Enhanced Media Multitasking:
The restorative cognitive effects of temporarily escaping the multitasking mindset

Jordan McCarthy

Thesis submission for the degree of master of arts in Communication

Stanford University

June 7, 2013

INTRODUCTION

There can be little doubt that multitasking has become a dominant—indeed, some would say essential—feature of modern society[1]. As the proliferation of digital technologies and ever-increasing rates of information flow have continued to shape 21st-century society, their cognitive compliments—attention-splitting and parallel processing—have become deeply ingrained in contemporary culture[16]. Today, the necessity of multitasking is generally taken for granted, and new opportunities to juggle additional media forms and informational inputs are frequently seen not only as enticing novelties, but also as essential means for keeping tabs on an increasingly complex and fast-paced world. Indeed, one of the most frequent justifications that people give for heavy multitasking is in fact that they need to "keep up" with everyone else who has jumped on the bandwagon of hyper-connectivity, whether by being able to respond quickly to a note from a supervisor or potential employer, or simply having the ability to monitor the latest drama in their social circles in real time. The great irony, then, is that multitasking habits and lifestyles continue to become more ensconced and pervasive even as concerns steadily grow about the long-term costs of chronic multitasking, and evidence mounts that these costs are already having very real consequences on the road, in the classroom, on the operating table, in social interactions, and in the basic information-processing abilities of people who multitask heavily [2][3][4][16][10][11].

Among the most compelling studies exploring the negative effects of long-term multitasking is Ophir et al., which revealed an inverse correlation between long-term media multitasking tendency and actual multitasking performance, suggesting that people who generally multitask more than average ("high media multitaskers") display significantly less mental agility than their peers who multitask less than average ("low media multitaskers") [2]. This study (along with many others in this field [15]) explicitly address "multitasking as a trait, not simply a state," thereby implying that an individual's multitasking ability is a fairly stable attribute that is developed over long time frames, and that is hence resistant to short-term change—and perhaps even to some extent immutable. But while Ophir et al. make a strong case that long-term behavioral patterns are *one* important determinant of multitasking ability, the study's findings do not in any way preclude the possibility that other, much shorter-term factors may play just as significant a role in determining a person's multitasking ability at any given moment in time. Indeed, it appears that very little work to date has directly addressed the short-term determinants of multitasking ability.

This gap in the literature inspires the central question of the present research: is multitasking ability predominantly a function of intrinsic or conditioned behavior patterns, and thus highly resistant to change, or is multitasking ability also influenced by short-term cognitive and behavioral choices, and thus more susceptible to conscious improvement? More specifically, can the cognitive penalties observed in prior research be partly attributed to the very specific batch of "high media multitasking" that took place immediately before the test of multitasking skill—and can people effectively regain some multitasking skill simply by resisting the urge to multitask for a few minutes before they begin a particularly important or demanding task?

In this study, we postulate the existence of what might be called a "multitasking mindset": a *voluntary* mental state induced by ongoing multitasking activity, characterized by an excess of mental arousal and the gradual depletion of limited cognitive resources (fatigue) which renders the brain unable to effectively handle new stimuli—but whose duration is only as long as an individual chooses to make it. This proposition is consistent with the Unified Theory of the Multitasking Continuum and the corollary Threaded Cognition model [1]. The multitasking mindset is in effect the crisis-management state the brain is placed in when the cognitive processing queue becomes backed-up as multiple focci of attention compete for a limited pool of mental resources—a resource conflict that can be resolved in short order simply by allowing the processing queue to clear [5]. If such a mindset exists and does indeed have a negative effect on subsequent multitasking ability, then it should be be possible to significantly increase multitasking ability in those who are unwittingly trapped in the multitasking mindset by inducing them to get out of it, even if for only a few minutes.

This study evaluates the effect of inducing different states of mind on multitasking performance over short (ten minute) time frames. Specifically, the study incorporates well-established measures of multitasking ability into a pre-test—post-test design to examine the differential effects of cognitive interventions intended to either keep participants in a "multitasking mindset" or induce them to adopt a *non*-multitasking mindset for a few minutes prior to a demanding task. The overall goals of the study were first to determine whether or not multitasking ability can be significantly altered over a short time frame by deliberate, short-term mental readjustment strategies—and if so, what type of strategies have the greatest efficacy in restoring multitasking ability. Three candidate intervention strategies were devised, each designed to represent one of the leading classes of remedies that are frequently claimed to be effective at reducing feelings and effects of "information overload" (a colloquialism that seems to be generally synonymous with "excessive levels of mental multitasking"): doing only one thing at a time[1][6], taking "technology holidays" that are totally devoid of media experiences[7][8], and meditating[20]. It was initially unknown which of these interventions would be most effective, but a pilot test indicated that the first two had limited and inconsistent effects at best. Thus, the hypotheses of the research team at the start of the main study were as follows:

1. It is possible to significantly mitigate or reverse the negative cognitive effects associated with high levels of multitasking over short time frames, by temporarily inducing a non-multitasking mindset.
2. Of the mental strategies under investigation, meditation-style activities are the most effective at suppressing and reversing the effects of the multitasking mindset.

