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The Association between Media Multitasking, Task-Switching, and Dual-Task Performance.

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Abstract

The recent rise in media use has prompted researchers to investigate its influence on users' basic cognitive processes, such as attention and cognitive control. However, most of these investigations have failed to consider that the rise in media use has been accompanied by an even more dramatic rise in media multitasking (engaging with multiple forms of media simultaneously). Here we investigate how one's ability to switch between two tasks and to perform two tasks simultaneously is associated with media multitasking experience. Participants saw displays comprised of a number-letter pair and classified the number as odd or even and/or the letter as a consonant or vowel. In task-switching blocks, a cue indicated which classification to perform on each trial. In dual-task blocks, participants performed both classifications. Heavy and light media multitaskers showed comparable performance in the dual-task. Across two experiments, heavy media multitaskers were better able to switch between tasks in the task-switching paradigm. Thus, while media multitasking was not associated with increased ability to process two tasks in parallel, it was associated with an increased ability to shift between discrete tasks.

As technology has become more readily accessible and mobile, media use has increased dramatically. For example, in the past decade the amount of time US youth spend interacting with media has increased by about 20% to 8 hours per day (Rideout, Foehr, & Roberts, 2010). The ubiquitous use of media has also become a global phenomenon, involving individuals of all ages and occupations (Rogers, 2009). It has permeated the workplace and the classroom alike, and has transformed the way in which we interact and communicate (Benson, Johnson, & Kuchinke, 2002; Duhaney, 2000).

This rise has prompted concern about the impact that media use is having on user's mental health and brain function. This concern is buttressed by work demonstrating that prolonged exposure to an environment (Blakemore & Van Sluyters, 1975) and learning new skills (Draganski & May, 2008) can lead to dramatic cortical reorganization. Although research has not yet fully addressed whether media use is impacting mental health and cognition, initial reports suggest that this concern may be valid (Biocca, 2000). In the mental health field, it has been suggested that heavy media use is associated with decreased social well-being and impaired psychosocial functioning (Moody, 2001; Kraut, et al., 1998). Research in the education domain has found evidence that media use is impacting the way students process information and learn (Prensky, 2001).

In addition, researchers in the cognitive domain suggest that extensive exposure to media and technology use are influencing basic cognitive processes. For instance, some argue that technologies such as mobile devices and vehicle navigation systems are lowering the need for human memory and spatial skills, thus reducing the cognitive effort required to complete daily tasks (Rogers, 2009). Recent work has suggested that the internet is becoming a primary form of external memory, thereby changing the way our brains remember information (Sparrow, Liu, &

Wegner, 2011). Furthermore, several reports have provided evidence that the habitual use of one form of media, video games, can influence performance on a range of cognitive tasks and alter visual attention processes (Green & Bavelier, 2003). In short, a number of findings indicate the pervasive use of media may have profound influences on media users.

To date, most of the research investigating the influence of media use on users has focused on the absolute amount of time spent with media, thereby ignoring a major trend that has accompanied the rise in media use: the simultaneous use of several media forms. While absolute time spent with media has increased, time spent multitasking with media has grown even more rapidly. Within the past decade, there has been a 120% increase in the time that youth between the ages of 8 and 18-years-old media multitask (Rideout, Foehr, & Roberts, 2010). This rapid increase in multitasking with media raises the question of whether this method of interacting with media may be influencing users' mental health and cognitive systems.

The few reports that have investigated the specific effect of media multitasking suggest that media multitasking is uniquely impacting both mental health and cognitive processes. In terms of mental health, a recent report suggested that multitasking with media is associated with higher symptoms of depression and social anxiety, even after accounting for overall media use (Becker, Alzahabi, & Hopwood, 2012). Also, increased media use, and particularly media multitasking, is associated with negative social well-being in young girls (Pea et al., 2012). In terms of cognitive processes, multitasking with media, particularly instant messaging, was found to have detrimental effects on academic performance in college students (Junco & Cotten, 2010); and people who frequently multitask with media have been reported to have a decreased ability to effectively filter irrelevant information (Ophir, Nass, & Wagner, 2009).

In one of the few laboratory-based investigations of the association between media multitasking and cognition, Ophir, Nass, & Wagner (2009) found that heavy media multitaskers had difficulty switching back and forth between tasks in a commonly used task-switching paradigm. In the number-letter task-switching paradigm used by Ophir et al. (2009), participants were presented with a number-letter pair and had to classify either the number (as even or odd) or the letter (as a consonant or vowel). A cue informing participants about which classification to perform was presented just before the stimuli appeared on each trial. In some trials, the classification required was identical to the previous trial (a repeat trial), and in other trials, the classification was different from the previous trial (a switch trial). In this task, people generally take longer to perform the classification for switch trials than repeat trials, presumably because switch trials require one to mentally reconfigure the task set involved (Monsell, 2003).

Using this task, Ophir and colleagues (2009) found that heavy media multitaskers showed an even greater task-switching cost than light media multitaskers. They suggested that this finding was counter-intuitive and striking, since it would imply that extensive practice with switching (between forms of media, in this case) produces a reduction, rather than a boost, in task-switching ability. One possible explanation of this counter-intuitive claim is to posit that frequent practice with multiple streams of media improves users' ability to process streams of information in parallel, reducing the need for switching. This view is consistent with some recent work documenting a small population of "super-taskers" who are able to simultaneously drive and converse on a cell phone without showing any deficits (Watson & Strayer, 2010).

This explanation suggests that media multitasking is akin to practicing parallel processing rather than task-switching. If so, there would be no reason to believe that heavy media multitaskers should show fewer task-switching costs, and might, in fact, show increased task-switching costs in a lab-based task-switching paradigm. In the task-switching paradigm, two stimuli are presented, but the participant must respond to only one of the items. Processing the irrelevant item may require the inhibition of the irrelevant item in order to decide which response to make or may produce response conflict (particularly on incongruent trials in which the two stimuli are mapped to opposite button presses). Under either of these scenarios, one would expect greater task-switching costs for people who have increased ability to process both tasks in parallel. If this explanation is correct, heavy media multitaskers might show increased task-switching costs because they are processing both tasks in parallel, leading to response conflict. At the same time the explanation predicts that heavy media multitaskers should actually perform better in a dual-task paradigm, in which they are asked to classify both stimuli.

