. D. Wickens, 2001). Sensitivity measures how well the signal (target) can be detected from the noise (non-targets). When d' is close to zero, targets are difficult to detect and when it is large they are easy to detect. Typically, participants have little to no control over signal detectability as it is mostly influenced by the way the stimuli are created in the experimental design (e.g., size of stimulus). Signal detectability is also influenced by the physiology

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involved in the detection process (T. D. Wickens, 2001). In the current experiment the presentation of the stimuli remained consistent throughout the experiment, thus any reduction in sensitivity levels is a result of cognitive fatigue. The response criterion (*c*) represents the amount of evidence needed by the observer in order to classify a stimulus as a target. When the evidence is greater than the response criterion level, the observer classifies the stimulus as a target, and when it is below, it is classified as noise. Response criterion levels however, are controlled by the individual, as this is a representation of their response strategy/bias. The response criterion is a representation of the amount of evidence needed by the participant for them to determine whether a stimulus is a signal (target) or noise (non-target); if the evidence is above the response criterion level, the stimulus is classified as a signal. Thus, decreasing response criterion levels indicate an increased propensity to respond to a stimulus (less evidence is needed), resulting in more correct responses but also more false alarm errors (T. D. Wickens, 2001).

Participants also completed a 20-minute version of the updated MATB (MATB-II) prior to, and after the gradCPT task. Comparing task performance when rested and fatigued is a common method for assessing the effects of fatigue (Chaiken et al., 2011). Performance on the first MATB-II session provided an initial measure of executive function for VGPs and NVGPs and any decline in MATB-II performance between the first and second MATB-II sessions is therefore attributed to cognitive fatigue.

At the end of the second MATB-II session, participants played the first-person shooter (FPS) video game *Unreal Tournament 2004* by Atari, on a computer. Previous research has classified participants as ‘video game experts’ based purely on self-report measures of how often they play (Latham, Patston, & Tippett, 2013b) and although the process of becoming an expert may require many hours of practice (VanDeventer & White, 2002), it is not a sufficient criterion for being considered an expert. Experts are individuals

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who display superior performance compared to novices, as measured by speed, accuracy and/or efficiency (Speelman, 1998). Although it has been previously suggested (Latham et al., 2013b; Towne, Ericsson, & Sumner, 2014; Wang, Richard, & Schmular, 2014), there is a lack of research that uses objective measures to classify participants as either VGPs or NVGPs, and many authors often use the argument that doing so is impractical (Gobet et al., 2014). To maintain consistency with previous research, a self-report questionnaire was used to classify participants as VGPs or NVGPs, in conjunction with participants' video game performance.

Hypotheses

Previous research has shown that VGPs outperform NVGPs on short vigilance tests (Dye et al., 2009b), and that they demonstrate superior performance on tasks related to sustained attention (Boot et al., 2008; Castel et al., 2005; Green & Bavelier, 2003, 2006, 2007; Hubert-Wallander et al., 2011; Schmidt et al., 2012). Therefore it was predicted that VGPs would perform better than NVGPs on all measures of the gradCPT. Due to the vigilance decrement, it was expected that performance for both groups would decline as time-on-task increases. However, it was hypothesised that the decline would be greater for NVGPs than VGPs.

Video game experience has been shown to improve divided attention performance (Chiappe et al., 2013). Therefore it was hypothesised that VGPs would perform better than NVGPs on both the first and second sessions of the MATB-II. Due to the time-on-task effect and being fatigued from the gradCPT, it was expected that MATB-II performance for both groups would decline from session 1 to session 2. However, it was predicted that VGPs would experience a smaller reduction compared to NVGPs. The MATB-II also includes a measure of subjective workload. It was predicted that as VGPs should perform better in the MATB-II they should also experience lower levels of workload.

Method

Participants

The study was granted approval from the ECU Human Research Ethics Committee (11490 BROOKS). Participants confirmed their consent to participate in writing. Forty-seven individuals participated in the study. Three participants withdrew from the study and therefore their data was not used. All participants went into a draw to win one of two $50 gift cards. Two participants were over the age of 60 years and therefore their data was removed in order to avoid a potential age confound. In addition, one of these participants reported that they were a VGP, however their video game performance suggested that they should be considered a NVGP. The removal of these participants resulted in data for 42 participants being used in the present study.

Participants were classified as VGPs if they reported playing FPS games for 4 or more hours per week, for a minimum of 1 hour each time, over the previous 6 months. Participants were also asked to specify which video games (of any genre) they most commonly played as well as the video game genre and platform. After completing the cognitive tests, participants practiced the video game for 2 minutes on ‘novice’ difficulty and then completed three 5-minute games on ‘expert’ difficulty. Performance was calculated by subtracting the number of deaths from the number of kills and averaging over the three games. Participants who were classified as VGPs based on their self-report measure all scored above 0, indicating that they killed the enemy target more times than they themselves were killed. In addition, there were seven participants who scored above 0 but did not meet the self-report VGP criteria. However, upon further investigation, it was found that these individuals did report to playing FPS games for less than 4 hours per week and/or reported to playing other action video games (e.g., racing, 3^{rd} person shooter games) for 4 or more hours per week over the previous 6 months, and so they were also classified as VGPs. Thus, all participants who scored above

0 in *Unreal Tournament 2004* reported playing action video games for 4 or more hours per week over the previous 6 months, and all participants who scored below 0 reported playing no video games of any genre. To confirm group allocation, a between-groups t-test was conducted on *Unreal Tournament Performance 2004* performance. There was a significant difference in *Unreal Tournament Performance 2004* (UT2004 score) between those classified as VGPs and those classified as NVPGs, $t(40) = 13.86$, $p < .001$ (see Table 1).

Table 1

Participants' demographic details and video game performance

	Sex		Age (years)		UT2004 score (Kill – Death)	
	Male	Female	Mean	SD	Mean	SD
VGP	15	3	26.50	7.33	6.39	3.35
NVGP	5	19	37.92	11.28	-8.40	3.48

Tasks

Sustained attention (gradCPT).