STUDY DESIGN

Population

Participants for the study were drawn from a pool of approximately one hundred and fifty undergraduate students enrolled in either of two large lecture classes at Stanford University. The participant pool was first asked to complete a preliminary survey that included questions about past meditation and video-gaming experience, as well as an updated version of the Media Multitasking Index (MMI) Questionnaire. The MMI instrument asked participants to estimate how many hours they spent on a typical day using each of 12 different media types, and then what percent of that time they typically spent concurrently using each of the other media types. These responses were then aggregated into an overall MMI score for each participant using the following formula:

$$\sum_{i=1}^{11} \frac{m_i \times h_i}{h_{total}}$$

where "m_i is the number of media typically used while using primary medium *i*, h_i is the number of hours per [day] reportedly spent using primary medium *i*, and h_{total} is the total number of hours per [day] spent with all primary media."[2]

Members of the participant pool were invited to participate in the study if they had MMI scores that were at least 0.5 standard deviations above or below the population mean, so as to ensure a strong representation of both high and low media multitaskers in the study cohort. Of the fifty students who responded to the invitation, six eventually had to be excluded due to errors during the data collection process. The final analysis therefore included the data of forty-four participants, with fourteen males and thirty females distributed randomly across four conditions: downtime (n=9), meditation (n=12), multitasking (n=11), and single-tasking (n=11). Additionally, a pilot version of this study was also run on a different cohort (selected in the same fashion as the main cohort, but from a different subject pool), with twenty-four participants randomly distributed across the same conditions (n=6 in all cases). Because the study protocol was still being finalized during the pilot, the data from this pilot study was not included in the main analysis, but it is worth noting that the pilot data did show non-significant indications of the same effects that were seen in the main dataset.

In both the pilot and main studies, participants were granted course credit both for filling out the preliminary survey and for participating in the study. All aspects of the study were monitored and approved by the Stanford Institutional Review Board (Protocol #27031)

Procedure and Measures

After reading and verbally indicating their full understanding of an informed consent document, participants were each asked to complete a series of three back-to-back tasks in the same order: a pre-test, derived from Ophir et. al's filtering task; an intervention task, which varied depending on the subject's assigned condition; and a post-test, derived from Ophir et. al's task-switching task. Each of these exercises was designed to take no more than ten minutes, and all participants completed the full series within thirty to forty-five minutes. The pre-test and post-test were both implemented with EPrime 2.0, and took place on an HP Pavilion Desktop computer equipped with a PST Serial Response Box and a Dell 1905FP LCD monitor. Data from both the pre-test and post-test were parsed and cleaned for outliers by specialized scripts written in Python, and then cleaned again by hand. The automated cleaning operated on level of individual response times, and the manual cleaning was done at the level of per-participant means. In both cases, values were deemed to be outliers only if they both fell in the upper or lower ten percent of their category and were separated from prior values by more than 100 milliseconds.

The intervention task was implemented with the Qualtrics survey platform, and administered via the Firefox web-browser running on an Apple workstation with an LCD Cinema display, located in the same room as the first computer. The room in which the study took place was quiet, well-lit, and had the general ambiance of a typical office space.

Before beginning the study, participants were directed to turn off all electronic devices they had with them, and were strongly encouraged to leave the devices in the care of the administering experimenter. Participants were given the instructions for each task, asked if they had any questions, and then left in the study room by themselves to complete the task; the experimenter waited in the adjoining hallway until participants signaled that they were ready to move on to the next task. Experimenters were able to observe participants throughout the study through the glass door separating the study room from the hallway.

Pre-test

The pre-test was functionally identical to the filtering task used in Ophir et al., although the task length was shortened from approximately fifteen minutes to below ten minutes through the removal of some of the trials that were not relevant to the final analysis (The full task includes trials incorporating four, six and eight "target" rectangles, but the analysis is only concerned with those trials involving two targets and variable numbers of so-called "distractor" rectangles: 2-0, 2-2, 2-4, and 2-6 trials). The mechanics of the task, excerpted from Ophir et al., were as follows:

> In the filtering task, participants were told they would view a number of different arrays of red and blue rectangles. They were instructed to pay attention only to the red rectangles, and to ignore the blue rectangles. In each trial of the task, participants were presented with an array of red and blue rectangles of differing orientations for 100 ms. After an interval of 900 ms, a second array was presented, this time for 2,000 ms, and participants were asked to indicate whether one of the red rectangles had changed orientation (orientation changes consisted of rotation by 45° either clockwise or counterclockwise, and no more than one red rectangle ever changed orientation). Participants indicated that a change had taken place by pressing a button [on the PST response box] marked "yes," and that no change had taken place by pressing a button marked "no." Trials were separated by an interval of 200ms.[2]

The rationale for using the filtering task as a pre-test was twofold. First, the pre-test ensured that all participants entered the second phase of the experiment in a similar frame of mind: namely, the postulated multitasking mindset. The filtering task was well-suited to the purpose of inducing such a mindset, for it entailed the heavy use of memory management and spatial processing, mechanisms known to be closely implicated in multitasking performance[15]. Second, the test provided a comparative baseline measure of each participant's multitasking ability and proficiency with the response box, which was used as a secondary check (in addition to participants' MMI scores) to confirm parity across all conditions with respect to initial means and distributions of multitasking abilities.

Eight measures were extracted from the results of this test: each subject's average response time and accuracy rate for each of the target-distractor combinations of interest (ie, 2-0, 2-2, 2-4, and 2-6). The accuracy rates served as an approximation of Ophir et. al's measurement of filtering ability (which is understood and has been observed to be a key component of multitasking ability [2]); the response times served as a baseline measure of participants' responsiveness to timed trials using the PST response box.

