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Cognitive pitfall! Videogame players are not immune to dual-task costs

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Abstract With modern technological advances, we often find ourselves dividing our attention between multiple tasks. While this may seem a productive way to live, our attentional capacity is limited, and this yields costs in one or more of the many tasks that we try to do. Some people believe that they are immune to the costs of multitasking and commonly engage in potentially dangerous behavior, such as driving while talking on the phone. But are some groups of individuals indeed immune to dual-task costs? This study examines whether avid action videogame players, who have been shown to have heightened attentional capacities, are particularly adept multitaskers. Participants completed three visually demanding experimental paradigms (a driving videogame, a multiple-object-tracking task, and a visual search), with and without answering unrelated questions via a speakerphone (i.e., with and without a dual-task component). All of the participants, videogame players and nonvideogame players alike, performed worse while engaging in the additional dual task for all three paradigms. This suggests that extensive videogame experience may not offer immunity from dual-task costs.

Keywords Divided attention · Inattention · Dual-task performance · Multisensory processing · Video games

To be more productive, we often rely on technological advances that enable us to do multiple tasks at one time. People will engage in such multitasking even in potentially dangerous situations. For example, many drive while talking on a cell phone, despite this being as detrimental as drunk driving (Strayer, Drews, & Crouch, 2006) and a general source of performance costs (e.g., Caird, Willness, Steel, & Scialfa, 2008; Farmer, Braitman, & Lund, 2010; Strayer, Drews, & Johnston, 2003).

Why do people drive while talking on the phone, given the dangers (e.g., Hendrick & Switzer, 2007; Strayer & Johnston, 2001)? One possibility is that they are not aware of the dangers, especially with misconceptions over hands-free versus hand-held phones; laws that require the use of hands-free technology suggest that the problem is primarily manual rather than attentional. Another possibility is that, since most people multitask in many aspects of their lives with no (noticeable) costs, they may believe that they are immune to such costs. And, in fact, some people might actually be immune: A recent study found 2.5 % of the participants to be "supertaskers"—that is, individuals who were not affected by dual-task costs when performing a simulated driving task (Watson & Strayer, 2010). There may be a lucky few who can successfully drive while distracted, but what about the rest of us? What does this mean for the estimated ~65 % of Americans who regularly

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engage in phone conversations while on the road (Braitman & McCartt, 2010)? Are there any other groups of people who may be immune to dual-task costs?

A candidate group that might demonstrate dual-task immunity is avid action videogame players (VGPs). As compared to nonplayers (NVGPs), VGPs have greater visual acuity (Green & Bavelier, 2007) and contrast sensitivity (Li, Polat, Makous, & Bavelier, 2009), and more accurate multisensory discriminatory capabilities (Donohue, Woldorff, & Mitroff, 2010). Furthermore, VGPs are better able to track multiple moving objects (Green & Bavelier, 2006) and to divide their attention (e.g., Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994; Maclin et al., 2011). Moreover, some VGP benefits may stem from improved top-down cognitive control (Chisholm, Hickey, Theeuwes, & Kingstone, 2010) and strategy choices (Clark, Fleck, & Mitroff, 2011). Given that benefits such as these appear to manifest as generalized learning effects from merely playing games (e.g., Green & Bavelier, 2003), might VGPs have generally boosted abilities and be immune to dual-task costs? To test this, we had participants complete three experimental paradigms (a videogame-based driving paradigm, multiple-object tracking, and a non-computer-based image search) with and without a concurrent distracting task.

Method

Participants

A group of 60 individuals from the Duke University community (age: *M* = 20.2 years, *SD* = 3.5; 52 males, eight females) completed three experimental paradigms. The data from six additional participants were excluded because they were less than 25 % accurate on the baseline trivia. The participants then completed a questionnaire on videogame experience after the experiment. The VGPs[1] (*N* = 19, no females) were those who had actively played first-person shooter (FPS) games for the past 6 months (*M* = 3 h/week), who rated their FPS videogame expertise as average or above average, and who had played 5+ h/week of FPS games at another point in their lifetime. NVGPs (*N* = 26, 19 males, seven females) were those who had not played FPS games within the past 6 months, who had never played FPS games 5+ h/week, and who rated their expertise at FPS games as below average. The remaining participants (*N* = 15) had gaming experience between these extreme criteria. Female participants were included in the NVGP group because there were no a priori expectations of gender differences for any of the paradigms, because other recent studies have included female participants in NVGP groups (Bergstrom, Howard, & Howard, 2012; Cain, Landau, & Shimamura 2012), because female participants have revealed videogame training benefits similar to those of males (e.g., Green & Bavelier, 2006), and because it is hard to find male NVGPs.