The gradCPT was created using the E-Prime 2.0 software. In the gradCPT task, participants were required to respond (press the spacebar) to the numbers '1' through to '9', except for the number '4' (the target). There were a total of 2400 stimuli, with the target occurring 480 times (probability of occurrence of 0.2). The stimuli were presented individually, fading in and out at the centre of the computer monitor. The stimuli were separated by an inter-stimulus mask ('X') that also faded in and out. The duration of the transition from inter-stimulus mask to the next stimulus (and vice versa) was 500ms, and each stimulus was presented at 100% opacity for 500ms before beginning the transition back to the inter-stimulus mask. The stimuli were presented in size 72.5 Arial font, on a 20-inch computer monitor.

The gradCPT was divided into ten 6-minute periods, each consisting of 240 trials. Reaction times (RT) were collapsed to mean values that were used for the analysis. In addition, the standard deviations of RTs for each period were used to analyse the variability

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of the raw reaction times. Reaction times were measured from stimulus onset, that is, from when the inter-stimulus mask (‘X’) began the gradual transition into the numbered stimulus. Thus, a reaction time between 150ms and 500ms indicated a response that occurred when the inter-stimulus symbol was transitioning into the stimulus, a reaction time between 500ms and 1000ms indicated a response that occurred when the stimulus was at 100% opacity, and a reaction time between 1000ms and 1500ms indicated a response that occurred when the stimulus was transitioning into the following inter-stimulus mask. Response times less than 150ms were considered anticipatory and were therefore labelled as errors.

Divided attention (MATB-II).

Each MATB-II session was designed to include the same number of events so as to maintain task difficulty between sessions. For the System Monitoring task, participants had to respond within a 10-second time limit, and for the Communications task there was a 30-second time limit. The Tracking task remained in the ‘manual’ setting for the entire duration.

While the MATB-II produces data on 21 measures (Chiappe et al., 2013), only eight were used in the analysis. The Communications task consisted of two measures, mean RT (seconds) of correct responses and accuracy of correct responses. The Tracking task consisted of one measure, the root mean squared deviation (RMSD) of the distance (in pixels) of the reticle of the joystick to the centre of the target location. The Resource Management task consisted of one measure, the mean deviation of the fuel level in Tanks A and B, from the target level of 2500 units. The System Monitoring task was separated between the Light task and the Scale task. Each of these consisted of two measures, mean RT (seconds) of correct responses and accuracy of correct responses. For the Tracking and Resource Management tasks, low values indicate better performance.

The MATB-II also includes a Workload Rating Scale (WRS) that is completed at the end of the session and was analysed separately to the eight MATB-II performance measures.

The WRS is based on the NASA-TLX (Hart & Staveland, 1988) and consists of six subscales of workload: mental demand, physical demand, temporal demand, (subjective level of) performance, effort, and frustration. All subscales are measured on a 100-point scale, and each is measured from 'low' to 'high' except for the performance subscale which was reversed because a low rating of subjective performance is an indication of high workload.

Procedure

After providing informed consent, participants were instructed on how to perform the MATB-II. Participants were shown an image of the MATB-II and provided with verbal instructions on each of the four tasks. Participants then completed a 5-minute practice version of the task whilst the experimenter provided directions and assistance and answered any questions. Upon completion, the experimenter left the room and the participant completed the first 20-minute MATB-II session on their own.

The experimenter then provided instructions on how to complete the gradCPT, and informed the participants that they should respond as quickly and accurately as possible. Participants then completed a 1-minute practice version of the gradCPT while the experimenter ensured that they were attempting to respond correctly. The experimenter left the room whilst participants completed the 60-minute version of the task. Upon completion, the experimenter then initiated the second MATB-II session. No further practice was provided, however the experimenter answered any questions participants had about performing the task.

At the completion of the second MATB-II session, participants were allowed to take a short break before returning and playing the FPS game *Unreal Tournament 2004*. Similar to the other tasks, participants were shown an image of the game and provided verbal instruction on the controls and how to play. They then practiced the game for 2 minutes, before completing three 5-minute games. All verbal instructions for all tasks, including

Unreal Tournament 2004, were scripted to ensure the same instructions were provided to all participants regardless of video game experience.

Results

Sustained attention (gradCPT)

A doubly-multivariate profile analysis was initially conducted on the four measures of sustained attention performance (RT, RT variability, sensitivity, response criterion), with post hoc tests conducted as required.

Profile analysis is a multivariate alternative to the repeated-measures ANOVA. A popular extension of the profile analysis is the doubly-multivariate profile analysis, which is used when multiple dependent variables are measured at multiple time points (Tabachnick & Fidell, 2007). In profile analysis, parallelism is the multivariate alternative to the univariate test of interaction. When two or more profiles are parallel there is no interaction, that is, differences between the groups are constant across the levels of the dependent variable. The test for equality of levels (or equality of groups) is the multivariate alternative to the univariate between-subjects test. The flatness of profiles test (or test for equality of levels) is the multivariate alternative to the univariate within-subjects test (Tabachnick & Fidell, 2007).

Doubly-multivariate Profile Analysis

A 2 (group) x 10 (period) doubly-multivariate profile analysis was conducted on the sustained attention performance of VGPs and NVGPs using the four measures; RT, RT variability, sensitivity (d'), and response criterion (c). The group by period interaction (deviation from parallelism) was not significant, $V = 0.81$, $F(36, 5) = 0.59$, $p = .839$, partial $\eta^2 = 0.81$. The equality of levels test was significant, indicating a difference in sustained attention performance between VGPs and NVGPs, $V = 0.27$, $F(4, 37) = 3.33$, $p = .020$, partial $\eta^2 = 0.265$. For the flatness test, there was no significant change in performance over time (difference between periods), $V = 0.92$, $F(36, 5) = 1.59$, $p = .321$, partial $\eta^2 = 0.920$.

