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Does Multitasking Impair Studying? Depends on Timing

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Summary: It is often said that contemporary students frequently study while 'multitasking'. However, this rather diffuse term encompasses situations that vary as to the whether the learner controls the pace at which educational materials are provided. On the basis of prior cognitive research, we hypothesize that this may well be a critical determinant of interference. Three studies required students to read or listen to several short historical narratives and also to engage in five to eight very short conversations (akin to an instant messaging conversation). In Experiment 1, subjects read the narratives; here, multitasking marginally increased total time spent reading the narratives, especially when it occurred at random times. However, final memory for the narratives was not significantly affected. Similar results were obtained when the narratives were presented in audio format and the learner could pause them while conversing (Experiment 2). By contrast, when audio narratives did not pause, interruptions reduced comprehension performance (Experiment 3). Copyright © 2013 John Wiley & Sons, Ltd.

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It is a commonplace observation that the proliferation of digital technology that has occurred in recent years has led to a much greater amount of 'multitasking' in daily life. Of course, even before widespread digital technology, it was undoubtedly common for people to manage multiple tasks that overlapped in time (e.g., riding a horse and having a conversation). However, it seems very plausible that contemporary digital technology tempts or even requires people to switch from one source of visual or verbal information to another more frequently than would have been the case in the past.

Popular discussion of the increasing frequency of multitasking features two prominent—and rather contradictory—strands of thought. One is a very broad and undifferentiated condemnation of multitasking in all forms, especially as engaged in by students who combine studying with other tasks (e.g., Golovan, 2011; Straus, 2010). According to advocates of this negative view, multitasking is a contemporary curse, imperiling not only safe driving but also the educational achievement of modern youth. A second common idea, starkly opposed to the first, is that a new generation of 'super-tasking' young people is emerging whose brains have developed differently to the point that they have become superior multitaskers (e.g., Wallis, 2006). Both views seem to rest chiefly on casual observation and conjecture.

Dual-task research

The costs of multitasking[1] (often termed 'dual-task interference'; footnote 1) have been the subject of experimental research going back to the 1950s (for reviews, see Pashler & Johnston, 1998). One of the most robust findings to emerge from this research is the fact that the time sequence over which processing demands unfold is normally critical in determining the observable consequences of multitasking. For example, in the Psychological Refractory Period design, a person is required to perform two speeded choice tasks with stimuli presented very close together in time. In this situation, there is often little measurable interference when the stimulus onset asynchrony (temporal separation from the presentation of one stimulus to the presentation of the second) is, say, 1200 milliseconds; by contrast, when the same pair of tasks is performed with greater temporal overlap (say, with an asynchrony of 100 milliseconds), the time taken to perform the second task may be almost doubled (e.g., Pashler, Harris, & Nuechterlein, 2008, Figure 6). The point, then, is that whether two tasks show interference depends a great deal on the temporal structure of the situation. This finding seems to have had little impact on popular discussions of the effects of multitasking on educational and other real-world contexts (e.g., Straus, 2010). One of the purposes of the present paper is to present empirical evidence arguing that the effects of multitasking on real learning tasks are highly dependent on differences in timing (albeit over substantially greater time periods than those discussed in the refractory paradigm).

Multitasking and retention of information

Many cognitive researchers have performed studies in which people are presented with stimuli (such as word lists) while engaged in some secondary task and given the goal of trying to commit these stimuli to memory. The general finding is that even if the secondary task does not involve sensory inputs in the same modality as the stimuli to be remembered, multitasking still substantially impairs later memory for the stimuli (e.g., Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Mulligan, 1998; Naveh-Benjamin, Craik, Guez, & Dori, 1998). The problem appears to be a failure of storage, rather than a mere change in mental context, because if people multitask at the time of retrieval, this further exacerbates the interference, rather than alleviating it (Baddeley et al., 1984).

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[1] The term 'multitasking' is used here in a broad sense, to encompass any situation in which a person seeks to perform multiple tasks simultaneously or in a way that involves switching back and forth between one task and another. Empirical research on multitasking appears under a wide range of headers, including *dual-task performance, dual-task interference, divided attention, task switching, and task interruption*.