Single- and dual-task components

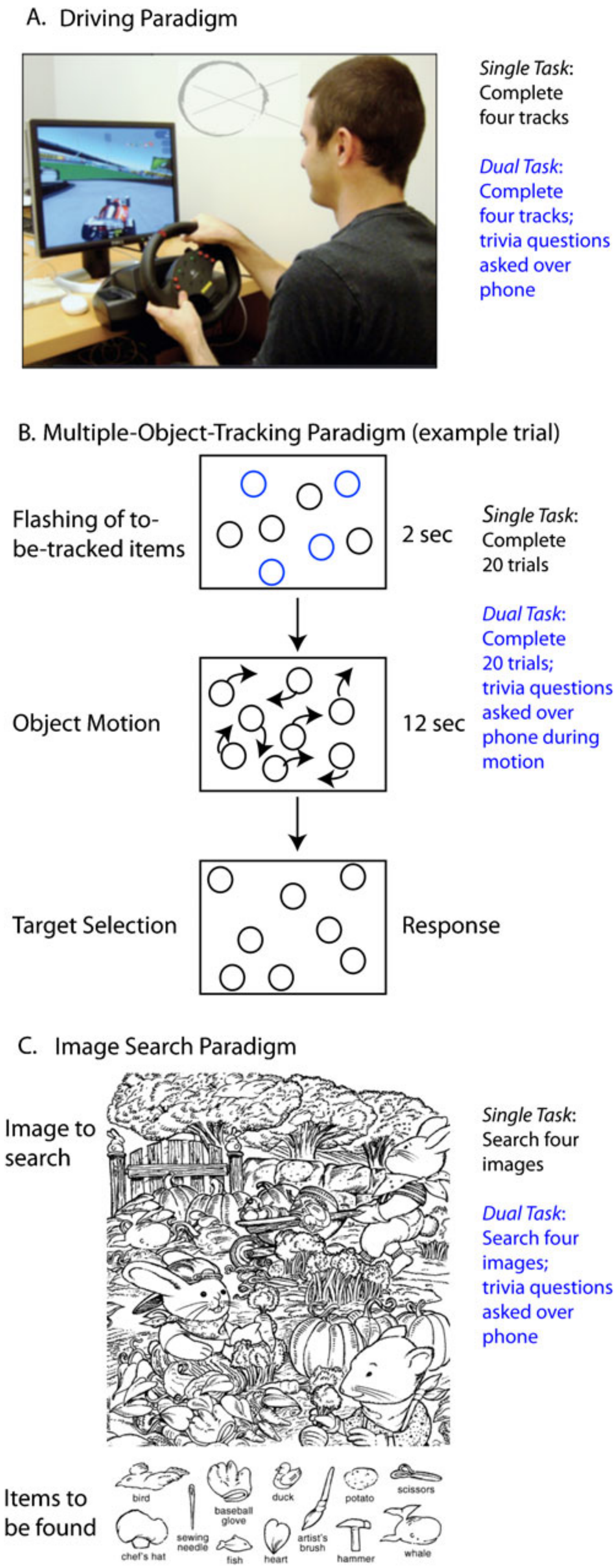
Each paradigm was conducted in a single- and a dual-task phase, and the orders of the paradigms and of the single versus the dual task in each were randomized and counterbalanced across participants. The dual tasks required participants to answer trivia questions (asked by an experimenter in another room) over a speakerphone, and the single tasks consisted of the same paradigms without the questions. The questions were from *Trivial Pursuit* (Genus II and Pop Culture editions) and had been prescreened with an additional ten participants; 196 questions that had been answered with 50 % – 90 % accuracy were used. Questions were randomly selected for the paradigms, as well as for a baseline accuracy assessment at the start of the experiment, in which participants answered 20 trivia questions over a speakerphone.