If heavy media multitaskers are able to perform dual-tasks more efficiently and only show deficits in a task-switching paradigm, then we would have support for the conclusion that extensive dual-task practice can lead to the ability to parallel process. Alternatively, if heavy media multitaskers show a task-switching deficit without a dual-task benefit, it would add additional evidence to Ophir and colleagues' (2009) counterintuitive finding and suggest that extensive practice switching between multiple forms of media leads to an impairment in one's ability to effectively switch attention to the pertinent information for one's current task.

To investigate these possibilities, we designed an experiment in which participants responded to blocks of task-switching and dual-task trials. The task-switch paradigm was similar to that used by Ophir, et al. (2009), in which participants switched between classifying numbers as odd or even and letters as consonant or vowel. Our dual-task paradigm consisted of the same number-letter task, but required participants to perform both classifications on each trial. If media multitasking results in parallel processing, we would expect that multitaskers would show deficits in a task-switching paradigm, but would show better dual-task performance.

Experiment 1

Methods

Participants. Ninety-two[1] university undergraduates (65 females; mean age = 19.6 years) successfully completed both parts of the experiment. They participated for course credit and had normal or corrected-to-normal vision. Approval was obtained from the Michigan State University Institutional Review Board and all participants gave written informed consent.

Measure of Media Multitasking. The Media Multitasking Index (MMI; Ophir, Nass, & Wagner, 2009) was used to assess participants' level of media multitasking. The questionnaire indexes how often a person uses each of 12 forms of media and how often each form of media is used with different forms of media simultaneously (see Appendix A). The 12 different media forms are print media, television, computer-based video, music, non-musical audio, video or computer games, telephone and mobile phone, instant messaging, SMS (text messaging), email, web surfing, and other computer-based applications (such as word processing). Responses to the questionnaire produced a relatively normal distribution (M= 4.07, SD= 1.64, skewness= .87, kurtosis= 1.91), which was verified by a Kolmogorov-Smirnov test of normality, $D(150) = .063$, $p = .20$[2].

Stimuli and Procedure. Data were collected individually in sound-attenuated booths. After completing a computer-based version of the questionnaire, participants completed a behavioral task that consisted of two blocks of trials programmed in E-prime and presented on a 19-inch CRT monitor with a 100 Hz refresh rate. One block consisted of a task-switching procedure and the other block consisted of a dual-task block. The order of block presentation was randomized across participants.

The Task-Switching Block. The task-switching procedure (See Figure 1a) we used was a variation of the number-letter task (Rogers & Monsell, 1995). In this task, a trial consisted of a fixation display (1000 ms) followed by a stimulus display that remained on the screen until participants responded. The stimulus display was comprised of a cue, one number (randomly selected from the set of 2, 3, 4, 5, 6, 7, 8, and 9) and one letter (randomly selected from the set of a, e, i, u, p, k, n, and s). The cue appeared at the location of the fixation point and was flanked by the stimuli, with one appearing 0.84 degrees above the cue and the other appearing 0.84 degrees below it. Whether the number or letter stimulus appeared above the cue was randomized across trials. For each trial, the cue was randomly set to be either the word "number" or "letter," indicating that either the number was to be classified as odd or even or that the letter was to be classified as consonant or vowel. The random selection of a cue on each trial yielded approximately 50% switch trials, in which the type of stimulus to be classified switched between trials from letters to numbers or vice versa, and 50% repeat trials, in which the type of stimulus to be classified stayed the same from one trial to the next. The block was comprised of a practice session (16 trials), followed by 192 task-switching trials, with a participant-terminated rest break half way through the set of trials.

Participants responded by pressing one of four possible response buttons on an E-prime serial response (SR) box. That is, there was a separate button for each possible response (consonant, vowel, odd, and even). Participants sat with their index and middle fingers from both hands over a button. The two responses associated with the letter response were mapped onto a single hand (i.e., the index finger was the “vowel” response and the middle finger of the same hand was “consonant” response) and the two responses associated with the number task were mapped onto the other hand (i.e., the index finger was the “odd” response and the middle finger was the “even” response). Button labels were provided on the bottom of the monitor screen on every trial.

Mapping the four possible responses onto separate buttons is not typical for a task-switching paradigm. We chose this mapping so that the response mapping between stimuli would be identical in the task-switching and dual-task blocks (see below), thereby allowing a more direct comparison of performance on both tasks. In addition, there is evidence for sizeable task switching costs when responses are separated in this fashion, as long as there is a short delay from the cue to the presentation of stimuli (Meiran, 2000). Here the cue and stimuli appeared simultaneously, so we anticipated that there would be sizable task-switching costs even with this method of four-button responding. It is worth noting that this method of responding did, however, eliminate the possibility of incompatible trials (the two stimuli on a given trial mapped to the opposite keys). If the task-switching deficits associated with heavy media multitasking were solely the result of response competition on incompatible trials, eliminating incompatible trials would also eliminate the association[2].

The Dual-Task Block. The dual-task block consisted of 5 miniblocks of trials. The first two and last two were single task miniblocks, in which the item to be classified remained constant throughout the run of 24 trials. One of the first two blocks was a number-only block and the other was a letter-only block and their order was counterbalanced across subjects. Similarly, one miniblock of each classification task occurred during the last two miniblocks. Participants were informed of the classification task and that it would remain constant throughout the mini-block prior to beginning it. These single-task trials allowed us to determine the time required to complete each task when done in isolation. These miniblocks occurred both at the beginning and end of the block to control for any overall speedup in the task that occurred throughout the course of the block.

In the critical 3^{rd} miniblock of trials, the cue was always "both" indicating that participants were to perform a dual-task, classifying both the number and letter in each trial. There were 96 of these dual-task trials.

The displays and response mappings in all of the miniblocks were the same as the displays and response mappings in the task-switching block. The only difference was that the cue remained constant in each of the single-trial miniblocks (either "number" or "letter" for 24 consecutive trials depending on the mini-block) and the cue was always the word "both" in the dual-task miniblock.