Conditions

Upon completing the pre-test, participants were reseated at the second computer and began one of four similar tasks, determined in advance by their condition assignment. Three of the tasks—the "downtime," "meditation," and "singletasking" tasks—were designed to induce participants to engage in one of the mental conditioning techniques that have been characterized as effective strategies for reducing the mental stress of multitasking in both scholarly and popular literature. The fourth task, "multitasking," was designed to sustain the multitasking mindset that had been established in the pre-test (and which many participants had probably been unwittingly operating under for many hours beforehand). The multitasking condition thus served as something of a control group, against which the results from the other conditions were compared to determine whether any of the short-term cognitive strategies those conditions represented could in fact mitigate the cognitive penalty exacted by sustaining a consistently high-multitasking mindset.

The latter characterization of the multitasking case as a control group warrants additional explanation. While the downtime case (in which participants did nothing for five minutes) in many ways appears to be the condition that most resembles a traditional control group, it would have in fact been far less suitable as a control group in this context than the multitasking group. For when left completely to their own devices, people tended to literally return to their (media) devices: in the pilot study, where prohibitions on using other media during the downtime case were looser than in the main study, almost none of the participants in the downtime case actually proved willing (or able) to sit quietly for five minutes without seeking out some form of media stimulation. Nevertheless, the downtime condition was included in the final study design (with tighter restrictions on media use) in the hope that it could serve as a secondary control group, the data from which might be used to determine how strong the impacts of induced multitasking and meditation mindsets might be as compared to a relatively neutral baseline (the condition did not ultimately prove suitable for this purpose, for reasons discussed below). However, the point still stands that in the present day sitting still and doing nothing for five minutes does not in fact constitute a neutral baseline, but rather an intervention in and of itself, which is one of several reasons why this condition must be considered a more imperfect control than the multitasking case[17].

Aside from the elements involved in inducing the differing states of mind described above, all other features of the four tasks were designed to be as similar as possible, down to the number of words used in each task's instructions. In particular, all four tasks were designed to take the same amount of time: five to six minutes. While this is admittedly a very short amount of time in which to effect a meaningful change in state of mind, the decision to make the intervention tasks so short was quite deliberate, informed by the research team's consensus that any cognitive intervention longer than five minutes would almost certainly be deemed impractical and impracticable by those who stand to benefit the most from them [1]. Once participants completed their assigned intervention tasks, they proceeded immediately to the post-test.

Singletasking

In keeping with the conventional wisdom that the easiest remedy for information overload is to simply focus on doing one thing at a time [16][7][8], the singletasking exercise was structured to encourage participants to focus their attention on only one mentally-engaging activity at any given moment.

This task was one of three built around the same five-minute slide show of a set of photographs taken in the Irish countryside, which had originally been published as a YouTube video. The slide show was carefully selected to be minimally arousing and have a consistently neutral valence, as both valence and arousal responses have been show to have a significant impact on multitasking performance [13]. The Irish countryside slide show offered a range of features that supported this goal, including black-and-white images, long periods between image switches (approximately fifteen seconds), slow fading transitions (approximately five seconds long), and relatively unremarkable content (dominated by tranquil but otherwise unremarkable nature scenes, with a smattering of old houses and other human artifacts). To reduce potential arousal and valence responses still further, a contrast-lowering filter was applied to the entire slide show, giving the images a uniformly soft aspect.

To incorporate the slide show into the intervention tasks, members of the research team downloaded a local copy of the video, and then imported it into Apple's iMovie software. All necessary changes were made within iMovie, and the resulting movies were then exported as medium quality, standard aspect-ratio .mp4 files. Each file was then re-encoded as an .flv file (to circumvent space constraints), and finally embedded within a dedicated Qualtrics survey in a fashion that prevented users from stopping, restarting, or changing the size or speed of the slide show (Qualtrics surveys were used to host the slide shows precisely because the Qualtrics system allowed for the degree of control necessary to achieve all of these goals).

Participants in the singletasking condition were informed that they were going to be shown a series of pictures, and were instructed to “try to remember as much as you can about all of the man-made artifacts you see in these pictures.” Participants then viewed the slide show in its entirety, and were immediately thereafter administered a simple questionnaire about the content of the slide show. The questionnaire asked participants to list all the man-made objects they remembered having seen, indicate whether the last image in the slide show contained any man-made objects, and then estimate the percentage of the images that contained predominantly natural objects, predominantly man-made objects, and a combination thereof. The answers to these questions were used solely to determine whether or a given participant made an earnest attempt to complete the task as instructed. (One participant did provide consistently low-quality and nonsensical answers, and this participant's data were consequently discarded.)

Meditation
The meditation task paired the same slide show described above with a script for a basic “mindfulness” meditation exercise, of the kind that has been observed to reduce cognitively-disruptive arousal responses [13] and decrease reaction times over long time frames (usually eight weeks) in cohorts that are given regular training in these mindfulness techniques [9][12][19]. However, the present study aimed to build on this prior work on meditation and multitasking by testing whether the restorative cognitive effects of meditation-style exercises seen over long time frames could also be observed over much shorter (ten minute) periods, in a population that had not been required to undergo prior training in meditation. The script for the mindfulness exercise used in this study was developed in consultation with the Berkeley Buddhist Monastery.

Participants in this condition were informed that they were going to play a “basic relaxation game.” They were then shown a modified version of the slides used in the singletasking condition in which the meditation script was overlaid on top of the pictures, one instruction at a time. After a brief introduction that asked participants to “find a comfortable position,” the meditation instructions alternated between asking participants to focus on various parts of their bodies (“Focus on your feet”), and asking them to simply “Relax.” Each prompt appeared for five seconds, and then faded into the next instruction. The last instruction in the script told participants to “let your body and mind return now to your usual level of alertness and wakefulness.” As participants in this condition had no opportunity to provide input, no data were collected from this condition.

