Laptop multitasking hinders classroom learning for both users and nearby peers

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ABSTRACT

Laptops are commonplace in university classrooms. In light of cognitive psychology theory on costs associated with multitasking, we examined the effects of in-class laptop use on student learning in a simulated classroom. We found that participants who multitasked on a laptop during a lecture scored lower on a test compared to those who did not multitask, and participants who were in direct view of a multitasking peer scored lower on a test compared to those who were not. The results demonstrate that multitasking on a laptop poses a significant distraction to both users and fellow students and can be detrimental to comprehension of lecture content.

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1. Introduction

Multitasking is ingrained in our daily lives. As you read this article, you may also be attending to a text message, sipping coffee, or writing out a list of to-dos. Such a lifestyle is intended to increase efficiency; however, there are limitations to how well multiple tasks can be carried out concurrently (Posner, 1982). Multitasking places considerable demands on cognitive resources, which, in turn, degrades overall performance, as well as performance on each task in isolation (Broadbent, 1958). The issue of multitasking and its consequences has become a growing concern in education, as students are more commonly found engaged with their laptops or smartphones during class time. The current study investigated the effect of laptop multitasking on both users and nearby peers in a classroom setting.

There is a host of theoretical and experimental research on divided attention and dual-task interference, terms that we consider homologous to multitasking and therefore relevant to the current discussion. Research suggests that we have limited resources available to attend to, process, encode, and store information for later retrieval (Posner, 1982). When focused on a single primary task, our attentional resources are well directed and uninterrupted, and information is adequately processed, encoded, and stored (Naveh-Benjamin, Craik, Perretta, & Tonev, 2000). When we add a secondary task, attention must be divided, and processing of incoming information becomes fragmented. As a result, encoding is disrupted, and this reduces the quantity and quality of information that is stored (Pashler, 1994). When we eventually retrieve information that was processed without interruptions, as a primary task, we are likely to experience minimal errors. When we retrieve information that was processed via multitasking or with significant interruptions from a secondary task, we are more likely to experience some form of performance decrement (Wickens & Hollands, 2000).

Indeed, managing two or more tasks at one time requires a great deal of attention. Attentional resources are not infinite (Konig, Buhner, & Murling, 2005; Pashler, 1994). When the level of available attentional resources is less than what is required to complete two simultaneous tasks, performance decrements are experienced since both tasks are competing for the same limited resources. This is especially true if both tasks are competing for resources within the same sensory modality (Navon & Gopher, 1979; Wickens, 2002; Wickens & Hollands, 2000). Limits to attentional resources means the quality (accuracy) and efficiency (reaction time) at which multiple tasks are processed will be compromised (Rubinstein, Meyer, & Evans, 2001). Numerous experimental studies have shown performance decrements under conditions of multitasking or divided attention (e.g., Broadbent, 1958; Tulving & Thomson, 1973).

Theoretical and empirical findings on multitasking are especially significant when considered in the context of student learning. In classroom environments, students tend to switch back and forth between academic and non-academic tasks (Fried, 2008). This behavior poses concerns for learning. The presumed primary tasks in many university classes are to listen to a lecture, consolidate information spoken by the instructor and presented on information slides, take notes, and ask or respond to questions. On their own, these activities require effort. If a secondary task is introduced, particularly one that is irrelevant to the learning context, attention must shift back and forth between primary and secondary tasks, thereby taxing attentional resources. This multitasking can result in weaker encoding of primary information into long-term memory (Bailey & Konstan, 2006; Ophira, Nass, & Wagner, 2009).

The personal computer provides a compelling source of classroom distraction and has become commonplace on university campuses. Survey data estimates that 99% of incoming freshmen own a laptop (University of Virginia, 2009) and about 65% of students bring their laptop to class (Fried, 2008). Research on educational laptop use addresses both the pros and cons of using this technology in the classroom. On the one hand, laptops have been shown to assist learning through active approaches to teaching (Finn & Inman, 2004) and promotion of academic success (Lindorth & Bergquist, 2010; Weaver & Nilson, 2005). When used for academic purposes such as taking notes and using software programs (Driver, 2002), accessing supplemental resources and web-based activities (Debevec, Shih, & Kashyap, 2006), and viewing Power-Point slides (McVay, Snyder, & Graetz, 2005), in-class laptop use can increase satisfaction, motivation, and engagement among students (Fried, 2008; Hyden, 2005; Weaver & Nilson, 2005). On the other hand, studies suggest that students who use laptops in class report low satisfaction with their education, are more likely to multitask in class, and are more distracted (Wurst, Smarkola, & Gaffney, 2008). Student self-reports and classroom observations suggest that laptops are being used for non-academic purposes, such as instant messaging and playing games (Barak, Lipson, & Lerman, 2006; Driver, 2002), checking email and watching movies (Finn & Inman, 2004), and browsing the Internet (Bugeja, 2007). Access to online entertainment makes it increasingly difficult for instructors to be "more interesting than YouTube" (Associated Press, 2010, p. 10), especially if students aren't intrinsically motivated by the subject materials. Moreover, time spent multitasking with these activities is significant; data from one study estimates that students multitask for approximately 42% of class time (Kraushaar & Novak, 2010).