In light of this well established literature, it might seem obvious that any sort of multitasking occurring while people study educational materials is bound to be harmful. Despite great interest in this topic, there has been rather little controlled research in this area. A recent study by Fox, Rosen, and Crawford (2009) is pertinent, however. These researchers had 69 subjects read texts (described as 'SAT passages' or 'GRE passages', whose length was not mentioned). Subjects read the passage either in isolation or while engaging in a conversation with an experimental confederate using the internet chat utility *AOL Instant Messenger*. They were instructed 'to take as much time as they needed to read and understand the passage' (p. 52). A test on the contents of the passage was given (sometimes while the instant messaging task continued). The results showed that concurrent instant messaging produced an increase in reading times from 3.33 minutes to 5.53 minutes, a highly significant difference. (It appears that the reading time estimates were measured from the start of reading to the completion, although this was not completely clear from the method section.) Interestingly, however, there appeared to be no significant effect of concurrent task upon memory for the contents of the passages (although no information was provided in that paper about effect sizes and variability or even mean levels of performance).

Why might there be so little interference here? One important point of contrast between this study and the memory experiments described previously is the following. The subjects in Fox et al. (2009) were allowed to take as much extra time as they needed for the reading task when it was performed with multitasking. By contrast, the subjects in the laboratory experiments by Baddeley et al. (1984) and the other studies mentioned previously were given a fixed period to study a set of words, and when a concurrent task was imposed, subjects were not allowed to compensate by devoting extra time to the word lists. However, it is important to note that even when adequate time is potentially available to complete an interrupted task, this completion may or may not take place (as Dodhia & Dismukes (2009) point out, the completion itself represents a prospective memory task, and prospective memory is notoriously fallible.)

The present study

From a practical standpoint, both situations (multitasking with and without the potential for compensatory increase in total time devoted to the materials to be remembered) would seem to be of practical importance to real-world educational concerns. The student reading a textbook or listening to an audiotape or videotape while experiencing frequent interruptions can often take as much extra time as he or she needs. (Of course, time is a limited resource, so it would be important to know if the sum of the time needed for both tasks is likely to be greater than it would have been if the two tasks had been performed serially.) In other situations, however, such as a student watching a lecture or educational film or a class discussion (while potentially engaging in some additional task such as text messaging), the situation would not offer any option to pause the educational presentation.

On the basis of what has been described thus far, it might appear that any careful examination of multitasking effects on studying is bound to disclose that multitasking either harms learning or has no effect. In fact, though, it does not seem inconceivable that multitasking could potentially *enhance* learning in certain situations. As Bjork and colleagues have pointed out, manipulations that add complications to the tasks performed during study may often reduce performance during learning but enhance the success of learning as assessed by performance on a later test (Schmidt & Bjork, 1992; Battig, 1979). Thus, one could imagine that frequent interruptions, requiring the learner to periodically retrieve and reactivate the meaning of the last-read portion of the passage, might enhance learning as assessed with a later test.

To sort out these possibilities, we performed three experiments, examining the consequences of multitasking superimposed upon studying of narrative texts—with attention paid to the temporal structure of the situation.

EXPERIMENT 1

In the first experiment, subjects read three different passages while experiencing a different multitasking condition for each. The secondary task was chosen to provide at least a rough experimental equivalent to composing a text message. Two of the conditions required subjects to switch to this secondary task several times while reading (they differed in terms of whether the interruptions occurred randomly or only at the end of paragraphs). The third condition was the read-only control in which the subject did not have to engage in the secondary task. At the conclusion of each passage, subjects were tested on their comprehension of the material they had just read.

Method

Subjects

From the University of California, San Diego, 109 undergraduate students participated in return for course credit.