Each of the four measures was analysed individually to determine on which measures the VGPs and NVGPs differed.

Reaction time

The RT profiles of the VGPs and NVGPs, seen in Figure 1, did not deviate significantly from parallelism, $V = 0.26$, $F(9, 32) = 1.25$, $p = .301$, partial $\eta^2 = 0.26$.

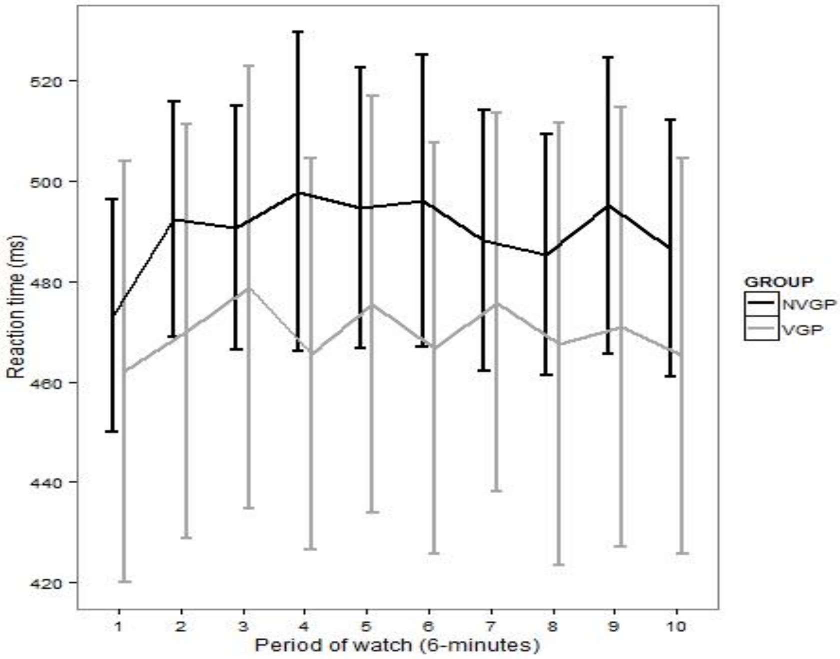

Figure 1. Mean RT (ms) of correct responses across periods. Error bars are 95% confidence intervals.

For the equality of levels test, when RTs were averaged over all periods, there was no significant difference between VGP ($M = 469.84$ms, $SE = 15.85$) and NVGP ($M = 490.06$ms, $SE = 13.73$), $F(1, 40) = 0.93$, $p = .341$, partial $\eta^2 = 0.023$.

For the flatness test, when averaged over groups, there was no significant difference between periods, indicating no deviation from flatness, $V = 0.27$, $F(9, 32) = 1.28$, $p = .285$, partial $\eta^2 = 0.265$.

VGPs

Mauchley's test of sphericity was conducted on the RT of VGPs. The assumption of sphericity was violated, $\chi^2(44) = 82.68$, $p = .001$, therefore the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.495$). The results showed that there was no significant effect of period, $F(4.46, 75.75) = 7.43$, $p = .580$, partial $\eta^2 = 0.042$, and using a Bonferroni adjustment, there were no significant pairwise comparisons (*p*s > .05).

NVGPs

Mauchley's test of sphericity was conducted on the RT of NVGPs. The assumption of sphericity was violated, $\chi^2(44) = 104.39$, $p < .001$, therefore the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.442$). The results showed that there was no significant effect of period, $F(3.98, 91.47) = 1.47$, $p = .219$, partial $\eta^2 = 0.060$. However, using a Bonferroni adjustment, there was a significant difference between period 1 and periods 2, 3, and 4 (*p*s < .05).

Variability (Standard Deviation)

The profiles of RT variability for VGPs and NVGPs, seen in Figure 2, were parallel, $V = 0.13$, $F(9, 32) = 0.54$, $p = .836$, partial $\eta^2 = 0.13$.

For the equality of levels test, when variability of RTs were combined over all periods, there was no significant difference between VGPs ($M = 90.89$, $SE = 6.46$) and NVGPs ($M = 93.92$, $SE = 5.59$), $F(1, 40) = 0.13$, $p = .725$, partial $\eta^2 = 0.003$.

For the flatness test, when combined over groups, there was a significant difference between periods, indicating a significant deviation from flatness, $V = 0.489$, $F(9, 32) = 3.41$, $p = .005$, partial $\eta^2 = 0.489$.

Post hoc tests were conducted to examine the differences between periods within each of the groups.

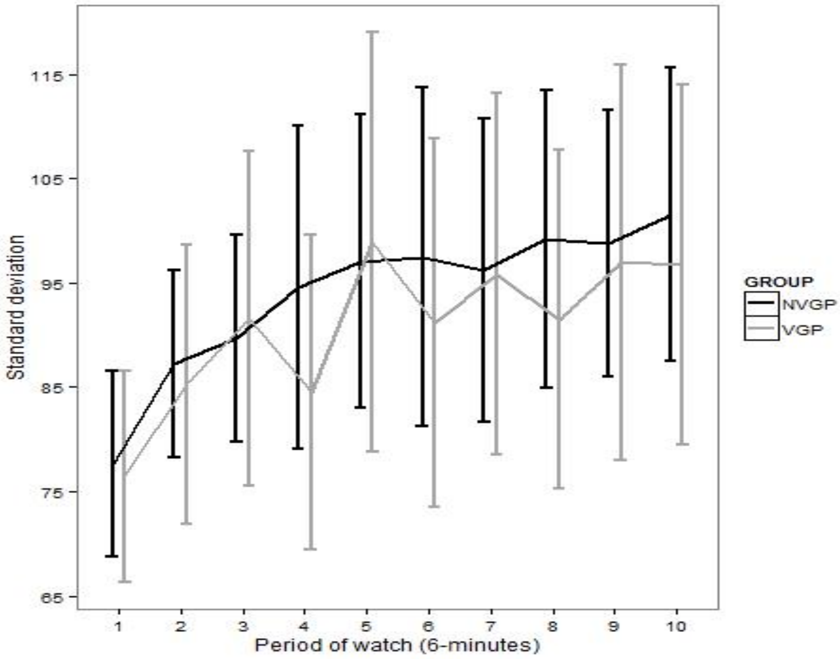

Figure 2. Variability of raw RTs (SD units) across periods. Error bars are 95% confidence intervals.