Importantly, distractions from in-class multitasking correlate with decrements in learning. Students who multitask on laptops during class time have impaired comprehension of course material and poorer overall course performance (Barak et al., 2006; Hembrooke & Gay, 2003; Kraushaar & Novak, 2010). In a recent study, Wood et al. (2012) measured the detriments of technology-based multitasking in a classroom setting. This study is one of few in the field that employed an experimental design (much of the literature is self-report). Students were assigned either to a single multitasking condition (using Facebook, MSN, email, or cell phone texting), a control group (paper and pencil notes-only or word processing notes-only), or a free-use-of-technology condition (where participants could choose to multitask or not multitask on their laptop as much as they wished). Over the course of three class lectures, participants' comprehension of the material was assessed via quizzes. In general, paper and pencil control participants outperformed multitasking participants on the quiz assessments (particularly MSN and Facebook users). However, as the authors admit, there were limitations to the methodology of this study. Most noteworthy was that 43% of participants self-reported that they did not adhere to their assigned instructions across all three lectures. For example, a participant assigned to the Facebook multitasking condition may have multitasked on Facebook and on MSN (i.e., two forms of multitasking when they were instructed only to use one form), or chosen not to multitask on Facebook at all. Therefore, the experimental manipulation was not successful, calling into question the validity of the quiz data. Although the authors corrected for this limitation in post-hoc analyses, the results should be interpreted with caution as they are reliant on self-report and the sample size of each group was significantly reduced. Wood et al.'s findings are relevant but restricted in terms of the pedagogical recommendations that can be offered. One goal of the present study was to replicate the findings of Wood et al. using a more controlled design and more stringent fidelity measures.

Disrupting one's own learning is an individual choice; harming the learning of other students in the class is disrespectful. Laptop distractions due to movement of images and laptop screen lighting (Melerdiercks, 2005) and multitasking activities (Crook & Barrowcliff, 2001) may cause involuntary shifts of attention among students in close proximity to laptop users (Barak et al., 2006; Chun & Wolfe, 2001; Finn & Inman, 2004). These studies suggest that students are annoyed and distracted by laptop use. However, to our knowledge, no studies have directly measured the effects of distraction caused by laptop users on surrounding peers' learning. Therefore, a second goal of the present study was to examine the indirect effects of laptop multitasking on student learning.

2. Experiment 1

In Experiment 1, we investigated whether multitasking on a laptop would hinder learning as measured by performance on a comprehension test. All participants were asked to attend to a university-style lecture and take notes using their laptops as a primary task. Half the participants, by random assignment, received additional instructions to complete a series of non-lecture-related online tasks at any convenient point during the lecture. These tasks were considered secondary and were meant to mimic typical student web browsing during class in terms of both quality and quantity. We hypothesized that participants who multitasked while attending to the lecture would have lower comprehension scores compared to participants who did not multitask.

2.1. Method

2.1.1. Participants

Forty-four undergraduate students from a large comprehensive university in a large Canadian city participated in the study (25 females; M age $= 18.9$ years, $SD = 2.0$). All participants were enrolled in an Introductory Psychology course and received course credit for participating in the experiment. Participants represented a variety of undergraduate disciplines (i.e., not only psychology). They were recruited using an online portal designed for psychology research, which explained that the study involved listening to a class lecture and filling out a few questionnaires. Only students who could bring a personal laptop to the experiment were invited to participate. Forty participants were included in the final data analysis, which included two experimental conditions: multitasking ($n = 20$) and no multitasking ($n = 20$). Of the four participants removed from the analysis, two had previous knowledge of the lecture content (as measured by a screening questionnaire), one performed below chance on the comprehension test, and one failed to follow instructions. The former two participants were removed from the no multitasking condition, and the latter two participants were removed from the multitasking condition.

2.1.2. Materials

A 45-min PowerPoint lecture on meteorology was created by one of the experimenters (TW) in conjunction with her peer colleagues and a faculty member with many years of teaching experience. The lecture was based on topics taken from an introductory meteorology textbook (Ahrens, 1999; e.g., discriminating cloud types, pressure systems, thunderstorm development). A second faculty member with expertise in Geology and Earth Sciences reviewed the lecture and approved the accuracy of its content, level of difficulty, and consistency with materials presented in related undergraduate classes (S. Carey, personal communication, August 16, 2012). The same experimenter (TW), an upper-level graduate student with lecturing experience, acted as the "professor" and presented the lecture live to the class. At the time of data collection, TW had practiced and given this lecture over a dozen times for an independent study. She followed a memorized script.