Data Preparation. Trials with RTs greater than 5000 ms and less than 200 ms were eliminated from further analysis. We then calculated the mean and standard deviation of correct trial RTs for each subject and eliminated any RTs that were more than three standard deviations from a participant's mean RT.

Results

Switch cost as a function of MMI. Data from participants whose overall accuracy on the task-switching trials was less than 75% (n= 8; mean accuracy = 47%, SE=.017) were eliminated from further analyses. Mean accuracy of the remaining subjects was 96.2% (SE= .5%). Four additional participants' data were eliminated from analysis, two for exhibiting large negative switch costs (more than 50 ms faster on switch than repeat trials), one for having an extremely high MMI score (11.34), and one for having an extremely large switch cost (610ms). This left 80 participants in the final data analysis. Each participant's mean RT was calculated for repeat and switch trials. Switch costs were determined by subtracting the mean repeat RT from the mean switch RT.

Average switch cost across participants was 230.15 ms (SE = 25.73ms). Participant switch costs and MMI scores were negatively correlated, r (80) = -.254, p =.023 (see Figure 2a). We also defined two groups, a heavy (upper quartile of MMI scores) and light (lower quartile of MMI scores) media multitasking group, and performed a 2 (group) X 2 (Trial type: Switch/Repeat) mixed model ANOVA. There was a main effect of Trial Type, $F(1, 38)$ = 118.76, p <.001, with faster response times for repeat trials (M = 1307.11, SE = 40.07) than switch trials (M = 1532.14, SE = 49.52). There was no main effect of group, $F < 1$, but there was a significant group by trial type interaction, $F(1, 38) = 5.88$, $p = 0.020$. The interaction (see Figure 2b) resulted because both groups performed equally quickly in the repeat trials, but the heavy media multitaskers showed less slowing in the switch trials.

We also calculated mixing costs (Rubin & Meiran, 2005) by subtracting each subject's mean RT for the four single-task blocks in the dual-task part of the experiment from the mean RT for repeat trials. Our participants showed large mixing costs (M = 480.50, SE = 27.52); however these mixing costs were not related to MMI scores, $r(80) = .009$, p = .94 in the full sample. Similarly, there was not a significant difference in mixing cost when one compared the mean mixing cost for the heavy MMI group (M = 469.56, SE = 56.41) to the light MMI group (M= 518.32, SE = 49.38), $t(38) = .65$, $p = .52$.

Dual cost as a function of MMI. Data from participants whose overall accuracy on the dual-task trials was less than 75% (n= 9) were eliminated from further analyses. Mean accuracy of the remaining subjects was 92.3% (SE= .6%). Two bivariate outliers were eliminated based on a Mahalanobis distance > 16 (critical value of 13.82, p < .001). Data analysis was based on the remaining 81 participants.

To evaluate the relationship between MMI and performance in the dual-task, we correlated MMI scores with a number of measures of dual-task performance. For each subject we calculated the mean time of the first response (RT_1), the second response (RT_2), and the response in the single task blocks (RT_{Single}). We also calculated a dual-task cost by comparing the time required to execute both responses minus two times the time to respond in the single-task blocks (RT_2- $2RT_{Single}$). Finally we calculated the lag between the two responses in the dual-task trials (RT_2- RT_1). While all these measures of dual-task performance were related to one another (see Table 1), none of them were related to MMI score, all p >.40. Out of due diligence, we also performed group analyses comparing performance on each of the dual-task measures between the heavy MMI and light MMI groups. None of these comparisons approached significance, all $t(42) < .4$, all $p > .7$.

Discussion

We assumed that we would replicate Ophir, Nass, and Wagner's (2009) finding that heavy media multitasking would be associated with worse task-switching performance, and we predicted that these task-switching deficits might be associated with better dual-task performance. Instead, we found that heavy media multitaskers showed significantly better task-switching performance, failing to replicate Ophir et al. (2009). In addition, we failed to find any relationship between media multitasking and dual-task performance. The most straightforward interpretation of this pattern of results is that rather than becoming efficient parallel processors, our heavy media multitaskers had acquired abundant practice switching back and forth between tasks and this practice allowed them to refine this task-switching skill. This extensive practice with task-switching has little effect of their ability to perform a dual-task, but allows them to rapidly reconfigure to a new task and/or more completely inhibit the old task, resulting in fewer task-switching costs.

In addition, our finding that decreased switch costs were caused almost exclusively by faster reaction times in the switch trials, rather than slower responses in repeat trials, provides additional evidence that the media multitaskers are more rapidly reconfiguring their task set. If multitaskers were simply keeping both tasks more active, then one might have expected more interference from the irrelevant task even during repeat trials. While Ophir, et al. (2009) found slower responses in repeat trials for their heavy MMI participants, we found no evidence for this. Instead, our data suggest that media multitaskers are able to more rapidly and/or completely switch to the new task, thereby limiting switch costs.

Further support for the conclusion that multitasking is uniquely associated with the task reconfiguration aspect of the task-switching paradigm is provided by our finding that mixing costs are unassociated with multitasking. Mixing costs represent a generalized slow down for responses in mixed trial blocks, relative to single trial blocks, that are thought to impact repeat and switch trials equally. This slow down results from the increased task uncertainty or task ambiguity present in mixed blocks (Rubin & Meiran, 2005). We found that multitasking was unassociated with the ability to cope with this ambiguity or uncertainty. Instead, media multitasking was only associated with a better ability to reconfigure tasks when a task-switch was required.