VGPs

Mauchley's test of sphericity was conducted on the RT variability (SD) of VGPs. The assumption of sphericity was violated, $\chi^2(44) = 73.67$, $p = .005$, therefore the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.52$). The results showed that there was a significant effect of period, $F(4.67, 79.35) = 3.03$, $p = .017$, partial $\eta^2 = 0.151$, and a significant linear trend, $F(1, 17) = 9.78$, $p = .006$, partial $\eta^2 = 0.365$. Pairwise comparisons using a Bonferroni adjustment revealed significant differences between period 1 and periods 3, 5, 7, 8, 9, and 10 ($p < .05$). There were also significant differences between period 2 and periods 5, 9, and 10, and between period 4 and periods 5, 9, and 10, and between periods 5 and 6 ($ps < .05$).

NVGPs

Mauchley's test of sphericity was conducted on the RT variability (SD) of NVGPs. The assumption of sphericity was violated, $\chi^2(44) = 68.80$, $p = .012$, therefore the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.58$). The results showed that there was a significant effect of period, $F(5.24, 120.49) = 3.99$, $p = .002$, partial $\eta^2 = 0.148$, and a significant linear trend, $F(1, 23) = 17.57$, $p < .001$, partial $\eta^2 = 0.433$. Pairwise comparisons using a Bonferroni adjustment revealed significant differences between period 1 and all other periods ($p < .05$). There were also significant differences between period 2 and periods 5, 8, 9, and 10, and between periods 3 and 10 (*ps* < .05).

Sensitivity (d')

The profiles of sensitivity of VGPs and NVGPs, seen in Figure 3, were parallel, $V = 0.08$, $F(9, 32) = 0.37$, $p = .967$, partial $\eta^2 = 0.079$.

For the equality of levels test, when d' values were combined over all periods, there was no significant difference between VGPs ($M = 3.95$, $SE = 0.21$) and NVGPs ($M = 4.46$, $SE = 0.19$), $F(1, 40) = 3.27$, $p = .078$, partial $\eta^2 = 0.076$.

For the flatness test, when combined over groups, the difference in sensitivity between periods was significant, $V = 0.58$, $F(9, 32) = 4.85$, $p < .001$, partial $\eta^2 = 0.577$.

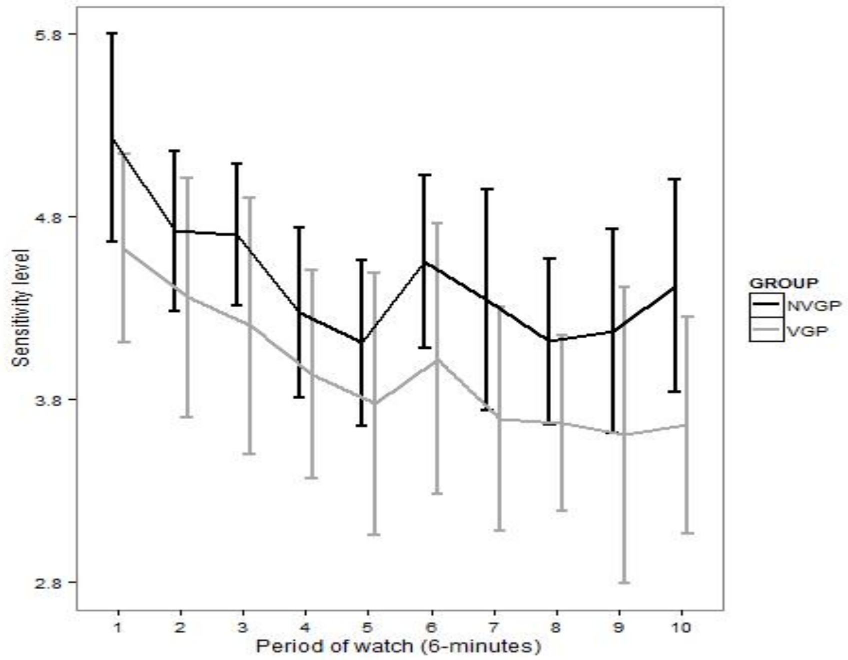

Figure 3. Sensitivity values across periods. Error bars are 95% confidence intervals.

VGPs

Mauchley's test of sphericity was conducted on the sensitivity levels of VGPs. The assumption of sphericity was violated, $\chi^2(44) = 99.74$, $p < .001$, therefore the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.487$). The results showed that there was a significant effect of period, $F(4.39, 74.57) = 2.53$, $p = .042$, partial $\eta^2 = 0.13$, and a significant linear trend, $F(1, 17) = 8.65$, $p = .009$, partial $\eta^2 = 0.337$. Pairwise comparisons using a Bonferroni adjustment revealed a significant difference between period 1 and periods 2, 4, 5, 7, 8, 9, and 10 (*p*s < .05).