For the multitasking condition, a set of 12 online tasks was created. An example of a task was "What is on Channel 3 tonight at 10 pm?" These online tasks were meant to mimic typical student browsing during class in terms of both quality (i.e., visiting websites of interest to a young adult sample, such as Google, YouTube, and Facebook) and quantity [~40% of class time, as suggested by Kraushaar and Novak (2010)]. A pilot study ($n = 5$), confirmed that completion of the tasks was not overwhelming; tasks could be completed in ~15 min (or 33% of the lecture time). Although we do not know if the participants of our study multitask more or less than 33% during lectures in a real-world setting, the online tasks were within the critical range of previously reported time spent on multitasking in real-world classrooms (~40%), and therefore unlikely to artificially increase the costs of multitasking.

The primary measure of learning was a four-option multiple-choice comprehension test with 20 questions evaluating simple knowledge (i.e., basic retention of facts from the lecture) and 20 questions evaluating application of knowledge (i.e., applying a concept from the lecture to solve a novel problem). Question type was included as variable to examine whether multitasking outcomes might differ depending on the difficulty level of the material being tested. There is some evidence to suggest that multitasking may be particularly detrimental to complex knowledge (e.g., Foerde, Knowlton, & Poldrack, 2006). The ordering of the questions on the test (simple vs. complex) was intermixed.

Participants also completed a brief questionnaire that collected demographic data (e.g., age, gender, and fluency in English) and screened participants for prior familiarity with the lecture content and general interest in the lecture presentation. Additionally, there were two questions, both listed on a 7-point Likert scale, directed toward participants in the multitasking condition: (1) To what extent do you think the act of multitasking hindered your learning of the lecture material? (1 = did not hinder my learning; 4 = somewhat hindered my learning; 7 = definitely hindered my learning) and (2) To what extent do you think your multitasking hindered the learning experience of other students? (1 = did not hinder others' learning; 4 = somewhat hindered others' learning; 7 = definitely hindered others' learning). Responses to these questions allowed us to measure subjective student views on multitasking outcomes.

2.1.3. Design and procedure

All participants were asked to bring their personal laptops to the experiment. They received an instruction sheet and a consent form. The instruction sheet asked participants to attend to the lecture and use their personal laptop to take notes on the information being presented, just as they might normally do in class. In addition to taking lecture notes, half of the participants (randomly selected) were instructed to complete the 12 online tasks at some point during the lecture.

The experiment was conducted in a classroom with four rows of tables, each with five chairs. Therefore, since there was a maximum of 20 seats, we repeated the experiment three times to obtain a total sample of 44 participants [each repeat included roughly the same number of total participants (range: 14–15), and an equal divide of participants within the two experimental conditions]. Participants faced a projector screen at the front of the classroom. Instruction sheets were randomly placed at each seat. Thus, seat location of participants in each condition was fully random. Participants were randomly presented with a seat number as they entered the classroom and were asked to settle in and read the instruction sheet and consent form at their assigned seat. While all participants were instructed to take notes on their laptops during the lecture, some were also required to complete the series of online tasks. An experimenter (FS) remained at the back of the classroom during the lecture presentation and used a seating map to track participants' seat location, monitor participants' screen activities, and ensure that all instructions were being followed. At the end of the lecture, participants were asked to email their notes and (if applicable) their responses to the online tasks to the experimenters and, finally, to put away their laptops. The comprehension test immediately followed and a 30 min time limit was enforced (as time limits are realistic of typical university examinations). All participants completed the test within the time limit. Once the experimenters collected all the tests, participants responded to the questionnaire, were debriefed and dismissed.

2.1.4. Fidelity measures

FS closely monitored participants' activities throughout the lecture presentation, observing each participant's activities at least once every 3–4 min interval. This was done to ensure that all participants adhered to their assigned instructions. If a participant was not on task (e.g., a non-multitasker engaging in multitasking activities, a multitasker browsing on a website irrelevant to the online tasks, or a multitasker completely ignoring the online tasks), they were probed once and reminded of their specific instructions. If a participant was probed more than 2 times, their data were discarded from the final analysis ($n = 1$).