Multitasking
The multitasking exercise was also constructed around the slide show. For this activity, the presentation was incorporated into a task flow that was designed to emulate the multitasking patterns that people generally exhibit when using their own computers, which often include juggling multiple (digital) media formats, rapid switches between input and output tasks, and entirely different thematic genres of content, all at the same time [18]. Participants were told that they would be “shown a series of pictures and asked a series of questions,” and were instructed to write the answers to the questions as they appeared, in a text box located just beneath the ongoing slide show. Just as in the meditation slide show, text prompts were overlaid on top of the images. But rather than being inducements to relax, these questions required participants to recall, synthesize, and extrapolate from both incoming and stored information. Of these twenty questions, half concerned the content of the slide show (eg, “Have you seen any water in the pictures so far?”), and half of asked for basic information about the participant's preferences and present circumstances (eg, “Describe your best friend using three adjectives.”). Participants had fifteen seconds to read and answer a question before the next one appeared, although all of their past answers remained editable until the end of the slide show. The two genres of questions were randomly interleaved during the creation of the slide show, so each participant in this condition was presented with the questions in the same order. The questions were designed to be straightforward and easy to answer, but also engaging enough that they would require participants to switch their primary focus between the video and their own experiences—much as queries that arrive via email and instant messaging often force their receivers to rapidly switch their focus between their primary task and the topic(s) of the ongoing conversation(s). Similarly, the time delay between the questions was intended to approximate the natural frequency of task-switching on a single device that has been empirically observed in similar populations [18]. As in the singletasking condition, answers to these questions were collected and analyzed only for the purposes of confirming that participants were making a good faith effort to complete the task as instructed (which appeared to be true in all cases).

Downtime
The downtime condition was the only one of the four to not involve the slide show; indeed, it involved almost no media at all. This condition was originally intended to provide an approximation of the opposite pole to the multitasking condition in terms of mental arousal, and thereby serve as an additional test of the hypothesis that the cognitive decline associated with routinely high levels of media multitasking is largely a function of mental fatigue (the sustained overextension of cognitive resources). In effect, this condition was designed to force participants to take a mental break. The pilot run of this study revealed this condition to be largely unsuitable for those original

purposes, but the condition was nevertheless included in the final study for a combination of exploratory and comparative reasons, with the understanding that any effects from this condition would almost certainly be inconsistent and insignificant.

Participants in this condition were first issued the same instructions used in the multitasking case, but when they attempted to proceed to the start of the slide show, they were presented with a fabricated error message indicating that "This program module has experienced a database connection error." The error page informed participants that they would not need to do anything for the duration of the module, and that the rest of the study would resume after five minutes. The page also requested that participants remain seated, and not use the computers (or, implicitly, any other devices) during this time. Experimenters knew when a participant had been assigned to this condition, and set a timer for six minutes as soon as the participant began the task (the extra minute was for the overhead associated with each of the other tasks, which were also nominally five minutes long but ended up taking at least six). At the end of the six minutes the experimenter returned to the participant, apologized for the inconvenience, and conducted the participant directly to the final phase of the study. No data were collected from this condition, except for the casual observations that led the study team to conclude that participants in this condition were not getting consistent experiences, as some spent the five minute period seeking out any available media experiences while others did not.

Post-test

Like the pre-test, the post-test was a shortened version of one of the major skill tests used in Ophir et. al: the task-switching exercise. The decision to base the pre-test and post-test on different but related tasks was quite deliberate, intended to avoid any potential noise that might have been introduced by the effects of practice. The mechanics of this second test, from Ophir et al., are as follows:

> In this task, participants switched back and forth between classifying numbers and classifying letters, according to a cue presented at the outset of each trial. Participants were presented with one of two cues ("NUMBER" or "LETTER") for 200 ms, followed by a stimulus that consisted of a digit-letter pair (such as "2b" or "b2"). Participants classified the stimuli using two buttons, depending on the task indicated by the cue. If shown the NUMBER cue, participants were to press the left button for an odd number and the right button for an even number. If, conversely, participants were shown the LETTER cue, they were to press the left button if the letter in the stimulus was a vowel and the right button if it was a consonant. The set of letters consisted of the vowels a, e, i, and u, and the consonants p, k, n, and s. The set of even numbers consisted of 2, 4, 6, and 8, whereas the odd numbers were 3, 5, 7, and 9. The relative positions of the number and letter were counter balanced across trials. The interval between cue offset and stimulus onset was set to 226 ms, and the intertrial interval was set to 950 ms.

Just as before, the original ePrime instrument was modified to shorten its duration from over fifteen minutes to just under ten. In this case the time reduction was achieved by eliminating one of the three "cycles" of all possible combinations of stimuli that were included in the original instrument.

The data from this task were parsed to generate mean accuracy rates and response times for each participant, and then disaggregated by a range of trial types: all trials, all switch trials, all non-switch trials, and every possible degree of "switch" and "non-switch" trials. A switch trial is defined as one preceded by a trial of the opposite cue type (eg, a LETTER trial preceded by a NUMBER trial). A non-switch trial, conversely, is one preceded by a trial of the same cue type. An *n*th-degree trial is one preceded by *n* trials of the same type (eg, the third trial in the series LETTER LETTER NUMBER is a second-degree switch trial). Each of these categories of data was further broken down into correct and incorrect response times, although accuracy rates were generally so high that the number of trials constituting the incorrect means was far too small to render those means significant.