NVGPs

Mauchley's test of sphericity was conducted on the sensitivity levels of NVGPs. The assumption of sphericity was not violated, $\chi^2(44) = 48.34$, $p = .323$. The results showed that there was a significant effect of period, $F(9, 207) = 3.84$, $p < .001$, partial $\eta^2 = 0.143$, and a significant linear trend, $F(1, 23) = 10.42$, $p = .004$, partial $\eta^2 = 0.312$, as well as a significant quadratic trend, $F(1, 23) = 7.01$, $p = .014$, partial $\eta^2 = 0.234$. Pairwise comparisons using a Bonferroni adjustment revealed a significant difference between period 1 and periods 2, 4, 5, 6, 7, 8, 9, and 10, and between period 2 and periods 4, 5, and 8, and between period 3 and periods 5 and 8, and between periods 5 and 6 (*p*s < .05).

Response Criterion (c)

The profiles of response criterion levels of VGPs and NVGPs, seen in Figure 4, were parallel, $V = 0.097$, $F(9, 32) = 0.38$, $p = .936$, partial $\eta^2 = 0.097$.

For the equality of levels test, when c values were combined over all periods, the difference between VGPs ($M = 1.05$, $SE = 0.08$) and NVGPs ($M = 0.96$, $SE = 0.07$) was not significant, $F(1, 40) = 0.734$, $p = .397$, partial $\eta^2 = 0.018$.

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For the flatness test, when combined over groups, the difference in the response criterion between periods was significant, indicating a deviation from flatness, $V = 0.45$, $F(9, 32) = 2.89$, $p = .013$, partial $\eta^2 = 0.448$.

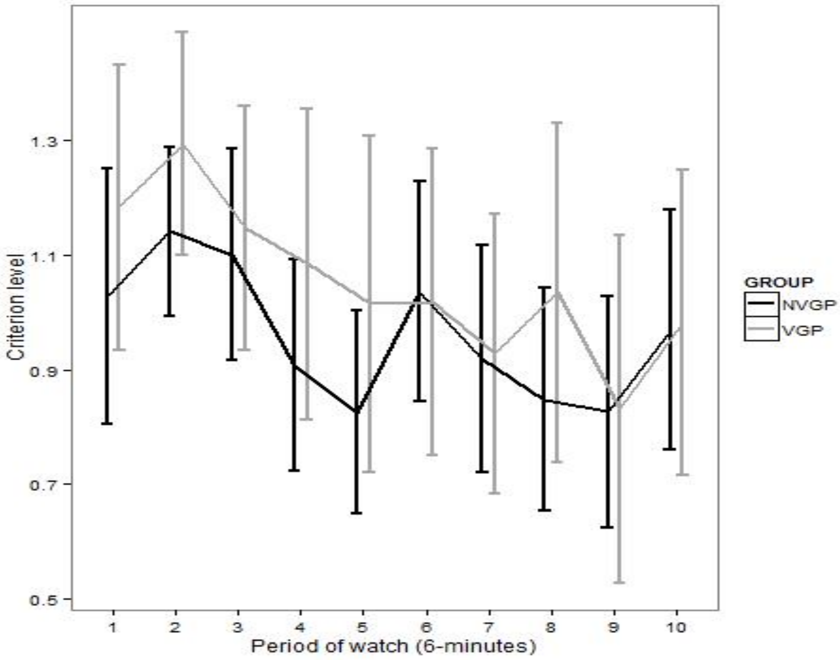

Figure 4. Response criterion values across periods. Error bars are 95% confidence intervals.

VGPs

Mauchley's test of sphericity was conducted on the criterion levels of VGPs. The assumption of sphericity was violated, $\chi^2(44) = 74.298$, $p = .005$, therefore the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.578$). The results showed that there was a significant effect of period, $F(5.21, 88.48) = 2.83$, $p = .019$, partial $\eta^2 = 0.143$, and a significant linear trend, $F(1, 17) = 9.29$, $p = .007$, partial $\eta^2 = 0.353$. Pairwise comparisons using a Bonferroni adjustment revealed a significant difference between period 1 and periods 7 and 9, and between period 2 and periods 3, 5, 6, 7, 8, 9, and 10, and between periods 3 and 9 (*p*s < .05).

NVGPs

Mauchley's test of sphericity was conducted on the criterion levels of NVGPs. The assumption of sphericity was violated, $\chi^2(44) = 65.57$, $p = .023$, therefore the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.653$). The results showed that there was a significant effect of period, $F(5.87, 135.107) = 2.07$, $p = .04$, partial $\eta^2 = 0.083$, and a significant linear trend, $F(1, 23) = 5.78$, $p = .025$, partial $\eta^2 = 0.201$. Pairwise comparisons using a Bonferroni adjustment revealed a significant difference between period 2 and periods 5, 7, 8, and 9, and between period 3 and periods 5, 8, and 9, and between period 6 and periods 5 and 9 (*p*s < .05).

Divided attention (MATB-II)

In session 1, there were two missing cases (2 NVGPs) in Communications task RT, and two missing cases (1 NVGP; 1 VGP) in System monitoring Scales task RT. In session 2, there was one missing case (1 NVGP) in Communications task RT and one missing case (1 VGP) in System monitoring Scales task RT. Missing values in RT measures indicate that these participants did not respond to any of the events, or in the case of the communications task, they may have selected the radio and frequency but did not click on the 'Enter' button to record their answer. The missing values were replaced with the mean value of each participant's respective group.

A 2 (group) x 2 (session) doubly-multivariate profile analysis was conducted on the eight measures (see Table 2) of MATB-II performance. The group by session interaction (deviation from parallelism) was not significant, $V = 0.17$, $F(8, 33) = 0.85$, $p = .563$, partial $\eta^2 = 0.172$. The equality of levels test was significant, indicating a difference in divided attention performance between VGPs and NVGPs, $V = 0.36$, $F(8, 33) = 2.31$, $p = .044$, partial $\eta^2 = 0.359$. For the flatness test, there was a significant change in performance between sessions, $V = 0.63$, $F(8, 33) = 6.98$, $p < .001$, partial $\eta^2 = 0.629$.