Participants' notes and online task answers were analyzed for completion and quality. In terms of the online tasks, all multitaskers attempted to answer at least some of the tasks. On average, multitaskers successfully completed 9 out of the 12 tasks ($M = 0.75$; $SD = 0.25$). In terms of participants' notes, all participants took some form of notes on the lecture content. Notes were scored for quality (1–5) by the experimenter most familiar with the material (TW). She was blind to participants' condition while scoring. A score of 1 meant the participant attempted to copy the lecture slides verbatim, but the notes were disorganized and/or missing information. A score of 3 meant the participant copied the lecture slides verbatim, but did not include additional information presented verbally by the lecturer. A score of 5 meant the participant copied all slide information and included all information presented verbally by the lecturer. Analysis of the quality scores revealed that multitaskers' notes ($M = 2.7$, $SD = 1.2$) were of a poorer quality than non-multitaskers' notes ($M = 4.1$, $SD = 1.0$), $t(34) = 3.6$, $p = .001$, $\omega^2 = .23$.

Therefore, our fidelity measures (i.e., participant monitoring, discarded data, analysis of notes and online tasks files) clearly show that participants stayed on task throughout the experiment. It is evident that multitasking played a role in impairing participants' note-taking ability.

2.1.5. Results and discussion

There were no demographic differences between participants of the two conditions in terms of age, gender, fluency in English, or high school GPA. To examine potential differences between conditions on the comprehension test, a 2 (condition: multitasking, no multitasking) × 2 (question type: simple, complex) mixed factorial ANOVA was conducted with condition as a between-subjects factor and question type as a within-subjects factor. The main effect of condition was significant, $F(1,38) = 10.2$, $p = .003$, $\omega^2 = .20$. Participants who multitasked during the lecture ($M = 0.55$, $SD = 0.11$, $n = 20$) scored significantly lower than participants who did not multitask ($M = 0.66$, $SD = 0.12$, $n = 20$). The main effect of question type was also significant, $F(1,38) = 17.7$, $p < .001$, $\omega^2 = .30$. Participants scored higher on simple factual questions ($M = 0.60$, $SD = 0.13$, $n = 20$) than on complex apply-your-knowledge questions ($M = 0.56$, $SD = 0.13$, $n = 20$). This main effect simply reflects the difficulty of the questions created. The interaction was not significant, $F(1,38) = 0.79$, $p = .380$. These findings demonstrate a strong, detrimental effect of multitasking on comprehension scores. Overall, participants who multitasked scored 11% lower on a post-lecture comprehension test (Fig. 1).

3. Experiment 2

In Experiment 2, we investigated whether being in direct view of a multitasking peer would negatively influence learning as measured by performance on a comprehension test. A new group of participants was asked to take notes using paper and pencil while attending to the lecture. Some participants were strategically seated throughout the classroom so that they were in view of multitasking confederates on laptops, while others had a distraction-free view of the lecture. Confederates mimicked multitaskers from Experiment 1 by typing notes on the lecture and performing other concurrent, irrelevant online tasks. We hypothesized that participants who were seated in view of multitasking peers would have lower comprehension scores compared to participants who had minimal or no visual distraction from multitasking peers.

3.1. Method

3.1.1. Participants

Thirty-nine undergraduate students from the same university participated in the study (26 females; M age $= 20.3$ years, $SD = 4.2$). None had participated in Experiment 1. Recruitment procedures and participant incentives were the same as in Experiment 1. Thirty-eight participants were included in the final data analysis, which included two experimental conditions: in view of multitasking peers ($n = 19$) and not in view of multitasking peers ($n = 19$). The one participant excluded from the analysis was removed because of prior familiar with the lecture content (as measured by a screening questionnaire). Thirty-six undergraduate students were recruited to be confederates.

3.1.2. Materials

The same materials were used as in Experiment 1 with the exception of two questions on the questionnaire. Instead of asking about whether or not multitasking hindered self and peer learning, the two questions in this experiment were directed toward participants in view of technology: (1) To what extent were you distracted by other students' laptop use around you? (1 = not distracted at all; 4 = somewhat distracted; 7 = very distracted) and (2) To what extent do you think being in view of other students' laptop use hindered your learning of the lecture material? (1 = did not hinder my learning; 4 = somewhat hindered my learning; 7 = definitely hindered my learning). Responses to these questions provided us with subjective student measures on whether or not their multitasking peers were a distraction, and whether they perceived this distraction to be a barrier to learning.