Design

The design was a within-subjects comparison between three different conditions: a control condition (Read-only) involving reading without any interruptions, a multitasking condition with interruptions at paragraph breaks (Multitasking-Paragraph Break, denoted MT-PB), and multitasking with interruptions at random times (MT-Random). Each subject reads three passages, one in each of the conditions. The assignment of texts to conditions was counterbalanced across subjects. The order in which the passages were presented (and hence the order of conditions) was individually randomized for each subject. The critical dependent variables were as follows: (1) time spent reading the texts and (2) performance on comprehension questions relating to each of the three texts.

Materials

Study passages were approximately 1500 words long and consisted of nine to ten paragraphs, written in an academic style and chosen to be interesting but unfamiliar to the

typical US college student. The passages had a mean Flesch reading ease score of 45.30 and a Flesch–Kincaid reading level of 12.57. The three passages dealt with the Canadian Arctic expeditions of John Franklin, the history of cheese production, and the history of manufactured fibers (Supporting Information). The secondary task in the two multitasking conditions required subjects to answer opinion questions (presented one at a time), with responses ranging from one to three sentences in length. These opinion questions (APPENDIX A) are related to current events and topics of general controversy. The comprehension tests given on the study passages consisted of 25 items each, of which 18 were in true/false format and seven were four-alternative multiple-choice questions. At the end of the experiment, subjects were given a questionnaire with questions on the following: (i) subjects' personal practices in regard to multitasking, instant messaging, and texting; (ii) which articles they found interesting; and (iii) which condition they thought they performed the best in (APPENDIX B).

Procedure

Subjects were seated at a computer terminal and instructed that they would be reading three passages, one under each of three different task conditions. They were also told that sometimes they would be asked to converse in writing about their opinions on questions posed to them while they were reading the passages. Opinion questions were presented in a separate and smaller pop-up window; when the opinion question was presented, the text of the passage was not visible. Subjects were required to provide at least 160 characters of response (when they submitted a response briefer than that they were prompted to elaborate). Subjects were instructed that their most important goal would be to learn as much information as possible from the passages—on which they would later be quizzed.

In the Read-only (control) condition, the passage was presented on the computer screen one paragraph at a time (paragraphs contained approximately 150–200 words). The subject clicked on a button labeled 'Next' with a mouse to advance to the next paragraph. Subjects read at their own pace but were not allowed to return to previous paragraphs.

In the MT-PB condition, opinion questions were displayed immediately after the subject clicked on the Next button to advance to a new paragraph. These interruptions occurred on a randomly chosen five out of the eight paragraph breaks.

In the MT-Random condition, the interruptions took place *within* a randomly chosen five out of nine paragraphs. At a randomly chosen time point between 5 and 15 seconds after they had started reading a paragraph, the opinion question was presented, and the text that was being read disappeared from the screen during that time. In each of the multitasking conditions, after the subject had typed a response to the opinion question into the box provided on the computer screen, she/he was returned to the passage reading task (in the MT-PB condition, she/he would go on to view the next paragraph, whereas in the MT-Random condition, the same text display that had been visible prior to the interruption would reappear on the screen).

After subjects finished reading each passage, they took a comprehension test on the material. Questions were presented one at a time, with no option to return to previous questions and no feedback about the correctness of responses. Upon the completion of the last comprehension test, subjects completed the questionnaire described previously (APPENDIX B).

Results and discussion

The mean reading times are displayed in Figure 1. As can be seen in Figure 1, there was a trend toward an increase in reading time for the conditions in which reading was interrupted—and particularly when the interruptions occurred while the subject was reading individual paragraphs. A repeated measures analysis of variance (ANOVA) revealed a marginally significant effect of study condition, $F(2, 216) = 2.75$, $p = .066$, $\eta_p^2 = .025$. Pairwise comparisons among the three conditions indicated that the only significant difference was between the MT-Random and Control conditions, $t(108) = 2.31$, $p = .023$ (uncorrected), $d = 0.22$.