To examine whether VGPs have superior executive functioning compared to NVGPs, a MANOVA was conducted using performance on the first MATB-II session. Box's test of equality of covariances was significant, $F(36, 4520.03) = 1.84$, $p = .002$. The result of the

MANOVA revealed no significant difference in performance between the two groups, V = 0.31, $F(8, 33) = 1.84$, $p = .104$, $\eta^2 = 0.309$. However, univariate results were analysed as it is possible that the different groups may have chosen to focus on particular sub-tasks at the expense of performance on the remaining tasks.

Levene's test of equality of variances was only significant for communication task accuracy and the tracking task (ps < .05). VGPs performed better on all measures compared to NVGPs. However, there was only a significant difference between the two groups on three of the eight MATB-II measures (see Table 2).

Table 2

Session 1 MATB-II sub-task performance

Task	Measure	VGP (SD)	NVGP (SD)	ANOVA
Communications	RT	3.397 (1.47)	3.55 (1.38)	$F(1, 40) = 0.11$, $p = 0.739$
	Accuracy	0.97 (0.03)	0.90 (0.14)	$F(1, 40) = 4.89$, $p = .033$
Resource Management	Mean	376.02 (387.33)	558.74 (363.38)	$F(1, 40) = 2.46$, $p = .125$
Tracking	RMSD	34.43 (7.89)	42.30 (14.74)	$F(1, 40) = 4.20$, $p = .047$
System Monitoring - Lights	RT	2.73 (0.66)	3.25 (0.97)	$F(1, 40) = 3.89$, $p = .056$
	Accuracy	0.83 (0.15)	0.76 (0.19)	$F(1, 40) = 1.86$, $p = .180$
System Monitoring - Scales	RT	4.01 (0.76)	4.66 (0.70)	$F(1, 40) = 8.196$, $p = .007$
	Accuracy	0.66 (0.27)	0.64 (0.19)	$F(1, 40) = .13$, $p = .724$

An additional MANOVA was conducted using only data from session 2 of the MATB-II. Box's test of equality of covariances was not significant, $F(36, 4520.03) = 1.38$, $p = .067$. The result of the MANOVA revealed a significant difference in performance between the two groups, $V = 0.41$, $F(8, 33) = 2.80$, $p = .017$, $\eta^2 = 0.405$. Univariate results were analysed to determine which tasks the groups differed on.

Levene's test of equality of variances was non-significant for tasks (*ps* > .05). VGPs performed equal to or better than NVGPs on all tasks. However, there was only a significant difference between the two groups on three of the eight MATB-II measures (see Table 3).

Table 3

Session 2 MATB-II sub-task performance

Task	Measure	VGP (SD)	NVGP (SD)	ANOVA
Communications	RT	2.76 (1.51)	3.29 (1.41)	$F(1, 40) = 2.88, p = .249$
	Accuracy	0.98 (0.30)	0.96 (0.94)	$F(1, 40) = 0.003, p = .453$
Resource Management	Mean	259.11 (171.44)	394.31 (237.78)	$F(1, 40) = 4.18, p = .048$
Tracking	RMSD	30.16 (5.51)	36.16 (9.85)	$F(1, 40) = 6.41, p = .015$
System Monitoring - Lights	RT	2.50 (0.55)	3.05 (0.60)	$F(1, 40) = 9.39, p = .004$
	Accuracy	0.89 (0.10)	0.89 (0.10)	$F(1, 40) = 0.002, p = .960$
System Monitoring - Scales	RT	3.68 (0.92)	4.16 (0.86)	$F(1, 40) = 2.96, p = .093$
	Accuracy	0.74 (0.23)	0.78 (0.14)	$F(1, 40) = 0.65, p = .424$

Workload Rating Scale (WRS)

A doubly-multivariate profile analysis was conducted on the raw responses to the WRS. The group by session interaction (deviation from parallelism) was not significant, $V = 0.09$, $F(6, 35) = 0.54$, $p = .75$, partial $\eta^2 = 0.089$. The equality of levels test was not significant, indicating no difference in subjective workload between VGPs and NVGPs, $V = 0.27$, $F(6, 35) = 2.12$, $p = .075$, partial $\eta^2 = 0.267$. For the flatness test, there was a significant change in subjective workload between sessions, $V = 0.37$, $F(6, 35) = 3.38$, $p = .01$, partial $\eta^2 = 0.367$.

Inspection of the data revealed that both groups had lower scores on all measures in the second session compared to the first, matching the pattern of MATB-II performance. To determine whether there were any initial differences in workload a MANOVA was conducted using responses from the first MATB-II session. Box's test of equality of covariances was not significant, $F(21, 4926.67) = 1.17$, $p = .272$. The result of the MANOVA revealed a significant difference in workload rating between the two groups, $V = 0.33$, $F(6, 35) = 2.88$, $p = .022$, $\eta^2 = 0.309$. Univariate results were analysed to determine on which sub-scales the groups differed. Levene's test of equality of variances was non-significant for all of the sub-scales (*ps* > .05). There was a significant difference in subjective workload ratings between the VGPs and NVGPs on only one of the six sub-scales (see Table 4).

Table 4

Session 1 WRS results

Sub-scale	VGP (SD)	NVGP (SD)	ANOVA
Mental	70.61 (17.11)	76.29 (17.61)	$F(1, 40) = 1.10$, $p = .301$
Physical	38.83 (19.45)	32.92 (27.15)	$F(1, 40) = .62$, $p = .437$
Temporal	57.83 (21.72)	61.38 (23.52)	$F(1, 40) = .25$, $p = .621$
Performance	32.22 (17.49)	58.75 (23.98)	$F(1, 40) = 15.71$, $p < .001$
Effort	65.06 (17.91)	70.29 (19.78)	$F(1, 40) = .78$, $p = .383$
Frustration	35.94 (18.86)	48.71 (27.45)	$F(1, 40) = 2.87$, $p = .098$

A MANOVA was also conducted using only responses from the second MATB-II session. Box's test of equality of covariances was not significant, $F(21, 4926.67) = .081$, $p = .711$. The result of the MANOVA revealed no significant difference in workload rating between the two groups, $V = 0.17$, $F(6, 35) = 1.21$, $p = .322$, $\eta^2 = 0.172$. Univariate results were analysed to determine if groups differed on any of the individual sub-scales. Levene's test of equality of variances was not significant for all of the sub-scales (*ps* > .05). The only significant difference between the groups was on the Performance sub-scale (see Table 5).