3.1.3. Design and procedure

As in Experiment 1, participants were asked to bring their personal laptops to the experiment; however, only those assigned as confederates actually used their laptops ($n = 36$). The experimental participants ($n = 38$) were instructed to keep their laptops in their knapsacks.
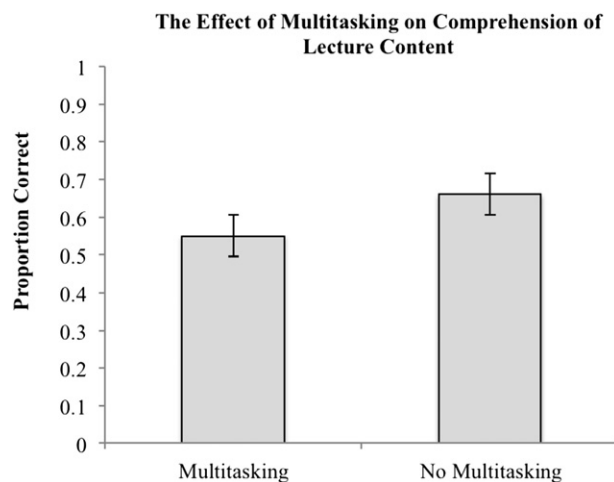

Fig. 1. Proportion correct on the comprehension test as a function of condition (multitasking vs. no multitasking). Multitasking lowered test performance by 11%, $p < .01$. Error bars represent standard error of the mean.

All participants received an instruction sheet and a consent form. The confederates' instruction sheet explained that they were confederates, and they were required to use their laptops to flip between browsing the Internet (e.g., email, Facebook) and pretending to take notes on the lecture content as the lecture was presented. In fact, they were told they were not required to pay attention to the lecture. The participants' instruction sheet asked them to keep their laptops stored, and to use the paper and pencil provided by the experimenters to take written notes on the lecture content, just as they might normally do in class.

The room set-up was the same as in Experiment 1. Again, since there was a maximum of 20 seats, we repeated the experiment four times to obtain a total sample of 39 experimental participants and 36 confederates [each repeat included roughly the same number of total participants (range: 18–20), with more confederates in the classroom than participants (roughly a 2:1 ratio)]. Instruction sheets and consent forms were strategically placed at each seat. Participants were randomly presented with a seat number as they entered the classroom. Some participants were seated so that they were behind two multitasking confederates (i.e., they were in view of one laptop user in their left visual field and another laptop user in their right visual field; Fig. 2). These participants were considered in view of multitasking peers. Other participants were seated behind participants who, like themselves, were asked to take written notes on the lecture. These participants were considered not in view of multitasking peers (Fig. 2).

The lecture was presented as in Experiment 1. While the lecture was being presented, an experimenter (FS) remained at the back of the classroom and used a seating map to track participants' and confederates' seat locations, monitor laptop screen activities and note-taking, and ensure that all instructions were being followed. When the lecture ended, written notes were collected from the participants, and confederates were asked to finish up their work and store their laptops. At this point, confederates were asked to leave the room. They were debriefed by one of the experimenters and dismissed. The remaining participants were given the comprehension test and a 30 min time limit was enforced, with all participants successfully completing the test within the time limit. To maintain motivation levels, participants were told a cover story that those students who had left the classroom were going to return one day later, at which time they would complete a delayed comprehension test. Once the experimenters collected all the tests, participants responded to the questionnaire, were debriefed and dismissed.

3.1.4. Fidelity measures

FS closely monitored participants' activities throughout the lecture presentation, as in Experiment 1. This was done to ensure that all participants adhered to their assigned instructions. If a participant or confederate was not on task (e.g., a confederate not using their laptop,
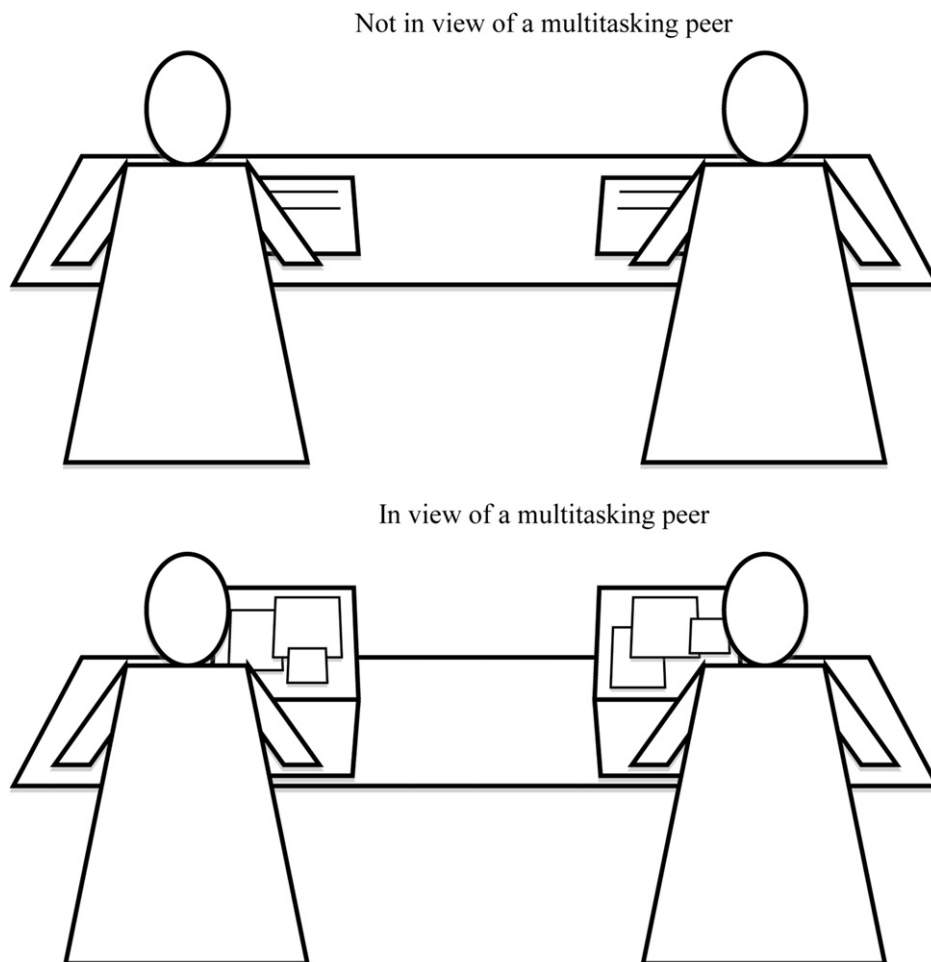