In addition, we found no relationship between MMI and dual-task performance. If during the dual-task condition, people performed one task then switched to the other, one might have expected that heavy media multitaskers' increased ability to shift between tasks would also produce improved performance in the dual-task condition. However, the reconfiguration stage associated with task-switching is presumably only one of many components that contribute to the overall RT. For instance, processes such as the perception of the stimuli, the response selection, and response execution will also contribute to the overall RT and can contribute variability to the RT measure, which will decrease the correlation. The more complex dual-task required two perceptual, response selection, and response production stages. Thus, it includes additional sources of variability that may obscure any possible correlation between media multitasking and dual-task cost. Increased variability in the RT is particularly likely for the type of dual-task scenario we used in which the order of responding was not set, but rather was a choice that the participants must make (Sigman & Dehaene, 2006). Finally, it is worth noting that the dual-task costs we report (RT_2- $2RT_{Single}$) were positive values. This finding is inconsistent with much of the psychological refractory period work investigating dual-task performance, and suggests that the two tasks are interfering with one another, eliminating any benefit that may have been caused by an ability to processes aspects of the two tasks in parallel. This interference may have resulted because both tasks required similar manual responses (Pashler, 1990) or because the participants had to decide the order of responses (Sigman & Dehaene, 2006).

In short, while the finding of no relationship between MMI and dual-task performance provides evidence that participants who frequently multitask with media have not developed an increased ability to process items in parallel (ie., have not become super-taskers), the dual-task method we used may be too insensitive to provide much insight in the types of task-switching processes that might be associated with heavy media multitasking. A more refined dual-task method such as a Psychological Refractory Period paradigm which systematically varies the stimulus onset asynchrony between the onset of two stimuli in a dual-task situation may be able to shed light on these types of issues, but for now, we will emphasize the more sensitive task-switching method as our preferred method of investigating the relationship between media multitasking and cognitive control.

The task-switching paradigm provided clear evidence that shift costs decrease as MMI increased, but this finding and its implications are extremely different from those of Ophir, et al. (2009). It is important to note that there were a number of methodological differences between our experiment and Ophir et al.'s (2009) that may be responsible for the inconsistent findings. First, we presented the cue and stimulus simultaneously, while Ophir, et al. (2009) separated the presentation by 226 ms. Their method allows for task preparation, which can facilitate performance and may reduce the switch cost (Monsell, 2003). Also, their method requires one to hold the cue in memory because it is not presented while one is performing the task, which can also potentially impact the switch cost. Another source that may influence the switch cost is the presentation of the stimulus itself. While Ophir, et al. (2009) presented the digit and letter components of the stimulus horizontally, adjacent to one another, we presented them above and below the cue. Our method eliminates the possibility of a Simon effect, responses being made more rapidly when the correct response spatially corresponds to the stimulus itself, even when the stimulus location is irrelevant to the task (Simon, 1969). Additionally, Ophir, et al. (2009) controlled the frequency of repeat trials, such that they appeared equally often in sequences of 1, 2, 3, or 4 within each block of trials. This yielded approximately 40% switch trials and 60% repeat trials, while our design of randomly choosing the cue on each trial yielded approximately 50% switch and repeat trials.

Lastly, the number of response buttons differed. Our design used four buttons (i.e., univalent responding), in order to allow direct comparison between the task-switch and dual-task trials, while Ophir et al. (2009) employed a two-button design (i.e., bivalent responding). In the two-button design, two responses correspond to one button (e.g., odd and vowel onto the left button press and even and consonant onto the right button press). On each trial, participants were only responding to either the number or the letter, but the stimuli itself consisted of both a number and a letter. Thus, it is possible to have both congruent and incongruent trials, in that both components of the stimuli are mapped either to the same button press or opposite button presses, respectively. If both components of the stimuli are processed during an incongruent trial, this would likely cause response conflict and slower response times.[3] The four-button design that we used does not have an issue of response congruency, as each possible response activates one and only one button press.

Experiment 2 was designed as direct replication of Ophir, et al. (2009) to investigate whether differences in the experimental design could account for the conflicting results. In addition, the inclusion of the two-button responding method, allows us to determine whether the relationship between media multitasking and task-switching is maintained or reverses when the response mapping allows for incompatible trials and response conflict. If the relationship reverses with this two-button responding, it would resolve the discrepancy between our findings and Ophir, et al.'s (2009).

Experiment 2

Methods

Participants. Fifty-eight[1] university undergraduates (40 females; mean age = 19.5 years) successfully completed both parts of the experiment. They participated for course credit and had normal or corrected-to-normal vision. Approval was obtained from the Michigan State University Institutional Review Board and all participants gave written informed consent.

Procedure. Participants completed the MMI followed by a direct replication of the behavioral task used by Ophir, et al. (2009), which was comprised only of task-switching trials. Except where noted, the methods were identical to those used in Experiment 1. There were 120 practice trials, equally divided among number only, letter only, and switch trials, followed by 240 experimental trials, divided into four blocks of 80 trials (see Figure 1b). First, a cue-stimulus interval of 226 ms was introduced such that the cue and stimulus were temporally separated. A fixation display appeared for 950 ms, followed by the cue for 200 ms, a blank screen for 226 ms, and lastly the stimulus until the participant responded. The digit-letter pair stimulus was presented such that the digit and the letter were adjacent to one another and presented in the center of the screen, at the location of the fixation point. Lastly, we controlled the frequency of repeat trials, such that they appeared in sequences of 1, 2, 3, or 4 within each block of 80 trials. This yielded approximately 40% switch trials and 60% repeat trials. Responding was made on 2 buttons. That is, the “odd” and “vowel” responses were made with the left button press while the “even” and “consonant” responses were made with the right button press. Button labels were not provided on the bottom of the monitor screen and there was no auditory feedback.

Data Preparation. The data preparation was identical to Experiment 1.

Results

Switch cost as a function of MMI. Data from participants whose overall accuracy on the task-switching trials was less than 75% (n= 4; mean accuracy = 59.58%, SE=.05%) were eliminated from further analyses. Mean accuracy of the remaining subjects was 95.37% (SE= .005%). Five additional participants’ data were eliminated from analysis, two for exhibiting large negative switch costs (more than 50 ms faster on switch than repeat trials), one for having an extremely large switch cost (442ms), and two bivariate outliers. This left 49 participants in the final data analysis. Each participant’s mean RT was calculated for repeat and switch trials. Switch costs were determined by subtracting the mean repeat RT from the mean switch RT.