The mean comprehension scores are shown in Figure 2. Differences between conditions were minimal, and a repeated measures ANOVA showed no significant effect of study condition, $F(2, 216) = 1.96$, $p = .144$. The effect size for the difference between the Control and the MT-PB condition was $d = 0.12$, and the effect size for the difference between the Control and the Random was $d = 0.07$. These are both in the range commonly understood to be extremely small effects.

When asked on a questionnaire at the end of the experiment which condition they thought they performed best and worst in, the majority of subjects thought that their comprehension was worst in the MT-Random condition (57%; 17% answered MT-PB; 26% answered Read-only) and best in the Read-only condition (48%; 34% answered MT-PB; 18% answered MT-Random). Also, when asked whether they thought that 'instant messaging' or 'texting' while studying affects memory for the material, 89% answered in the affirmative. Interestingly, even though the majority of subjects seemed to have the metacognitive belief that multitasking hurts reading comprehension, 89% of subjects indicated that they multitasked 'sometimes' or 'often' while studying.

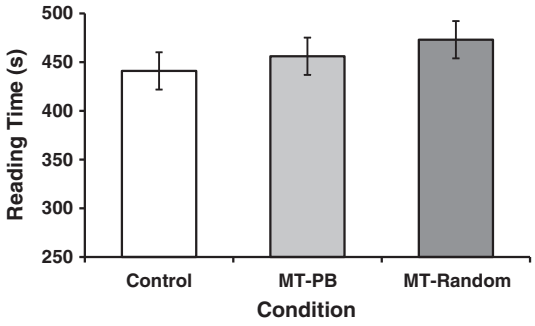

Figure 1. Mean reading time as a function of study condition in Experiment 1. The times for the multitasking conditions reflect the total time spent both before and after the opinion question but exclude the time during which the subject viewed and responded to the opinion question. Error bars represent 95% confidence intervals

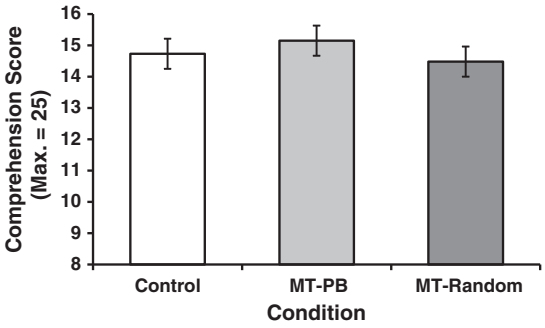

Figure 2. Mean comprehension score as a function of study condition in Experiment 1. Error bars represent 95% confidence intervals

EXPERIMENT 2

The second experiment posed the same question as the first using the same educational materials, the same conversational task, and the same tests. The main difference, however, was that the educational materials were audio taped and presented in spoken form. Aside from the difference in modality, there was also a rather subtle difference: When a person is interrupted in reading, they could potentially start reading at point prior to where they left off, thus providing themselves with a brief review of the final portion of the reading materials; with an audiotape that pauses and then resumes at the exact point of interruption (as in Experiment 2), this opportunity is not present. Conceivably, this could affect the results.

Method

Subjects

From the University of California, San Diego, 109 undergraduate students participated in return for course credit.

Design

The design was a within-subjects comparison between three different conditions: a control condition involving listening without any interruptions (Listen-only), MT-PB, and MT-Random. Each subject listened to three passages, one in each of the conditions. The assignment of passages to conditions was counterbalanced across subjects. The order in which the passages were presented (and hence the order of conditions) was individually randomized for each subject. The critical dependent variable was performance on comprehension questions relating to each of the passages.

Materials

Experiment 2 used the same educational materials, the same conversational task, and the same tests as in the first experiment.

Procedure

Subjects were seated at a computer terminal and instructed that they would be listening to three passages, one under each condition. They were told that sometimes, they would have to answer unrelated opinion questions while they were listening to the passages but that their main goal was to remember as much information as possible about the passages because they would later be quizzed on them.