RESULTS

MMI and other demographic factors

The aggregate means of MMI scores across the four conditions were roughly equivalent, with a four-way ANOVA turning up no significant difference ($F(3, 44)=0.51$). However, the singletasking condition did have an markedly low mean (1.38) relative to the other three groups, and the scores of that group came very close to differing significantly from those of the multitasking group ($t(21)=1.16$, $p=0.13$). The MMI scores for the multitasking and meditation groups (1.96 and 1.78, respectively) were the most similar of any two cases, with the group means separated by less than 1/8 of standard deviation, and the variance in the distributions being quite insignificant (t(22)= -0.3855).

Gender ratios were somewhat more divergent, largely due to the small number of males who volunteered to participate in the study, and the fact that several of the participants whose data had to be excluded from the analysis were also male. In particular, the downtime cohort was 56% male (n=5), while the singletasking cohort was only 18% male (n=2). Here again, however, the multitasking and meditation cohorts were comparable, with 33% (n=4) and 25% (n=3) males, respectively.

Self-reported video-game playing (presumed to be associated with decreased reaction times [14]) bifurcated the conditions, with the multitasking and meditation cohorts once again clustered together. The latter cohorts reported playing video games, on average, for 1.83 hours per week and 1.67 hours per week, which was not significantly different (t(22)=-0.083). The group means for the singletasking and downtime cohorts were both 0.55 hours, and both were on the cusp of differing significantly from the multitasking cohort (t(21)=1.03, p=0.15; t(19)=-0.96, p=0.18).

The multitasking and meditation cohorts maintained their close similarity with respect to past meditation experience, as reported on a five point scale where 1 designated “None” and 5 designated “A great deal”). The downtime cohort had on average slightly more prior meditation experience (2.44) than either the multitasking cohort (2) or the meditation cohort (2), to a degree that once again approached but did not quite meet the level of statistical significance (t(19)=0.89, p=0.19 and t(19)=0.93, p=0.18, respectively). The singletasking cohort fell in the middle of these values (2.18), and hence displayed no significant difference when paired when any of the other three conditions. But the multitasking and meditation conditions were nearly equivalent, with identical means (2, indicating “a little” prior meditation experience) and almost identical distributions (t(22)=0.00). There were no significant differences among the four cohorts with respect to attitude towards meditation, with all group means falling between 3.75 and 3.9 on a five point scale (where 3 indicated a “neutral” attitude, and 4 indicated a “positive” attitude).

Pre-test

The pre-test was used as a secondary check (on top of MMI) to confirm that the cohorts in different conditions did not significantly differ in pre-intervention multitasking capability. The means for all of the measures taken from this task were generally very similar across all conditions, although both the downtime and singletasking groups did differ significantly from the multitasking group on at least one important measure (respectively: accuracy rate for trials with four distractors, and accuracy rate for trials with six distractors, both of which are trial types that have been shown to be capable of detecting differential multitasking abilities [2]). On the measures in question, the the multitasking group scored 8% higher than the downtime group (t(19)=-1.46, p=0.08), and 6% lower than the singletasking group (t(21)=-1.49, p=0.08).
However, consistent with the findings from the preliminary survey, the multitasking and meditation groups displayed remarkably similar multitasking aptitude in the pre-test. Mean response times for these two cases differed by no more than 10ms for each of the target-distractor combinations (t(22) < 0.2 for all combinations), with the multitasking cohort being infinitesimally faster for all combinations. Mean accuracies for the two groups were separated by no more than 2 percentage points for all target-distractor combinations (t(22) < 0.75 for all combinations, and t(22) = 0.17 for the aggregate means). There was a slight drop in accuracy in both groups as the number of distractors increased, which was to be expected.

Intervention cases
As mentioned previously, the only recorded data taken from the intervention tasks were quality controls to ensure that participants in the multitasking and singletasking cases were making a good faith effort to complete their assigned task. This was true in all but one case, which was subsequently dropped from the dataset.

However, experimenters also reported a variety of anecdotal observations based on their experiences with different participants. During the course of the pilot run of this study these informal observations quickly revealed that the downtime condition was problematically unique, and that the data from this condition would probably not be directly comparable to that gleaned from other conditions. The first complication was that almost every participant came out of the study room within one minute of beginning the downtime task, and informed the experimenter that there had been an error—despite the fact that the on-screen instructions explicitly asked participants to remain seated. Accordingly, for the main study experimenters were trained to respond by affecting an apologetic air and telling participants that such errors had been occurring “more often than we'd like,” and that the experimenter needed five minutes to “go fix the problem.” Experimenters reassured participants that they would not have to spend any extra time in the study, and that they would be advanced directly to the next module at the end of the five minute period.

But when participants had been reseated in the study room, they engaged in a wide range of behaviors, many of which were clearly the product of deeply-ensconced habits of media use and multitasking. Granted, several participants did exactly as they were instructed, and sat quietly for the five minute period. But some, quickly becoming bored, started rifling through documents associated with other studies that were being conducted in the study room. Some pulled out other forms of reading material. At least one participant pulled out his smart phone and spent the full five minute period using it, in direct violation of the instructions given at the outset of the study and repeated in the downtime condition's error message. Given this high degree of variance in behavior and induced mindset, it would have been surprising if the post-test data from this group were *not* at least somewhat inconsistent and intermediate (indeed, the consistency and magnitude of the difference between the post-test results of the downtime group and the multitasking group was striking, even given the fact that the significance of those differences was compromised by confounds).