Average switch cost across participants was 93.14 ms (SE = 13.25 ms). Participant switch costs and MMI scores were negatively correlated, $r\,(49) = -.300$, $p = .036$ (see Figure 3a). We also defined two groups, a heavy (upper quartile of MMI scores) and light (lower quartile of MMI scores) media multitasking group, and performed a 2 (group) X 2 (Trial type: Switch/Repeat) mixed model ANOVA. There was a main effect of Trial Type, $F(1, 24) = 29.83$, $p < .001$, with faster response times for repeat trials (M = 872.04, SE = 39.90) than switch trials (M = 958.62, SE = 44.72). There was no main effect of group, $F < 1$, but there was a significant group by trial type interaction, $F(1, 24) = 6.66$, $p = 0.016$. The interaction (see Figure 3b) resulted because both groups performed equally quickly in the repeat trials, but the heavy media multitaskers showed less slowing in the switch trials.

Discussion

In Experiment 2, we performed a direct replication of Ophir, Nass, and Wagner's (2009) task-switching method. Despite the identical methods, we replicated our findings from Experiment 1 that MMI score and task-switching costs were negatively correlated. In addition, our extreme group analysis showed that the two groups did not differ in terms of their reaction times for the repeat trials, but the heavy MMI group responded more rapidly than the light MMI group in the switch trials. In short, we again found evidence that people who frequently multitask with media are able to switch between tasks more efficiently than those who do not frequently multitask with media.

General Discussion

The present research examined the influence of frequent media multitasking on an individual's ability to switch between tasks, in a task-switching paradigm, and perform two simultaneously presented tasks, in a dual-task paradigm. While we found no evidence for a relationship between media multitasking and dual-task performance, we found that media multitasking was associated with an enhanced ability to switch between tasks. This relationship between multitasking and task-switching was present for both univalent responding (Experiment 1) and bivalent responding (Experiment 2). In addition, the reduced task-switching costs were driven by faster responses during task-switch trials, rather than slower responding during repeat trials. Finally, frequent media multitasking was not associated with changes in mixing costs. Taken together this pattern of results suggests that that media multitasking does not interfere with attentional control. Instead, we found clear evidence that it produces a more efficient ability to reconfigure tasks when it is required, as in a task-switch trial.

One interpretation of these results is that frequently multitasking with media provides vast experience alternating between tasks, which results in an ability to rapidly shift between tasks that generalizes to the task-switching paradigm we used. The first part of this interpretation is consistent with recent work demonstrating that simultaneous exposure to multiple forms of media elicits frequent switches between media sources (Brasel & Gips, 2011). However, research suggests that training effects are often very task-specific, potentially raising some doubt about the claim that frequent switching in a multimedia context generalizes to other task-switching contexts.

While the training of cognitive skills has been demonstrated in numerous studies (Bherer et al., 2006; Ho & Scialfa, 2002; Rogers, Fisk, & Hertzog, 1994), research on the transfer of training to untrained cognitive tasks is less consistent. Aside from a few exceptions (Karbach & Kray, 2009; Jaeggi et al., 2008, but also see Redick et al., 2012), the larger majority of research argues against the generalizability and transfer of training (e.g., Healy et al., 2006).   In general, it seems that the success of transfer depends on the amount of similarity in mechanisms recruited in the trained and untrained tasks. Dahlin et al. (2008), for example, argue that the transfer of training is contingent on whether the training and target tasks engage overlapping brain regions and processing components.

Even with these constraints, there are several reasons to believe that extensive media multitasking may generalize to the lab-based task-switching paradigm we used.   First, frequent multitasking with media is not comprised of training with one specific task or stimulus, but instead encompasses a broad range of tasks, types of media stimuli, and occurs in a variety of contexts and situations. The common aspect which is involved in switches that occur across these varied contexts and forms of media is likely to be some form of task reconfiguration. Thus, these forms of media multitasking may involve the same brain regions required to switch between tasks in the lab-based experiment. Second, the recent proliferation of technological devices has allowed the behavior of media multitasking become extremely ubiquitous. Unlike prior studies on the generalizability of training in which participants train in a specific context for relatively minimal time periods, frequent media multitasking is resulting in extensive amounts of media exposure, particularly for the "net generation." Multiple studies have documented the dramatic growth in media multitasking practices (e.g., Carrier et al., 2009; Rideout, Foehr, & Roberts, 2010). Indeed, it has been argued that media multi-tasking is self-reinforcing leading, to more and more pervasive engagement with the activity (Wang & Tchernev, 2012). Thus, for some, media multitasking becomes an extremely frequent activity that is likely to have more dramatic changes on individual's cognition than more lab-based training procedures. Indeed, it is more in line with the type of extensive practice that an expert musician might engage in, a form of extensive practice that has been demonstrated to produce robust changes in cortical organization (Elbert et al., 1995). In sum, media multitasking is a form of behavior that may well lead to expertise in a general form of task-reconfiguration, and thus may generalize to a lab-based task-switching paradigm.

However, it is worth noting that the sheer extent of engagement with media multi-tasking that may make it have such a general impact on cognition, also makes it difficult to manipulate as an experimental variable. Thus, the findings we report are correlational rather than causal. That is, instead of the above explanation that extensive practice causes changes in cognition, it might simply be that those who are able to perform task-reconfiguration more readily are better able to multitask with media, and therefore are the ones who are likely to do so. Establishing the causal direction of this effect will require more extensive training methods, or longitudinal designs. Even so, our results clearly demonstrate that media multitasking is not producing the types of exaggerated task-switching difficulties reported by Ophir et al. (2009).

While we report findings quite different from those reported by Ophir, Nass, & Wagner (2009), we are fairly confident in this result. We replicated the finding with two different samples of subjects, using two different methods, one of which was a direct replication of Ophir, et al. (2009). In addition, a few recent reports provide additional support to our finding that media multitasking is not associated with decreased attentional control. For instance, it was recently reported that heavy media multitaskers have better multisensory integration, which translated to better search performance in the face of distraction (Lui & Wong, 2012. In addition, this view is generally consistent with findings suggesting that action video game players are better at allocating attention, have enhanced visual processing, and increased speed of processing compared to non-video game players (Green & Bavelier, 2003; Green & Bavelier, 2007; Dye, Green, & Bavelier, 2009).