Subjects listened to the audio presentation of the material through headphones and were unable to voluntarily pause or fast-forward through the content. In the Listen-only condition, subjects listened to an audio presentation of the material, which was approximately 9 minutes long, straight through without any interruptions. In the MT-PB condition, subjects listened to the audio presentation with five different interruptions in between paragraphs during which the audio playback stopped and they responded to opinion questions. In the MT-Random condition, the interruptions took place within five of the paragraphs, at times that would have appeared random to the subject. The timing of the 'random' interruptions was actually predetermined so as to avoid having interruptions in the middle of words, which would have impaired auditory word recognition. (For each passage, three different random timings for the five interruptions were created in advance—with the constraint that the interruptions would not occur mid-word—and the particular set of interruption timings used for each subject was randomly selected by the computer.) In keeping with the presentation of the material in Experiment 1, the audio presentation paused while the conversational task was performed. During these pauses, the audio stopped playing, and a box appeared on the computer screen containing an opinion question and a text box to provide a response. Once the subject finished typing a response and pressed the submit button, audio playback continued where it had left off.

After subjects finished listening to each passage, they took a comprehension test on the material, followed by a questionnaire at the end of the experiment, presented in \exactly the same way as in Experiment 1.

Results and discussion

The mean comprehension scores are shown in Figure 3. Differences between conditions were minimal, and a repeated measures ANOVA showed no significant effect of study condition, $F(2, 216) = .678$, $p = .509$. The effect size for the difference between the Control and the MT-PB condition was $d = 0.02$, and the effect size for the difference between the Control and the Random was $d = 0.11$ (again, extremely small effects).

The questionnaire at the end of the experiment contained the same questions as in the previous experiment except that

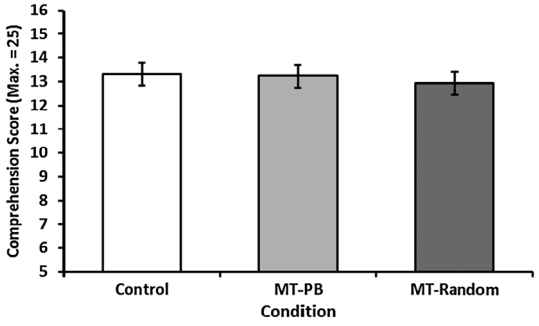

Figure 3. Mean comprehension score as a function of study condition in Experiment 2. Error bars represent 95% confidence intervals

it included a question asking whether students used podcasts or audiobooks to study. Of subjects, 54% reported using podcasts or audiobooks to study 'sometimes' or 'often', whereas 46% use these methods 'rarely'. The majority of subjects thought that their comprehension was worst in the MT-Random condition (52%; 16% answered MT-PB; 32% answered Listen-only) and best in the Listen-only condition (45%; 41% answered MT-PB; 14% answered MT-Random). Although 87% of respondents believed that instant/text messaging while studying affected their recall memory, 67% of subjects said they still did so while studying.

EXPERIMENT 3

The first two studies reported previously disclosed that whether educational passages were read or spoken, a secondary conversational task presented so that the learner had the opportunity to pause the presentation of the educational narratives while doing the conversational task produced (a) little cost to later memory for the narratives and (b) a slight increase in the total time spent reading the material. With regard to (b), it should be kept in mind that the slight increase is over and above the extra time taken for the secondary task. As noted in the Introduction, however, many real-world multitasking situations do not allow the learner to control the presentation of educational content and to pause presentations at will (listening to a lecture in class is one obvious example of this). Experiment 3 used the same audio presentations as Experiment 2, except that here, the audio presentations did not stop while the person carried out the conversational task (as in the previous experiments, the conversational task did not involve audio input or output).

Method

Subjects

From the University of California, San Diego, 82 undergraduate students participated in return for course credit.

Design

The design was a within-subjects comparison between two different conditions: Listen-only and MT-Random. Each subject listened to two passages being read, one in each of the conditions. The assignment of passages to conditions was counterbalanced. The ordering of the passages (and hence the ordering of the conditions) was randomized for each subject. The critical dependent variable was performance on comprehension questions relating to each of the passages.