Fig. 2. Visual representation of participants who were and were not in view of a multitasking peer. In view participants were strategically seated behind two confederates, with one confederate's laptop screen ~45° to the participant's right and the other's ~45° to the participant's left. Not in view participants were seated similarly behind two experimental subjects who took handwritten notes.

or a participant not taking any notes), they were probed and reminded of their specific instructions. All confederates and participants complied with their instructions.

Participants' notes were scored for quality using the same scale reported in Experiment 1. All participants took some form of notes on the lecture content. The notes of participants not in view of multitasking peers ($M = 3.6$, $SD = 1.3$) were similar in quality to the notes of participants in view of multitasking peers ($M = 3.7$, $SD = 1.2$), $t < 1$.

Therefore, our fidelity measures (i.e., participant monitoring, analysis of notes) clearly show that participants stayed on-task throughout the experiment and took comprehensive notes. Being in view of multitasking peers did not reduce note quality.

3.1.5. Results and discussion

There were no demographic differences between participants of the two conditions in terms of age, gender, fluency in English, or high school GPA. To examine potential differences between conditions on the comprehension test, a 2 (condition: in view of multitasking, not in view of multitasking) × 2 (question type: simple, complex) mixed factorial ANOVA was conducted with condition as a between-subjects factor and question type as a within-subjects factor. The main effect of condition was significant, $F(1,36) = 21.5$, $p < .001$, $\omega^2 = .36$. Participants in view of multitasking peers scored significantly lower on the test ($M = 0.56$, $SD = 0.12$, $n = 19$) than participants not in view of multitasking peers ($M = 0.73$, $SD = 0.12$, $n = 19$). The main effect of question type was also significant, $F(1,36) = 11.3$, $p = .002$, $\omega^2 = .21$. Participants scored higher on simple questions ($M = 0.69$, $SD = 0.14$, $n = 20$) than on complex questions ($M = 0.60$, $SD = 0.15$, $n = 20$). The interaction was not significant, $F(1,36) = 0.91$, $p = .347$. These findings suggest that peer multitasking distracted participants who were attempting to pay sole attention to the lecture. Those in view of a multitasking peer scored 17% lower on a post-lecture comprehension test (Fig. 3).

4. General discussion

Our experiments replicate one important finding and introduce a new finding. First, participants' comprehension was impaired when they performed multiple tasks during learning, one being the primary task of attending to the lecture material and taking notes, and the other being the secondary task of completing unrelated online tasks. This result is not surprising and is consistent with those reported by other studies (e.g., Barak et al., 2006; Hembrooke & Gay, 2003; Kraushaar & Novak, 2010; Wood et al., 2012), but we confirm it using a more controlled procedure. Second, comprehension was impaired for participants who were seated in view of peers engaged in multitasking. This finding suggests that despite actively trying to learn the material (as evidenced by comprehensive notes, similar in quality to those with a clear view of the lecture), these participants were placed at a disadvantage by the choices of their peers.

Our experiments were applied in nature and, as a result, do not make major contributions to multitasking or attention theory. However, the results are consistent with theory, namely that the degree of attention that is allotted to a task is directly related to the quality and quantity of information processed. Although we did not directly measure attention, all participants were actively listening to and taking notes on the information presented. We had strong fidelity measures that allowed us to be more certain (compared to previous studies) that factors unrelated to our manipulation were not adding other sources of variance to the data. Thus, we can speculate that attention was impaired due to our manipulation, either in the form of self-multitasking or being in view of a multitasking peer.