Nevertheless, it is worth speculating about possible explanations for the discrepancy between our results and Ophir, Nass, and Wagner's (2009). It is possible that the nature of media multitasking has changed so dramatically in the few years between studies that its impact on cognition has changed. While it might seem unlikely that such a dramatic shift could occur in such a short period of time, the media landscape has changed extremely rapidly. For instance, in February 2009, about the time when Ophir et al. (2009) were likely to be collecting data, there were an estimated 175 million Facebook users. By February 2011, when we were collecting data, that number had grown to 650 million users (Foster, 2011). Similarly, only 1 billion apps had been downloaded from Apple's Apps Store by April 2009 (Apple Press Info, 2009). By July 2011 that number had reached 15 billion downloads (Apple Press Info, 2011). These two examples highlight how dramatically the media landscape changed in the two years separating the studies. It is possible that these new forms of media have changed how media multitaskers engage with multiple sources of media, thereby changing the how the multitasking behavior impacts cognition. We attempted to get the original Ophir et al. (2009) MMI survey responses to make a comparison of the types of media that were being combined, but were only able to get the summary scores. Thus, we are unable to determine whether such a shift was responsible for the differences between studies.

It is also possible that the two studies sampled different segments of the media multitasking population. For instance, our sample consists primarily of females and, while Ophir et al. (2009) do not record their gender distribution, it is possible that males were more represented in their sample. Research has shown that males and females generally differ in their media use practices, particularly video game playing (Lucas & Sherry, 2004). It is possible that a more male dominated sample, or one that was comprised of more video game players, would have produced results more similar to Ophir, et al.'s (2009).

More generally, both the possible explanations we offer for the discrepancy between our findings and Ophir et al.'s (2009) suggest that it would be fruitful for future work to use a more fine grained analysis of specific media multitasking behaviors in an attempt to determine whether different types of media multitasking produce unique changes in cognitive functioning. In order to do so, a more refined measure of media multitasking may be required. The MMI provides a single index of the proportion of media time spent multitasking, but does not differentiate between different types of media combinations. Further, the index is by definition a proportion, and as such, does not account for the absolute time spent using media. In theory one might be able to use the MMI for such an investigation, but that would require a much larger sample size than we have used here. With such a sample size, one might be able to perform factor analysis on the MMI survey results to determine whether there are different factors with the global MMI measure that are uniquely associated with particular changes in cognitive function.

Even so, we believe the current work reveals important findings about the consequences of media multitasking on cognition. Although this research does not provide causality, our data suggest an increased ability to task-switch among those who media multitask more frequently. At a general level, these data suggest that multitasking with media may not be as potentially detrimental to cognitive functioning as previous reports suggest. Further research assessing the influence media use and media multitasking may have on cognitive control is needed. In addition, the long-term consequence of ubiquitous media multitasking is necessary.

As we said at the outset, there has been a good deal of interest in determining how the increased prevalence of media may be impacting people's mental health and cognitive functioning. Most of this work has focused on either the effects of the total amount of time people spend engaged with media or on the effects of specific types of media (e.g., video games). Here we demonstrate that it is informative to not only consider what types of media people are accessing, but also how they are accessing media. Multitasking with media may be associated with specific types of cognitive differences. Given that there has been a dramatic increase in these multitasking behaviors in recent years, the finding that this method of interacting with media is associated with specific differences in cognitive functioning is informative. In addition, it suggests that future work investigating the impacts of media on mental health and cognitive function should consider not only how much time people spend with specific forms of media, but should consider the extent to which they multitask with media.

Footnotes

[1] A handful of additional subjects reported using media more than 165 hours per week on the MMI questionnaire. Given that this equates to ~24 hours of media use every day of the week, we eliminated these participants from the experiment.

[2] These statistics are based on the combined questionnaire responses from Experiments 1and 2; the responses from the two experiments were not significantly different, $t(148) = -0.11$, $p = .911$.

[3] Ophir et al. (2009) did not present data for incompatible and compatible trials separately, so it is possible that there results were driven completely by the incompatible trials.

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Table 1: Correlations between MMI and the dual task performance measures in Experiment 1.

		M (SD)	1	2	3	4	5	6
1.	MMI		-	-.021	.027	.048	.077	.049
2.	Single Task RT	791.47 (145.88)		-	.486**	.577**	-.330**	.312**
3.	1st RT in Dual-Task	1455.65 (288.17)			-	.854**	.502**	.004
4.	2nd RT in Dual-Task	1928.99 (338.34)				-	.581**	.524**
5.	Dual-Task Cost	346.05 (292.87)					-	.295**
6.	Lag Cost	473.34 (176.23)						-

** $p < 0.01$ level (2-tailed).

Figure Captions

Figure 1. Stimuli and Procedure. (A) Experiment 1 procedure using 4-button response mapping. (B) Experiment 2 procedure using 2- button response mapping.

Figure 2. Data from Experiment 1. Panel A presents the correlation of participants' average switch cost (repeat RT-switch RT) and Media Multitasking Index score. Panel B presents the average reaction times for Light Media Multitasking (lower quartile of MMI scores) and Heavy Media Multitasking (upper quartile of MMI scores) groups on repeat and switch trials. Error bars are standard error of the mean.

Figure 3. Data from the Experiment 2. Panel A presents the correlation of participants' average switch cost (repeat RT-switch RT) and Media Multitasking Index score. Panel B presents the average reaction times for Light Media Multitasking (lower quartile of MMI scores) and Heavy Media Multitasking (upper quartile of MMI scores) groups on repeat and switch trials. Error bars are standard error of the mean.