Materials

Experiment 3 used the same educational materials, the same conversational task, and the same tests as in the first two experiments.

Procedure

Experiment 3 used the same procedure as Experiment 2, the only difference being the circumstances of the multitask condition.

In the Listen-only condition, subjects listened to the entire nine-minute passage all the way through. There was no way for the subject to pause or advance the passage. In the MT-Random condition, the subject was presented with five opinion questions, presented randomly throughout the presentation of the passage in a separate, smaller pop-up window. At the presentation of this pop-up window, an alert noise sounded—a very brief beep similar to one produced by an instant messaging program or a text alert on a cell phone During the time that the opinion question was presented, the audio reading of the passage continued to play. Again, there was no way to pause or advance the speed of the audio passage. To ensure that subjects were performing the secondary task, we informed subjects that they had 40 seconds to answer the question, and in the same window, the time remaining was counted down. After 40 seconds, the pop-up window went away.

After subjects finished listening to each passage, they took a comprehension test, followed by a questionnaire at the end of the experiment, just as in Experiments 1 and 2.

Results and discussion

The mean comprehension scores are shown in Figure 4. There was a significant decrease in performance on the comprehension test for subjects in the MT-Random condition, relative to the Listen-only condition (the means in the two conditions were 45 and 54, respectively). A repeated measures ANOVA showed a significant effect of the study condition, $F(1, 81) = 26.38$, $p < .001$, $\eta_p^2 = .25$. The difference corresponded to a Cohen's d effect size of 0.57, normally classified as a medium-sized effect.

GENERAL DISCUSSION

The results can be summarized as follows. Multitasking produced a marked and substantial reduction in information acquired from educational materials when the materials were presented in spoken form and played without waiting for the learner. On the other hand, when the learner read the materials at his or her own pace, there was no sizable or significant reduction in information acquired. This was true even when the interruptions occurred at moments chosen by the experimenter, rather than the learner. Finally, listening to the materials and pausing to do the concurrent task were also relatively harmless.

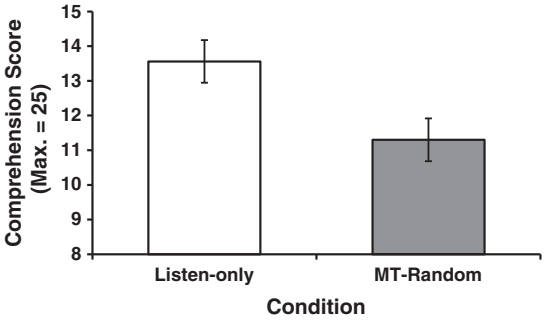

Figure 4. Mean comprehension score as a function of study condition in Experiment 3. Error bars represent 95% confidence intervals

The results have practical and theoretical implications. The practical implications are that there is no reason to believe that people studying factual material and permitting themselves to be interrupted on many occasions are consequently likely to learn much less. Undifferentiated warnings against the perils of multitasking while studying (e.g., Golovan, 2011; Straus, 2010)—at least when the studying involves reading fact-dense text material—seem overblown. On the other hand, we do not see any 'desirable difficulty' effect (Schmidt & Bjork, 1992) whereby the interruptions would enhance learning. Our results also indicate that when the presentation of educational materials is paced by events in the world—as it is in a lecture situation, for example—multitasking can have a large detrimental effect on learning—generally in keeping with the literature on 'divided attention effects on memory encoding' (e.g., Baddeley et al., 1984). Although these effects of temporal overlap are perhaps not entirely surprising from a common-sense standpoint, it is striking that this distinction between what might be termed interruption multitasking and simultaneous multitasking has not, as far as we can tell, figured in popular discussions of the perils or benefits of multitasking.