Post-test

Meditation vs. Multitasking

Though the multitasking and meditation cohorts had performed almost identically on the pre-test, the two groups' performances on the post-test were marked by large, consistent, and highly significant differences. In particular, the meditation group's mean response times were consistently more than 25% faster than those of the multitasking group, an effect that held across all trial types. Across all accurate trials (ignoring trial type) the mediation cohort was 27% faster, averaging 782 ms while the multitasking cohort averaged 1053 ms ($t(22)=3.11$ $p=0.01$). But the effect remained large and significant no matter how the data were disaggregated. On all accurate nonswitch trials the meditation group's mean response time of 741 ms was 25% faster than the multitasking group's 983 ms ($t(22)=3.43$, $p=0.01$). On all accurate switch trials, the meditation group's advantage held steady at 27%, with an average of 860 ms compared to the multitasking group's 1167 ms ($t(22) = 2.59$, $p=0.01$). These magnitudes and significance levels held firm across every possible disaggregation of accurate response times, from first-degree switch trials through third-degree nonswitch trials.

The meditation cohort's speed advantage appeared to be even greater on inaccurate trials—the difference in group means for all inaccurate response times was over 450 ms—although it makes little sense to attribute a quickly-supplied wrong answer to improved multitasking ability, and inaccurate responses were therefore excluded from the analysis. Their exclusion was further justified by the relatively high accuracy rates for both groups. But here, too, there was a significant difference between the cohorts: the meditation group averaged 96.4% accuracy across all trials, while the multitasking group averaged 92.8% ($t(22) = 2.37$, $p = 0.05$). Furthermore, although equivalence between measures on the pre-test and post-test has not been established and cannot be assumed, it appears that the meditation group's mean response times declined slightly from pre-test to post-test, whereas the multitasking cohort's mean response times rose dramatically.

Controlling for MMI produced no significant changes, and there were no significant interaction effects between the two conditions and MMI scores, indicating that the observed improvements in the meditation cohort's performance were the result of similar degrees of improvement on the part of both high and low media multitaskers.

Downtime vs. Multitasking

Although the comparability of the downtime cohort to any other of the other three groups was determined to be insufficient to support any definitive conclusions about this condition's relative effects on multitasking performance, this group did appear to perform consistently better than the multitasking cohort on the post-test. The effect in this case was intermediate, being considerably smaller and less significant than the differences between the multitasking and meditation groups. Nevertheless, the downtime cohort appeared to outperform the multitasking group by 15% on all accurate trials (892 ms vs. 1053 ms, $t(19)=1.59$, $p=0.06$); to respond 13% faster on accurate nonswitch trials (854 ms vs. 983 ms, $t(19)=1.55$, $p=0.07$)); and to achieve a pronounced advantage of 19% in the category of switch trials (944 ms vs. 1167, $t(19)=1.63$, $p=0.06$). There were no significant differences between the downtime and mulitasking conditions' respective accuracy rates on any trial type; indeed, these rates generally appeared to be almost identical. While these differences are notable and interesting, it must be reemphasized that the comparisons are rendered suspect by multiple confounds, such that the findings must be viewed as highly preliminary.

Singletasking vs. Multitasking

The same caveat that limits interpretation of the downtime results also applies to any comparison involving the singletasking condition: this cohort, too, may have had a different baseline multitasking ability relative to all of the other cohorts, particularly given its low mean MMI and unusually strong performance on one of the pre-test measures. Once again, however, the comparative results are worth reporting, in this case because the mean response times for the singletasking group and and the multitasking group were remarkably similar. Average response times for the two groups were never more than 100 ms apart for any accurate trial type (with the multitasking group always being the slower of the two), and the difference was consistently insignificant. The one metric that did differentiate the two groups' performance on the post-test was accuracy, with the singletasking group means lagging consistently behind the multitasking group's scores by at least 4%, albeit with borderline significance (4.8% for all accurate trial types, $t(21)=1.18$, $p=0.13$); 5.5% for accurate nonswitch trials, $t(21)=1.26$, $p=0.11$; and 3.8% for accurate switch trials, $t(21)=0.95$, $p=0.18$). Again, potential confounds require these data to be viewed only as preliminary—although most of the confounds operating on the singletasking cohort should theoretically have given the group a distinct advantage in baseline multitasking performance, which makes these data all the more provocative.

DISCUSSION

The most compelling results to be generated from this study were the observed differences between the multitasking and meditation conditions. Additionally, the data generated by this comparison come with two layers of quality assurance above and beyond simple statistical significance, having been gleaned from populations that (a) were known to be highly similar across a broad range of demographic and behavioral metrics, and (b) displayed very similar levels of multitasking ability on a rigorous pre-test. The data in question largely speak for themselves, indicating a pronounced and consistent reduction in multitasking ability immediately following a five minute period of relatively slow-paced multitasking, relative to the multitasking ability of a cohort that spent the five minutes engaged in a very simple mindfulness meditation exercise.