If a question was not answered within 5 s, it was counted as incorrect. The participants were told to guess if they did not know the answer, and no feedback was provided. Their responses were audio-recorded for verification. Across paradigms, each participant always completed the single-task component first or second (order counterbalanced across participants).

Driving paradigm

Nine tracks (eight test and one practice) created with TrackMania Nations were presented on a 21-in. LCD monitor at a distance of ~57 cm (Fig. 1A). Participants used a Logitech Moma Racing Wheel with accelerator and brake pedals. Each track was created to contain four obstacle areas with poles in the road or protruding walls, and all tracks were of approximately equal length. The participants were instructed to complete each track as quickly as possible while avoiding walls and obstacles (as if actually driving). The practice track provided 5 min of familiarization, and then the eight test tracks were randomly assigned, for each participant, as four single- and dual-task trials. For the dual task, participants answered questions for the duration of each trial. The trials were digitally recorded and later

[1] Most participants were recruited on the basis of prior access to their gaming experience (e.g., through a survey for a psychology course). They were not told that they were recruited due to their gaming experience, and their VGP status for the purposes of the present study was based on the postexperiment questionnaire. Other participants were recruited via flyers and a participation website, without any mention of gaming, and their gaming experience was assessed after the study.



◀ **Fig. 1** Paradigms. (**a**) Depiction of the driving paradigm. Participants navigated tracks created with Trackmania Nations: four with and four without answering trivia questions over a speakerphone. (**b**) Schematic depiction of a multiple-object-tracking trial. At the start of each trial, four target dots flashed three times, and then all eight dots moved for 12 s. After the motion, the participants were to click on the four target dots. For the dual-task component, trivia questions were asked during the motion. (**c**) Sample image-search trial (reproduced with permission from Highlights for Children, Inc.). Participants viewed the to-be-found items (bottom) for 30 s and then had 1 min to find the items within the scene. For the dual-task component, trivia questions were asked during the 1-min search period

scored by individuals blind to both condition and gaming status for driving speed and errors (numbers of walls and obstacles hit).

Multiple-object-tracking paradigm

The stimuli (eight identical white dots, diameter = 0.5 °) were presented with Psychophysics Toolbox (Brainard, 1997) using MATLAB, on a Dell Dimension E250 computer with participants seated ~57 cm away. In each trial, four target dots flickered (disappeared and reappeared three times), and then all dots moved around the screen. The participants tracked the motion of the target dots and used the mouse to click on each of them at the end of 12 s of motion (Fig. 1B). The dots changed color after each response to indicate accuracy (green = correct, red = incorrect). Because VGPs have heightened capacity in this paradigm (Green & Bavelier, 2006), we equated initial performance in order to best assess dual-task costs. The participants completed a 20-trial staircase protocol that titrated the speed of the dots' motion to achieve 80 % accuracy. The average speed of the final three trials of each participant's titration block was used as the speed for the subsequent blocks. There were no differences in final speed between the VGPs and NVGPs [$t(43) = 0.81$, $p = .330$]. After titration, the participants completed single-task and dual-task blocks of 20 trials each. For the dual-task trials, the participants answered two trivia questions during each 12-s motion period.

Image-search paradigm

This paradigm was performed on paper, to test the VGPs in a non-computer-based setting. Ten black-and-white images obtained from *Highlights for Children* magazine (Fig. 1C) consisted of to-be-found items hidden among a scene. For each scene, the participants were given 30 s to familiarize themselves with the items and then 1 min to search the scene with the to-be-found items still visible. For the dual-task component, trivia questions were asked during the 1-min search period. The participants completed two practice images and then four single-task and four dual-task images (the images were randomly selected for each component for each participant).

Results

All Participants (N = 60)

To first assess general dual-task costs across the population, the data from all 60 participants were analyzed. VGP- and NVGP-specific data are reported in the subsequent section.

Trivia Our primary focus was on task performance, and the trivia questions served as a means of inducing a dual task. Nonetheless, it was important to determine the impact of the dual-task activities on the trivia performance (see Table 1), so baseline trivia accuracy was compared to the accuracy in each paradigm. With a multiple-comparisons correction (Bonferroni) α of .017, there were marginal decreases in performance as compared to baseline for the driving [$t(59) = 2.32$, $p = .024$] and image-search [$t(59) = 2.46$, $p = .017$] paradigms, but not for multiple-object tracking [$t(59) = 1.62$, $p = .112$].