As mentioned in the Introduction (footnote 1), formal studies of multitasking (in the broad sense in which that term is used here) have appeared under a variety of labels, including *divided attention, task switching, interruption*, and *dual-task performance*. It would be tempting to say that the results described here suggest that interruption produces fairly minor effects on memory storage compared with true dual-task performance. However, research on bottleneck models of divided attention suggests that a great deal of what appears superficially to be parallel performance of two tasks at the same time is actually accomplished by a covert switching at the level of central processing operations, necessitated by the existence of a *central processing bottleneck* (Pashler, 1998, Chapter 7). It is not entirely clear whether encoding of information into long-term memory is subject to this same bottleneck in whole or in part (Pashler, 1998, Chapter 8). If it is, then it would seem accurate to say that even seemingly concurrent performance of a task and storage of information in memory actually involves a covert process of interruption and resumption.

Limitations

Several very important potential limitations should be noted. First, while the effects of multitasking in the pause conditions are small (as quantified, for example, with Cohen's *d* or when viewed as a proportional reduction in learning), a more sensitive test might have disclosed some effects. To the current authors, it seems implausible to suppose that the true costs are exactly zero. For example, it is possible that content close to the interruption point suffers from the interruption, but this effect was undetectable in the current study because it was aggregated together with content further from the interruption point. Follow-up research on this point could potentially use two counterbalanced sets of interruption points to determine if proximity to the interruption point is associated with greater costs. Of course, in principle, it is also possible that people may overcompensate for interruption, in which case proximity could (for some or all subjects) be associated with improvement rather than cost.

In any case, from a practical standpoint, whether or not one chooses to draw the conclusion that multitasking in this situation is 'harmless enough' should depend upon the practical situation one finds oneself in. If the goal is absolutely to maximize performance, then, it would probably be wise to avoid all forms of multitasking.

Second and perhaps more importantly, the learning task here required the learner to comprehend and store many facts in long-term memory, and it seems like a reasonable model for many tasks that go by the name 'studying'. However, it did not require the learner to synthesize new contents of their own, as for example in constructing a math proof, writing a computer program, or writing an essay. It seems plausible to the current authors that frequent interruption during this sort of synthetic tasks might well be more injurious to performance (and perhaps also to the acquisition of greater skill). Thus, it would be a mistake to conclude from the present results that multitasking while doing schoolwork is quite harmless so long as it is possible to pause the educational task—as a superficial reading of the present results might imply. Testing the effects on a range of synthetic academic tasks would seem to be an important task for future research on multitasking and education, but it will be challenging given the difficulties of obtaining reliable and valid measures of the quality of the output people produce in such tasks.

ACKNOWLEDGEMENTS

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APPENDIX 1

Opinion Questions

During your midterm you notice two students sitting nearby cheating on their test. What would you do?

What is your opinion of people spanking their children?

Is capital punishment ever justified, even when there is solid evidence linking the accused to the crime? Why or why not?

Should the family of the murder victim have the right to decide the murderer's fate? Why or why not?

What are your beliefs on animal research? When is animal research justified?

Should marijuana be legalized? Why or why not?

What are your views on former vice-presidential candidate Sarah Palin?

Under what conditions would you help a homeless person?

Do you believe that the new UC fee hikes are necessary given the lack of state funding for higher education? Why or why not?

APPENDIX 2

Questionnaire

How often do you multitask while studying?

(i) Rarely (ii) Sometimes (iii) Often

Do you use any kind of instant messaging program or SMS (texting)?

(i) Rarely (ii) Sometimes (iii) Often

Do you open your instant message program or text while studying?

(i) Yes (ii) No

Do you think that instant messaging/texting while studying affects your recall memory?

(i) Yes (ii) No

Was the article about manufactured fibers interesting to you?

(i) Yes (ii) No

Was the article about the Franklin Expedition interesting to you?

(i) Yes (ii) No

Was the article about the history of cheese interesting to you?

(i) Yes (ii) No

In which task do you think you did best?

(i) No Interruptions
(ii) Random Interruptions
(iii) Paragraph Interruptions

In which task do you think you did worst?

(i) No Interruptions (ii) Random Interruptions
(iii) Paragraph Interruptions

We are trying to understand how multitasking during studying affects students' performance. Please leave any comments describing how well you think you performed during the different conditions and why.