Table 5

Session 2 WRS results

Sub-scale	VGP (SD)	NVGP (SD)	ANOVA
Mental	63.36 (20.93)	65.54 (19.18)	$F(1, 40) = 0.12, p = .731$
Physical	37.00 (18.72)	31.83 (23.04)	$F(1, 40) = 0.61, p = .441$
Temporal	54.83 (20.26)	56.29 (21.59)	$F(1, 40) = 0.049, p = .825$
Performance	26.44 (20.41)	46.67 (28.19)	$F(1, 40) = 6.64, p = .014$
Effort	55.00 (23.50)	60.79 (22.96)	$F(1, 40) = 0.64, p = .428$
Frustration	31.72 (21.09)	34.96 (26.43)	$F(1, 40) = 0.18, p = .672$

Discussion

Overall, the results of the present study demonstrate that there is no difference in the levels of cognitive fatigue experienced between VGPs[1] and NVGPs. The results of performance on the sustained attention task revealed that both groups experienced similar reductions in performance as time-on-task increased. In addition, from the results of the divided attention task it is not possible to determine whether participants experienced cognitive fatigue from session 1 to session 2 as the performance of both groups improved, possibly due to practice/learning effects.

The doubly-multivariate profile analysis revealed that there was a significant difference between groups on the gradCPT, and that there was no significant change over time. However, individual profile analyses were conducted on each of the four measures from the gradCPT and revealed no significant difference in performance between the groups on any of the measures. As the between-group difference only occurred at the multivariate level, this suggests that the difference in performance between VGPs and NVGPs is detectable only when a combination of the sustained attention performance measures are analysed together. In addition, both groups exhibited a significant decline in sustained attention performance

[1] Due to the method of group allocation, the term VGP is used in the Discussion to refer to individuals who regularly play action video games, and not just specifically first-person shooter video games.

over time on the RT variability, sensitivity, and response criterion measures. The non-significant effect of time in the doubly-multivariate profile analysis was likely due to the non-significant effect on RT masking the significant effect of time on the other three variables.

The similarity of sustained attention performance, when measured at the univariate level, between the VGPs and NVGPs is in contrast to previous research in this area. In particular, when Dye et al. (2009b) compared sustained attention performance, not only were VGPs significantly faster than NVGPs, their RTs were so fast that their responses were initially considered to be anticipatory (less than 200ms). It was noted though that VGPs' responses were nearly always correct and thus these fast responses were considered to be 'real' responses. Thus, in the present study it is surprising that VGPs did not at least have significantly faster RTs than NVGPs. However, there is increasing evidence that the effects of playing action video games on improving cognitive abilities may have been over estimated in the literature (Unsworth et al., 2015) and that research in this area suffers from a number of different methodological limitations (Boot, Blakely, & Simons, 2011; Gobet et al., 2014). Therefore the current univariate results add to the existing evidence (Irons, Remington, & McLean, 2011; Murphy & Spencer, 2009; van Ravenzwaaij, Boekel, Forstmann, Ratcliff, & Wagenmakers, 2013) that action video games do not enhance cognitive abilities involved with performance in sustained attention tasks. However, as evidenced from the present study, it is important that measures of cognitive performance are also analysed at a multivariate level to provide a more in-depth exploration of the phenomena.

The decline in sustained attention performance over time is consistent with results in the previous research. Both VGPs and NVGPs experienced significant reductions in performance on all measures except for RT. As time-on-task increased, RT variability increased, sensitivity levels decreased, and response criterion levels decreased. These results are all consistent with the previous research on the time-on-task effect and the effects of

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fatigue, however, the decline in performance did not stop after 30 minutes as has been demonstrated by previous research on the vigilance decrement (Buck, 1966; Hancock, 2013; Helton & Russell, 2012; Mackworth, 1948; See et al., 1995). Instead, there were significant linear trends for both groups in RT variability, sensitivity, and response criterion levels that persisted beyond 30 minutes on the task. It is suggested for future research that any investigation of sustained attention and the vigilance decrement should be at least 30 minutes in duration, and that sustained attention performance needs to be examined over the entire duration of the task.

Accuracy in sustained attention performance was assessed with signal detection theory, using d' (sensitivity) and c (response criterion) (T. D. Wickens, 2001). Decreasing sensitivity levels indicate a decreased ability to detect the signal (targets) from the noise (non-targets). Signal detectability is influenced by the way the stimuli are created in the experimental design and by the physiology involved in the detection process (T. D. Wickens, 2001). In the current experiment, as the presentation of the stimuli remained consistent throughout the experiment, any changes in sensitivity were a result of fatigued sustained attention processes.

Response criterion levels are controlled by the individual, as this is a representation of their response strategy/bias (T. D. Wickens, 2001). The response criterion is a representation of the amount of evidence needed by the participant for them to determine whether a stimulus is a signal or noise; if the evidence is above the response criterion level, the stimulus is considered to be a signal. Decreasing response criterion levels therefore indicates an increased propensity to respond to stimuli (as less evidence is needed), resulting in more correct responses but also more false alarm errors (T. D. Wickens, 2001). Therefore, as time-on-task increased, participants compensated for this reduced ability to detect signals by lowering their response criterion and making more responses, inadvertently resulting in more false alarm responses. This adjustment in response behaviour, as a result of fatigue, supports the work of others (Hancock, 2013; Hockey, 2013; Thomson et al., 2015) who have proposed that being cognitively fatigued results in adaptive behaviour aimed at maintaining optimal task performance.