In Experiment 1, participants were listening to the lecture, taking notes, and completing the online tasks. This exercise of carrying out multiple tasks at the same time seemed to have impeded retrieval of information at the test, likely as a result of poor encoding during learning (as evidenced by multitaskers' poorer quality of notes) and inefficiency at allocating limited attentional resources. In Experiment 2, participants were listening to the information being presented and taking notes while in the presence of distracting activity in their peripheral vision. Confederates' laptop screens may have distracted participants from directing their full attention to the lecture. Participants were still able to take notes on the lecture; however, a lack of complete attentional focus may have compromised the elaboration and processing of the information being written, thereby lowering successful retrieval attempts during the comprehension test. Future experiments should aim to bridge the gap between cognitive principles of memory and attention and applied pedagogical research to definitively and directly test these theoretical claims surrounding multitasking and attention. More stringent methods could provide further experimental evidence to test these hypotheses. For example, one could use eye-tracking methodologies to determine when, where, and for
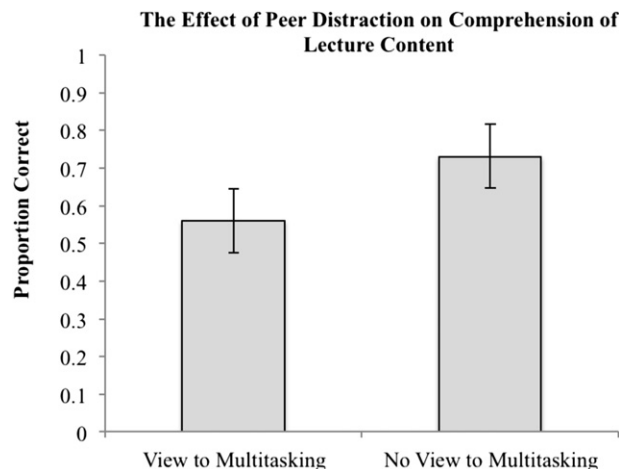

Fig. 3. Proportion correct on the comprehension test as a function of condition (view to multitasking vs. no view to multitasking). Being in view of multitasking peers lowered test performance by 17%, $p < .001$. Error bars represent standard error of the mean.

how long a student's attention is diverted, and whether looking-away-from-lecture time correlates with test performance specific to the information missed by the student.

Results from the questionnaires add to the discussion of technology's impact on learning. Responses from Experiment 1 show that participants in the multitasking condition were aware that multitasking during the lecture would "somewhat hinder" their learning ($M = 5.5, SD = 2.0$). However, they estimated peers' learning would be "barely hindered" ($M = 3.3, SD = 1.9$). By contrast, the observed effect size from peer distraction (Experiment 2) was nearly twice as large as the observed self-distraction effect size (Experiment 1). Multitaskers appear to have been able to time their multitasking activities in a manner that reduced distraction to some degree. Those in view of multitasking appear to have been lured into watching other students' laptop screens even during inopportune moments of the lecture, thus creating worse learning for those in view of a multitasker compared to the actual person who was multitasking. These conclusions should be interpreted with caution and deserve follow up in future studies. Our conclusions are based solely on effect size; we cannot directly compare test performance across experiments due to methodological variation.

Questionnaire responses from Experiment 2 suggest that participants reported being "somewhat distracted" by nearby confederates ($M = 3.3, SD = 2.1$), and that being in view of a multitasking peer "barely" hindered their own learning ($M = 2.7; SD = 1.6$). Thus, overall, the questionnaire ratings suggest students are not in touch with the indirect consequences of their peers' actions.

Despite literature suggesting that multitasking may be particularly detrimental to the learning of complex knowledge (e.g., Foerde et al., 2006), our results show that multitasking impaired both simple factual learning and complex application learning to the same degree. Therefore, even the learning of a new fact (e.g., "Which cloud type is found highest in the atmosphere?") can be interrupted by self-multitasking or distraction from peers who are multitasking.