Figure 1

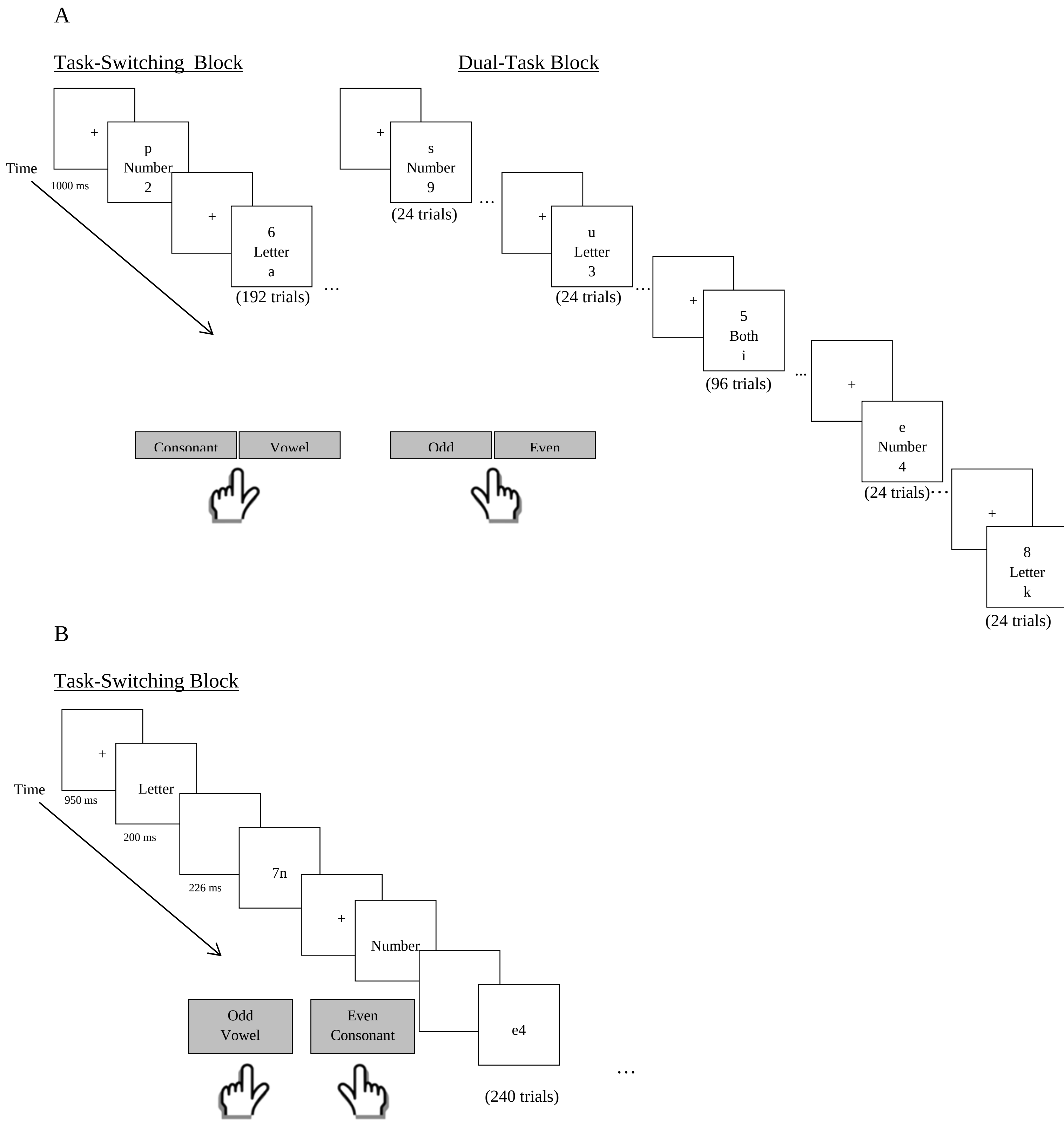
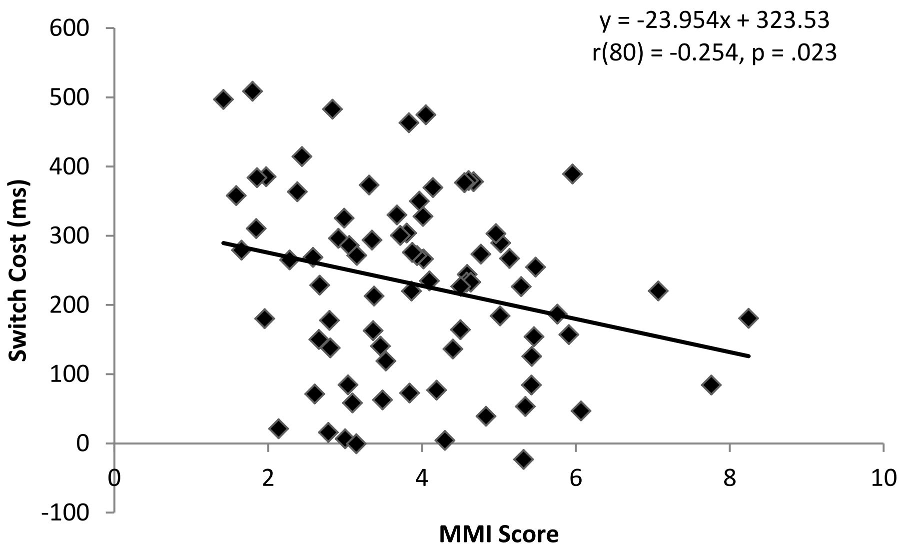

A
Task-Switching Block
Dual-Task Block
Time
1000 ms
+
p
Number
2
6
Letter
a
(192 trials)
s
Number
9
(24 trials)
u
Letter
3
(24 trials)
5
Both
i
(96 trials)
e
Number
4
(24 trials)
8
Letter
k
(24 trials)
Consonant
Vowel
Odd
Even
B
Task-Switching Block
Time
950 ms
Letter
200 ms
226 ms
7n
Number
e4
Odd
Vowel
Even
Consonant
(240 trials)

Figure 2

A


y = -23.954x + 323.53
r(80) = -0.254, p = .023
Switch Cost (ms)
600
500
400
300
200
100
0
-100
0
2
4
6
8
10
MMI Score