As discussed previously, sustained attention tasks are effective measures of executive control as these tasks require ignoring irrelevant stimuli and inhibiting automatic responses (Thomson et al., 2015). It was therefore hypothesised that those with greater executive control would be better at performing these tasks as they would be more efficient at controlling attention, allowing them to perform better for longer. Overall, VGPs exhibited better sustained attention compared to NVGPs at the multivariate level, suggesting that they have superior executive control. In spite of this result, however, given the non-significant interaction effect in the doubly-multivariate profile analysis, and the significant effect of time in the univariate tests, it can be concluded that both VGPs and NVGPs are equally susceptible to the time-on-task effect and cognitive fatigue.

With regards to divided attention performance, there was no evidence of participants experiencing cognitive fatigue over the two sessions of the MATB-II. In fact, both VGPs and NVGPs significantly improved in performance from session 1 to session 2. This can be attributed to a learning effect, and is a methodological issue rather than a theoretical one. This is further supported by the doubly multivariate profile analysis on WRS scores that revealed a significant decline in subjective workload from session 1 to session 2. It is possible that the cognitive fatigue induced from the gradCPT task did impact MATB-II performance but that the practice effect was so large that it overcame any fatigue-related performance decline. However, this conclusion cannot be confirmed by the data available from the present study. Future studies investigating fatigue should use tasks on which optimal performance can be achieved in a short period of time in a practice trial, or to use tasks in which all participants are already proficient, as these will be more likely to show greater increases in fatigue (Ackerman, Calderwood, & Conklin, 2012).

Session 1 of the MATB-II was examined to assess differences in the two groups' initial level of executive functioning/control before they became fatigued. Multivariate analysis revealed that there was no significant difference between the groups, however univariate results were analysed as it was possible that groups may have varied in which sub-tasks they focussed on. VGPs performed better than NVGPs on all measures, but at the univariate level, differences on only three of the eight measures were significant. VGPs performed significantly better than NVGPs on the Tracking task, Communications accuracy, and System monitoring – Scale RT. VGPs' superior performance on the Tracking task is not surprising as this task required controlling a joystick, a device often used in computer-based video games. The other two measures, Communications accuracy, and System monitoring – Scale RT, are considered to be secondary tasks on the MATB-II, although it should be noted that no distinction was made to participants.

The fact that VGPs performed better on the secondary tasks is theoretically significant. This finding supports those of Chiappe et al. (2013), who found that video game training significantly improved performance on the secondary tasks without sacrificing performance on the primary tasks. One explanation for this is that VGPs required less attentional resources to perform the primary tasks and were therefore able to focus on the secondary tasks. Although this is a significant point, it should be noted that one of the primary tasks was the Tracking task, and this is a potential confound for the current study. Thus, as VGPs were already familiar with controlling the joystick from playing video games, they were able to direct more cognitive resources to performing the secondary tasks. This is supported by the finding that VGPs performed significantly better than NVGPs on the Tracking task in both sessions of the MATB-II. All NVGPs reported that they were unfamiliar with using the joystick and it is likely that this required most of their attention whilst performing the task, especially as the joystick target was located in the centre of the screen, making it the primary visual focus. It is suggested that future research should use the option already available in MATB-II to turn off the Tracking task in order to remove any potential confounds.

Interestingly, the MANOVA of MATB-II performance in session 1 revealed no significant difference between the two groups, whilst in session 2 there was a significant difference. Although not related to fatigue, these results indicate that VGPs may be faster learners than NVGPs. Bavelier et al. (2012) proposed that the main advantage of regular action video game playing is an increased ability, referred to as 'learning to learn'. Although both groups demonstrated significant improvements from session 1 to session 2, VGPs performed significantly better than NVGPs in session 2. However, these results from session 2 should be interpreted with caution; the confound of the Tracking task remains; VGPs were only significantly better on three of the eight measures (including the Tracking task); and the group x session interaction of the doubly multivariate profile analysis was not significant, indicating that both groups experienced similar learning effects.

Most research in the video game field classifies VGP experts as individuals who have played approximately 4 hours of action video games per week over the previous 6 months. As previously discussed, this is an inadequate criterion for classifying individuals as 'experts'. In addition, there is no evidence that playing video games for this amount of time is sufficient to become an expert (Latham, Patston, & Tippett, 2013a). The present study used video game performance in conjunction with self-report measures to classify participants as either VGPs or NVGPs. Importantly, when participants were only grouped according to the amount of action video game experience they had, there was a significant difference in video game performance between the two groups. Thus, this is the first study to provide statistical evidence to support the use of self-report measures in classifying individuals as either VGPs or NVGPs. Whilst further investigation is needed into the specific requirements of becoming a video game expert, research that only uses self-report measures to classify participants should not be discounted, on the proviso that VGPs are referred to as having more 'video game experience', rather than as 'video game experts'.

The present study is not without its limitations. As discussed above, it was difficult to recruit participants who solely played first-person shooter video games, thus the conclusions drawn here are in relation to the broader category of action video games. The lack of significant differences between VGPs and NVGPs may be due to the possibility that not all action video games induce the same cognitive benefits as FPS games. Investigation of this possibility however, is still in its early stages (Oei & Patterson, 2015). In addition, the groups were not balanced with regards to age and sex, and so these variables are possible confounds to the between group differences.

In conclusion, action video game players experienced similar levels of cognitive fatigue compared to non-video game players. Although VGPs demonstrated superior sustained attention performance compared to non-video game players at the multivariate level, the performance of both groups significantly declined over time. In addition, VGPs were significantly better at multitasking compared to NVGPs and appeared to be faster learners. Finally, the results of the present study reveal that although action video game experience improves sustained attention and divided attention performance, it does not assist with resisting the effects of cognitive fatigue.

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