Because the pre-test and post-test were in fact different tasks, and the singletasking condition was unsuitable for use as a neutral point of comparison, there is no way to tell for certain what proportion of this difference was due to the remedial influence of meditation, as opposed to the deleterious influence of the multitasking task. But given how much of their daily lives people from all walks of life now spend triaging email, fielding incoming instant messages, sharing thoughts with their social networks, and actually trying to get work done all at the same time, it seems fairly safe to posit that the multitasking task used in this study was one of the least taxing media-multitasking experiences that most study participants had probably had on the day of the study. For such participants, the multitasking exercise probably did little more than to sustain the multitasking mindset that they had been in from the moment when they blearily picked up their smartphone to turn off their alarm and found six texts waiting to be read. While much further research is needed to explore the causes and effects of the multitasking mindset and the benefits of short-term meditation exercises, it seems very likely that participants in the meditation category emerged from the study in a more agile, multitasking-*capable* state of mind than the one they had entered with. These results therefore offer an important contribution to the existing literature on meditation, suggesting that some of the positive effects observed in cohorts subjected to long-term training in mindfulness meditation can also be realized over the course of only a few minutes, by cohorts with little to no prior meditation experience.

The data from the preliminary survey and the differences in pre-test multitasking performance jointly established that only the meditation group was sufficiently similar to the multitasking cohort to allow for meaningful comparisons. While it would theoretically have been possible to control for the potential confounds affecting the singletasking and downtime cohorts, the complexity of simultaneously controlling for multiple interrelated covariates (prior meditation experience, MMI score, empirically-established baseline mulitasking performance, etc.) ruled out such an approach. In light of these considerations, and the fact that the primary goal of the study—to establish what the maximum possible extent of short-term change in multitasking ability was and how it could be achieved—was met by the meditation condition, the data from the singletasking and downtime cases should be considered only speculative and supplemental. Nevertheless, should the patterns of differences displayed by the singletasking and downtime cohorts prove replicable, the data from these two conditions could offer additional insight about the nature of the multitasking mindset, and how its effects can be best mitigated.

The remarkably weak overall performance of the singletasking group suggests that this condition was not nearly as different from the multitasking condition as it was intended to be—perhaps because it placed heavy demands upon two cognitive resources that are known to be closely implicated in multitasking performance: spatial reasoning and memory management [15]. Thus, it may be that once a multitasking mindset has been established, it can be fueled and sustained by other, loosely-related cognitive loads, even if those loads do not directly involve multitasking. Whatever the underlying mechanism, however, it seems likely that the singletasking exercise had a powerfully detrimental effect on the participants who completed it, for that group of participants had baseline characteristics that would ordinarily be predicted to *elevate* overall multitasking ability—an unusually low aggregate MMI score, and unusually strong performance on one of the key components of the pre-test—and nevertheless ended up scoring worse on some metrics than any other cohort. The experimentally-induced decreases in the singletasking cohort's relative cognitive agility therefore strongly support the proposed construct of the short-term multitasking mindset, and suggest that the effects of such a mindset on cognitive performance are at least as strong as long-term multitasking tendency (MMI). The experiences of this cohort also suggest that the multitasking mindset, once fully induced, cannot necessarily be mitigated by simply reducing the number of tasks one is juggling: a more substantial cognitive readjustment is required to allow the brain to recover from a sustained bout of multitasking.

Conversely, the downtime condition showed signs of being unexpectedly effective at establishing a non-multitasking mindset, despite the best efforts of several participants to maintain what was probably in their view a "natural" mental state of constant media-based stimulation. The results from this condition are particularly tentative, given all of the confounds present in the cohort assigned to it. But assuming the relative differences between this condition and the multitasking condition are valid, they suggest that simply taking a short break from one's usual media environment may be sufficient to at least partly displace the multitasking mindset. In any case, a great deal more research will be required to determine what aspects of "taking a break" are most influential in allowing the brain to shed and recover from a multitasking mindset, and whether these effects can in any way compare to the effects of a structured mindfulness meditation exercise.

Overall, the results of this study confirm our initial hypotheses that it is possible to change multitasking ability over short time frames using targeted cognitive interventions, and that the technique that is most effective at doing so (of those under investigation) is a structured mindfulness meditation exercise. The findings therefore strongly support the existence of the postulated multitasking mindset, showing that even transient activities and behavior patterns that force the brain to multitask have an immediate and sizable detrimental impact on cognitively-demanding tasks that are undertaken immediately afterwards. Conversely, the results also demonstrate that it is possible to quickly reverse the negative effects of the multitasking mindset through the use of mental strategies that allow the brain to escape from the multitasking mindset, even if for only five minutes. It is important to note that these results do not undermine the prior research on the long-term determinants of multitasking ability, but rather complement it, suggesting that multitasking ability has elements of both trait and state, and is a function of both long-term conditioned behavioral patterns and short-term cognitive choices.

Limitations

This study suffered from a range of significant limitations, many of which have already been discussed in the context of the confounds that were present in the singletasking and downtime cohorts. Most of the biggest limitations in this research were related to the participant pool, which was both relatively small and in many respects highly homogeneous, being comprised exclusively of undergraduate students attending a single private university. The small number of participants per condition may have diluted the significance of effects or introduced bias that artificially inflated effects. The small proportion of males in this study (less than 33%) and unequal distribution of males across conditions make it impossible to rule out that some observed effects may have been partly a function of gender differences.

Another limitation involving participants concerned the data that was collected about their behavior. The casual observations that led the experiment team to determine that the downtime condition had flaws should have been formalized, with experimenters carefully monitoring participants in all conditions for apparent diligence and adherence to study rules, and recording all aberrations. As it was, the only checks on participant cooperation were the responses provided in the mulitasking and singletasking conditions; participants in the other two conditions were simply given the benefit of the doubt. Relatedly, it would have been highly beneficial to have information from each subject concerning how she felt about the study, and what she guessed its purpose to be (as it was, debriefings were highly informal affairs, and no reliable record was kept of what participants said). Because that information is unavailable, we cannot know if participants in different conditions had different conscious or subconscious understandings of how experimenters "expected" them to behave.