Relatedly, multitasking may have different overall effects depending on the difficulty of the tasks being juggled. Some studies suggest that if a primary task is more difficult or novel, it will inherently require a greater degree of attentional resources to perform the task at a satisfactory level (Kahneman, 1973; Posner & Boies, 1971; Styles, 2006). Therefore, the primary task may only be performed well if no other tasks must be completed at the same time, or if any secondary task is relatively simple or automatic (i.e., if the secondary task does not require many attentional resources; Kahneman & Treisman, 1984). This latter case was the scenario of our Experiment 1. Participants were asked to learn something novel in a primary task (where many attentional resources were required), while simultaneously attending to a simple secondary task (where attentional resources were still required, albeit not to the same extent). We designed the difficulty level of the primary and secondary tasks to mimic what has been reported as typical classroom behaviors (i.e., students who switch back and forth between attending to a classroom lecture and checking e-mail, Facebook, and IMing with friends). Our results suggest that even though the secondary task was rather mindless for an undergraduate student (i.e., casual Internet browsing) it still had an impact on the performance of the primary task, as evidenced by multitaskers' lowered test scores. Future studies could further examine the impact of multitasking in the classroom by manipulating the level of difficulty of the primary and/or secondary tasks beyond the manipulations of the current design. According to dual task theories (e.g., Pashler, 1994), one would expect to see greater deficits in learning performance as the difficulty level of either primary or secondary tasks increases (e.g., a student who attends their physics lecture, but chooses to spend most of the class time studying for a history exam taking place during the next period).

In light of the evidence reported in this study, what might we recommend to educators as a means of managing laptop use in the classroom? A ban on laptops is extreme and unwarranted. It cannot be overlooked that laptops foster positive learning outcomes when used appropriately (e.g., web-based research, pop quizzes, online case studies, and discussion threads; e.g., Finn & Inman, 2004). When laptops are used strictly for note-taking purposes, typed notes have been shown to have similar positive influences on learning compared to written notes (Quade, 1996). Our results confirm this finding through a rudimentary cross-experiment comparison; that is, we saw no striking differences between participants in the no multitasking condition of Experiment 1 (participants who typed notes) and participants in the no view of technology condition of Experiment 2 (participants who wrote notes) in terms of quality of notes ($M = 4.1$ and $M = 3.6$, respectively) as well as subsequent comprehension test scores ($M = 0.66$ and $M = 0.73$, respectively, keeping in mind that non-multitaskers in Experiment 1 sometimes were in view of multitaskers, which could explain their qualitatively lower comprehension test score). Thus, for a variety of reasons, laptops should remain a tool of the modern classroom, perhaps with some sensible constraints.

One suggestion is for teachers to discuss the consequences of laptop use with their students at the outset of a course (Gasser & Palfrey, 2009). Teachers are in a position to inform students about negative educational outcomes of laptop misuse, as well as to compare and contrast their views with the views of their students. In this discussion, the class could collectively come up with a few rules of technology etiquette that are enforced in the classroom throughout the semester (e.g., sit at the back of the classroom if you plan to multitask, so at least other students are not bothered; McCreary, 2009). In this way, the issue of technology and distraction is highlighted and students can make informed choices, rather than assuming they (and their peers) are immune to multitasking deficits.

Another suggestion is to explicitly discourage laptop use in courses where technology is not necessary for learning. One could argue that courses where information is generally presented in textbooks and on lecture slides do not require a laptop to the same extent as courses where hands-on learning is an integrated component of the course, likely in the form of specialized computer software. This recommendation is made with caution as some students might not benefit from a course without laptops. For example, students with disabilities often rely on computer technology to assist in learning (Fichten et al., 2001). Therefore, perhaps one could allow laptops in all courses but restrict the use of the Internet to course-based websites only (if possible).

Ultimately students must take accountability for their own learning; however, enthusiastic instructors can influence how students choose to direct their attention during class time. A third suggestion is to provide educators with resources to help them create enriching, informative, and interactive classes that can compete with the allure of non-course websites, so that students are deterred from misusing their laptop in the first place. This could include incorporating the laptop into real-time classroom exercises. For example, instructors could ask their students to search the Internet for missing lecture information, or to find an interesting online video to share with the class. Furthermore, instructors could use a shared website where students are able to rank the difficulty level of lecture concepts, thereby allowing the instructor to gauge student comprehension levels in class. The instructor could then review these concepts and provide feedback to students prior to the end of the class. Indeed, inventive instructors can shape how students choose to use their laptops during class time, so that laptop use is constructive.

In order to effectively integrate technology into classrooms, we must continue to examine the consequences—both positive and negative—of technology use on learning. While the present research examined only foundational learning from a lecture (i.e., immediate learning), future research could examine the effects of multitasking on longer-term retention, and could investigate subject material differences. Cognitive theories of divided attention and dual-task performance can help us understand the nature of how we learn and what distracts us. Applied research, using randomized experimental designs, will allow us to examine ways in which on-task activities during learning can be maximized and distraction minimized. We must ask ourselves: Under what conditions do the benefits of laptop use outweigh the detriments? Ultimately, engaging instructors and dedicated learners will need to work hard and stay focused to keep classroom learning at an optimal level.

Acknowledgments

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