Single- versus dual-task comparisons The primary dependent measures for each paradigm were compared as a function of single versus dual tasks,[2] and each revealed dual-task costs (Fig. 2A).

1. *Driving paradigm:* Driving time significantly increased for the dual-task tracks ($M = 111.81$ s, $SD = 16.70$) as compared to the single-task tracks ($M = 105.75$ s, $SD = 22.13$) [$t(59) = 2.38$, $p = .021$], while driving errors decreased from the single-task ($M = 3.34$, $SD = 3.10$) to the dual-task ($M = 2.52$, $SD = 2.84$) condition [$t(59) = 3.63$, $p = .001$].
2. *Multiple-object tracking:* Tracking accuracy was significantly worse in the dual-task condition ($M = 79.58$ %, $SD = 8.58$ %) than in the single-task condition ($M = 82.77$ %, $SD = 7.25$ %) [$t(59) = 3.54$, $p = .001$].
3. *Image search:* Fewer images were found in the dual-task condition ($M = 5.37$, $SD = 1.64$) than in the single-task condition ($M = 6.96$, $SD = 1.69$) [$t(59) = 7.18$, $p < .001$].

Videogame player (N = 19) versus nonvideogame player (N = 26) analyses

Trivia The impact of the dual task on the trivia performance was analyzed for VGPs and NVGPs (Table 1). There was no difference in baseline trivia accuracy between VGPs and NVGPs [$t(43) = 0.82$, $p = .422$]. For each task, an analysis of variance (ANOVA) was run with Gaming Status as a between-subjects factor (VGP vs. NVGP) and Trivia Condition as a within-subjects factor (baseline vs. concurrent with task).

1. *Driving paradigm:* There were no significant differences between the groups ($F < 1$), no interaction ($p > .2$), and only a trend toward a decrease in accuracy for the driving trivia as compared to the baseline trivia condition [$F(1,\ 43) = 3.21,\ p = .080,\ \eta_p^2 = .07$].
2. *Multiple-object tracking:* We found no main effects, and the factors did not interact (ps > .1).
3. *Image search:* There was a significant decline in image-search trivia performance as compared to baseline [$F(1,\ 43) = 5.24,\ p = .027,\ \eta_p^2 = .11$], but no significant main effect of gaming, and gaming did not interact with task (Fs < 1).

Single- versus dual-task comparisons For the comparisons below, separate ANOVAs with Gaming Status as a between-subjects factor (VGP vs. NVGP) and Task as a within-subjects factor (single vs. dual) were conducted. We were specifically focused on any interactions between gaming status and task type to determine whether VGPs and NVGPs were differently affected by dual-task demands.

1. *Driving paradigm:* Driving time revealed marginally slower speeds in the dual-task condition [$F(1,\ 43) = 2.96,\ p = .093,\ \eta_p^2 = .06$] and that VGPs completed the tracks in less time than did NVGPs [$F(1,\ 43) = 5.61,\ p = .022,\ \eta_p^2 = .12$], but we found no interaction between gaming status and task [$F(1,\ 43) = 1.69,\ p = .201,\ \eta_p^2 = .04$]; Fig. 2B]. A separate ANOVA for driving errors (number of wall and obstacle hits) revealed a main effect of task [$F(1,\ 43) = 6.41,\ p = .015,\ \eta_p^2 = .13$], with more errors in the dual-task ($M = 3.42$, $SD = 3.45$) than in the single-task ($M = 2.71$, $SD = 3.18$) condition, but neither a main effect of gaming nor an interaction between the factors was present (Fs < 1).
2. *Multiple-object tracking:* We did find a main effect of task, with lower accuracy in the dual task [$F(1,\ 43) = 8.39,\ p = .006,\ \eta_p^2 = .163$], but no main effect of gaming status nor an interaction (Fs < 1).
3. *Image search:* A main effect of task emerged, with participants finding fewer images in the dual-task condition [$F(1,\ 43) = 32.67,\ p.001,\ \eta_p^2 = .43$], but there was no main effect of gaming status nor an interaction (Fs < 1).