B

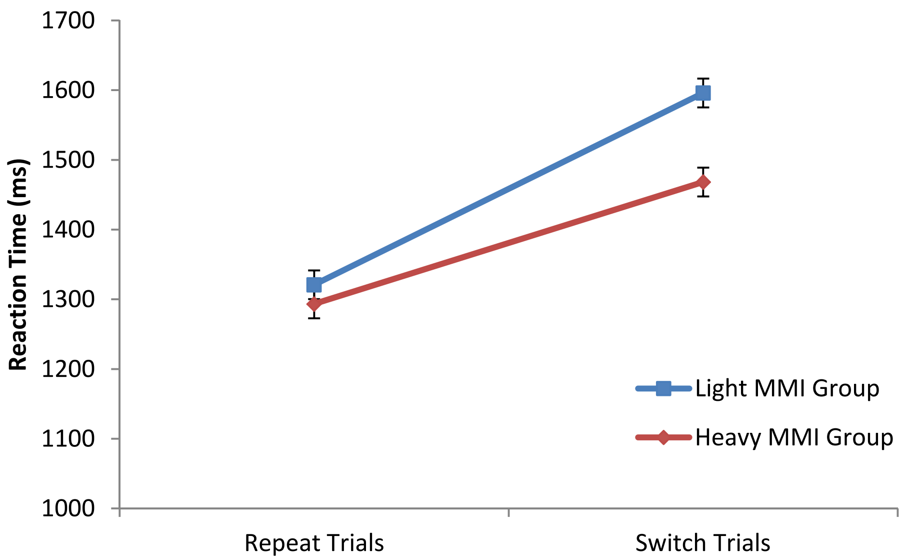
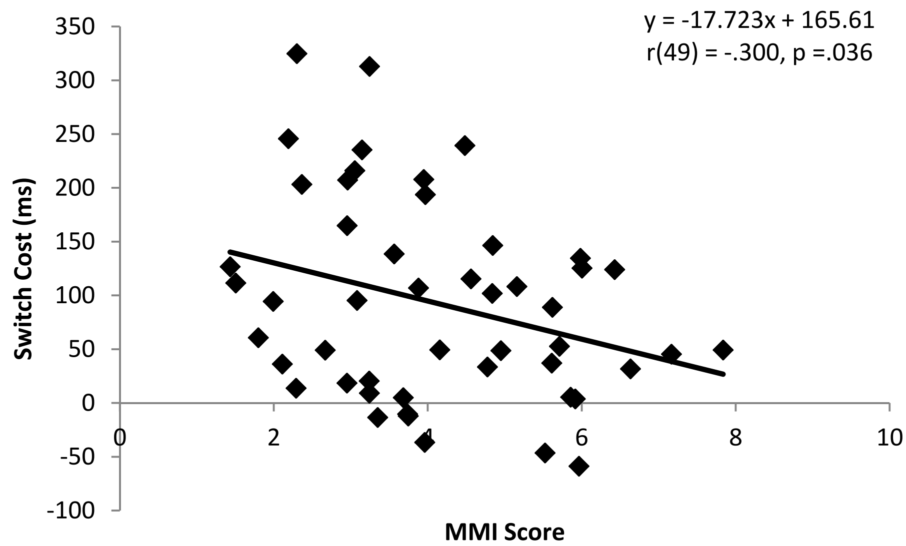
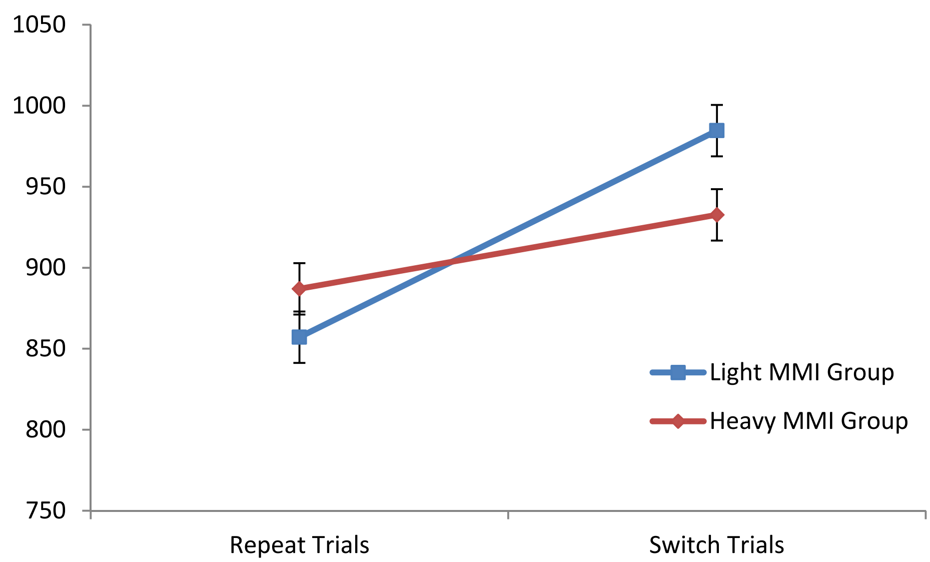

Reaction Time (ms)
1700
1600
1500
1400
1300
1200
1100
1000
Light MMI Group
Heavy MMI Group
Repeat Trials
Switch Trials

Figure 3

A


y = -17.723x + 165.61
r(49) = -.300, p =.036
Switch Cost (ms)
MMI Score
350
300
250
200
150
100
50
0
-50
-100
0
2
4
6
8
10

B


1050
1000
950
900
850
800
750
Light MMI Group
Heavy MMI Group
Repeat Trials
Switch Trials

Appendix A

The media multitasking index requires participants to indicate how many hours per week they use each of 12 forms of media (television, computer-based video, music, non-musical audio, video or computer games, telephone and mobile phone, instant messaging, SMS (text messaging), email, web surfing, and other computer based applications (such as word processing). Then for each media form, they indicate how often they use this primary media form concurrently with the each of the other 11 media forms. This is done by making 11 ratings of “Most of the time (=1),” “Some of the time (=0.67),” “A little of the time (=0.33),” or “Never (=0)”. These responses are summed to provide a measure of the average amount of media used while using each primary medium (this corresponds to m_i in the formula below).

The formula for the index is

$$MMI = \sum_{i=1}^{11} \frac{m_i \, x \, h_i}{h_{total}}$$

where, h_i is the number of hours per week spent using primary medium i, and h_{total} is the total number of hours per week spent with all primary media. The MMI indicates the average amount to media multitasking that is occurring during a typical hour of media usage.