Finally, although the choice to use different tasks was a deliberate move intended to prevent the effects of practice or differential rates of task learning across conditions from introducing noise into the data, this decision made it difficult to determine whether the performance of the meditation cohort represented a real net improvement in multitasking ability, or simply a more moderate rate of decline than the one exhibited by the multitasking cohort. Further research in this area should certainly explore this important question, perhaps by using the same task for both pre-test and post-test, or using different tests whose measures are known to be directly comparable.

REFERENCES

[1] Rosen, L., Carrier, L., and Cheever, N. Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior,* 29 (3). 948-958. http://www.sciencedirect.com/science/article/pii/S0747563212003305

[2] Ophir, E., Nass, C., and Wagner, A. Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences*, 106 (35) (2009). 15583–15587.

[3] Pea R, Nass C, Meheula L, Rance M, Kumar A, Bamford H, Nass M, Simha A, Stillerman B, Yang S, Zhou M. Media use, face-to-face communication, media multitasking, and social well-being among 8- to 12-year-old girls. *Developmental Psychology*, 48(2) (2012 Mar). 327-36.

[4] Richtel, Matt. Growing Up Digital, Wired for Distraction. *New York Times*, November 21, 2010. http://www.nytimes.com/2010/11/21/technology/21brain.html?pagewanted=all

[5] Salvucci, D. and Taatgen, N. Threaded Cognition: An Integrated Theory of Concurrent Multitasking. *Psychological Review*, 115 (1) (2008). 101–130.

[6] Paul, A. You'll Never Learn! - Students can't resist multitasking, and it's impairing their memory. *Slate*, Friday, May 3, 2013. http://www.slate.com/articles/health_and_science/science/2013/05/multitasking_while_studying_divided_attention_and_technological_gadgets.single.html

[7] Bittman, M. I Need a Virtual Break. No, Really. *New York Times*, March 2, 2008. [a]http://www.nytimes.com/2008/03/02/fashion/02sabbath.html?_r=0,

[8] Glaser, M. 'Technology Sabbath' Offers One Day to Unplug. *PBS*, June 5, 2008. http://www.pbs.org/mediashift/2008/06/technology-sabbath-offers-one-day-to-unplug157

[9] Sudsuang, R., Chentanez, V. and Veluvan, K. Effect of buddhist meditation on serum cortisol and total protein levels, blood pressure, pulse rate, lung volume and reaction time. *Physiology & Behavior*, 50(3) (1991). 543–548. http://www.sciencedirect.com/science/article/pii/003193849190543W,

[10] Sanbonmatsu, D., Strayer, D., Medeiros-Ward, N. and Watson., J. Who Multi-Tasks and Why? Multi-Tasking Ability, Perceived Multi-Tasking Ability, Impulsivity, and Sensation Seeking. *Plos One*. http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0054402

[11] Poolton, J., Wilson, M., Malhotra, N., Ngo, K. and Masters, R. A comparison of evaluation, time pressure, and multitasking as stressors of psychomotor operative performance. *Surgery*, 149 (6) (2011). 776–782. http://www.sciencedirect.com/science/article/pii/S0039606010006811

[12] Jain, S., Shapiro, S., Swanick, S., Roesch, S., Mills, P., Bell, I. and Schwartz, G. A randomized controlled trial of mindfulness meditation versus relaxation training: Effects on distress, positive states of mind, rumination, and distraction. *Annals of Behavioral Medicine*, 33 (1) (2007). 11-21.
http://link.springer.com/article/10.1207/s15324796abm3301_2

[13] Demanet, J., Liefooghe, B. and Verbruggen, F. Valence, arousal, and cognitive control: a voluntary task-switching study. *Frontiers in Psychology*, 2 (2011).
http://www.frontiersin.org/Cognition/10.3389/fpsyg.2011.00336/full#h2

[14] The effects of video game playing on attention, memory, and executive control
Boot, W., Kramer, A., Simons, D., Fabiani, M., and Gratton, G. *Acta Psychologica* 129 (2008). 387–398

[15] Werner, N., Chang, J., Cades, D., Khan, H., Boehm-Davis, D. and Thi. G. What makes us resilient to interruptions? Understanding the role of individual differences in resumption.
http://pro.sagepub.com/content/55/1/296.full.pdf+html

[16] Rosen, C. The Myth of Multitasking. *New Atlantis*, Spring 2008. 105-110.
http://faculty.winthrop.edu/hinera/CRTW-Spring_2011/TheMythofMultitasking_Rosen.pdf

[17] Michaels, R., Parra, J., Mcann, D., and Vander, A. Renin, Cortisol, and Aldosterone During Transcendental Meditation. *Psychosomatic Medicine,* 41 (1) 50-54.
http://www.psychosomaticmedicine.org/content/41/1/50.full.pdf+html

[18] Yeykelis, L., Cummings, J.J., and Reeves, B. (Under review): Multitasking on a single-device: Arousal and the frequency, anticipation, and prediction of switching between media content on a computer.

[19] Levy, D., Wobbrock, J., Kaszniak, A. and Ostergren, M. Initial results from a study of the effects of meditation on multitasking performance. *CHI '11 Extended Abstracts on Human Factors in Computing Systems*. 2011-2016.
http://dl.acm.org/citation.cfm?id=1979862

[20] Lyubomirsky, S. The How of Happiness: A New Approach to Getting the Life You Want. Penguin Press, 2007.