[2] There was an a priori expectation of dual-task costs for each paradigm, so we did not correct for multiple comparisons.

Table 1 Mean (and standard deviation) data for trivia accuracy for all participants—videogame players and nonvideogame players—for the baseline, driving, multiple-object-tracking, and image-search tasks

Paradigm	All Participants (N = 60)	Videogame Players (N = 19)	Nonvideogame Players (N = 26)
Baseline	56.74 % (16.25 %)	53.73 % (16.70 %)	57.71 % (15.58 %)
Driving	52.58 % (16.03 %)	52.55 % (16.53 %)	51.37 % (17.25 %)
Multiple-object tracking	53.66 % (17.31 %)	52.32 % (14.03 %)	52.22 % (20.14 %)
Image search	52.48 % (16.96 %)	48.53 % (17.00 %)	52.92 % (17.27 %)

Discussion

In the present study, we examined whether VGPs would be less susceptible to dual-task costs than NVGPs. Our participants completed three attentionally demanding paradigms, each with and without a distracting dual-task component. All of the participants, VGPs and NVGPs alike, performed worse during the dual-task condition, and there were no differences in how the VGPs and NVGPs were affected. These findings suggest that while some cognitive skills obtained from extensive gaming may be transferrable (see Bavelier et al., 2011; Green & Bavelier, 2012), under cases of high attentional demand across modalities, VGPs can be just as hurt as NVGPs.

These results both complement and challenge previous findings, making it necessary to address several possible concerns. First, the trivia questions were designed to keep participants engaged in the dual task rather than to mimic a phone conversation. That said, the costs were similar to those reported elsewhere (Drews, Pasupathi, & Strayer, 2008). Second, although the analyses including all participants revealed dual-task costs for all three paradigms, the analyses limited to just VGPs and NVGPs revealed only a marginal difference for the driving paradigm. The change for this one paradigm was likely due to reduced power in the more limited sample. Importantly, however, the interaction between gaming status and task was not significant, indicating that all participants took more time to complete the tracks in the dual-task condition.

Third, participants were slower in the dual-task condition of the driving paradigm and were also less error-prone (hitting fewer walls and obstacles). This speed–accuracy

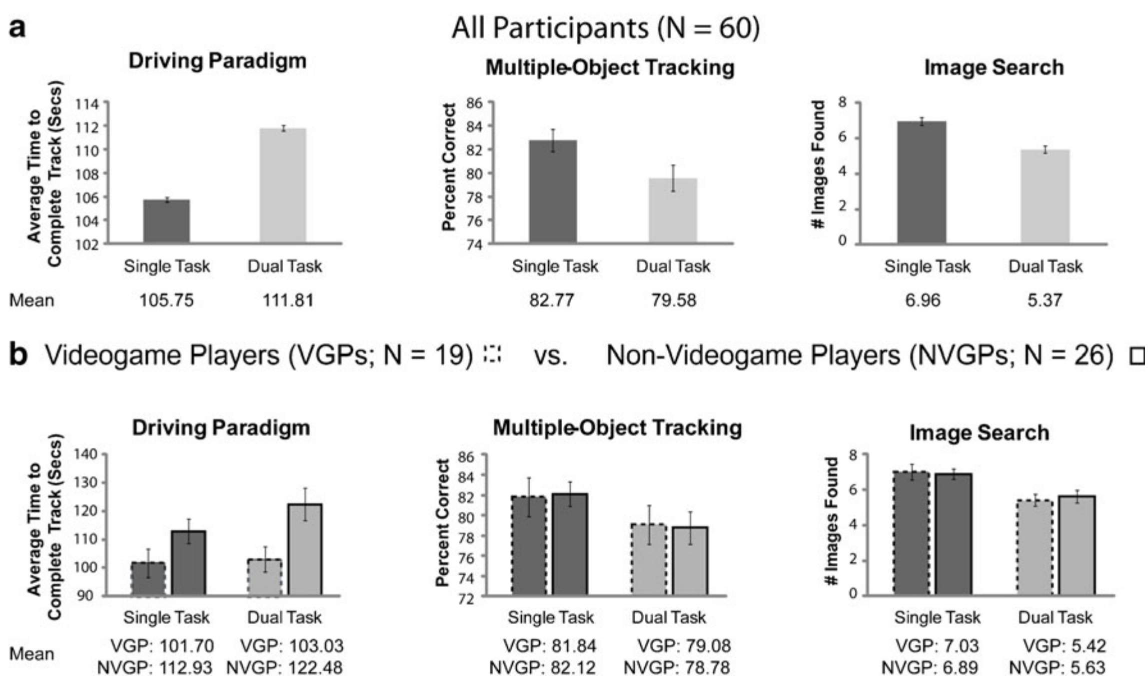


Fig. 2 Dual-task effects. (**a**) Data for all 60 participants for the driving, multiple-object-tracking, and image-search paradigms. Each paradigm revealed a significant performance decrement (see the text for statistics) in the dual-task condition as compared to the single-task condition. (**b**) Performance of VGPs (N = 19, bars with dashed outlines) versus NVGPs (N = 26, bars with solid outlines), as a function of single versus dual task. The error bars represent *SEM*s

trade-off is an interesting outcome, but one that is orthogonal to the present goals and claims; no matter the interpretation, these results reveal a difference between the single- and dual-task conditions, and that this difference is equally manifested for VGPs and NVGPs. While one could argue that this may be a beneficial outcome for driving (slower and more accident-free), it is important to note that obstacles in this situation were visible for a great distance before they were approached, whereas obstacles often emerge suddenly in actual driving.

Fourth, several factors suggest that our participant groups were properly classified as VGPs and NVGPs and were run without possible biases: (1) Our inclusion criteria were conservative and relied on factors including expertise and gaming experience. (2) The VGPs completed the tracks in the driving paradigm (a videogame) significantly faster than the NVGPs did. (3) We administered the videogame questionnaire *after* the study so as to avoid highlighting videogame experience, in order to reduce concerns over motivational differences.

Fifth, it is intriguing that VGPs were hurt just as much as NVGPs in the dual-task conditions in the image search and multiple-object-tracking paradigms, given previous findings of enhanced attention for VGPs (e.g., Green & Bavelier, 2006). One possible explanation lies in the modalities tested. While recent work has indicated that VGPs have more rapid discrimination capabilities within (Green, Pouget, & Bavelier, 2010) and across (Donohue et al., 2010) visual and auditory modalities, it is not known how these unimodal benefits persist when attention is divided over modalities. VGPs' heightened visual attention may come at the expense of the attentional resources available to other modalities (e.g., audition), and such costs may only emerge in paradigms with which the VGPs have not had previous experience. The extent to which videogames affect cognition is under debate (see Bavelier et al., 2011; Boot, Blakely, & Simons 2011), and the present results reveal that VGPs do not exhibit a universal attentional benefit. While research has shown generalized learning benefits from videogame exposure (e.g., Green & Bavelier 2003), these results show that there are indeed limits to these benefits, particularly when it comes to processing stimuli from different modalities and/or in situations of high attentional demand.

Finally, it is interesting to consider the present results in light of "supertaskers"—that is, individuals immune to dual-task costs (Watson & Strayer, 2010). While none of our participants met the supertasker criteria (see Watson & Strayer, 2010), the VGPs were intuitive candidates. Yet we nonetheless found that they were affected by dual tasks. The means of defining VGPs and supertaskers may offer insight: VGPs are categorized on the basis of videogame exposure over an extended time, and supertaskers are defined on the basis of superior performance in one testing session (Watson & Strayer, 2010). Moreover, NVGPs who undergo action videogame training can show VGP-like benefits (see, e.g., Green & Bavelier, 2003; but see Boot, Kramer, Simons, Fabiani, & Gratton, 2008), suggesting a causal effect of videogame exposure. Much remains unknown about supertasking (e.g., is it a long-term trait?), so further work will be needed for clarification.

The present results inform the nature of both cognition and society more broadly, where multitasking is widespread. Within the field of visual cognition, there are general consensuses that dual-task costs exist and that VGPs can possess performance benefits. In the present study, however, we demonstrated clear multitasking costs for both VGPs and NVGPs. This result demonstrates just how detrimental a concurrent distracting task can be. Combined with other, previous evidence (Caird et al., 2008), this highlights how important it is for society to understand the limits of attentional processing.

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