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Examining the impact of off-task multi-tasking with technology on real-time classroom learning

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ABSTRACT

The purpose of the present study was to examine the impact of multi-tasking with digital technologies while attempting to learn from real-time classroom lectures in a university setting. Four digitally-based multi-tasking activities (texting using a cell-phone, emailing, MSN messaging and Facebook™) were compared to 3 control groups (paper-and-pencil note-taking, word-processing note-taking and a natural use of technology condition) over three consecutive lectures. Comparisons indicated that participants in the Facebook™ and MSN conditions performed more poorly than those in the paper-and-pencil use control. Follow-up analyses were required to accommodate the substantial number of students who failed to comply with the limited use of technology specified by their assigned conditions. These analyses indicated that participants who did not use any technologies in the lectures outperformed students who used some form of technology. Consistent with the cognitive bottleneck theory of attention (Welford, 1967) and contrary to popular beliefs, attempting to attend to lectures and engage digital technologies for off-task activities can have a detrimental impact on learning.

1. Introduction

Computers, especially laptops, and other digital technologies that allow wireless access to the Internet, have become standard technologies in education (Weaver & Nilson, 2005). In general, there is a consensus that existing and emerging digital technologies have the potential to expand the reach and effectiveness of current educational tools. Ongoing advances in digital technology have provided educators with increasingly smaller, affordable and portable digital devices for use as teaching and learning tools in the classroom (Crippen & Brooks, 2000; Liu, 2007; Motiwalla, 2007). Because the increased availability of new portable digital technologies has made it possible to use these technologies anywhere and anytime, many individuals regularly access and interact with technologies in every context in their lives—including the classroom. Although these technologies can be harnessed for positive educational outcomes, recent research suggests that these same digital technologies can impair performance and distract learners if used inappropriately (e.g., Fried, 2008; Kraushaar & Novak, 2010; Wainer et al., 2008). In addition, students who engage in multi-tasking (i.e., engaging in more than one activity simultaneously; Pashler, 1994), might also be expected to show decrements in performance (Junco & Cotton, 2011). Indeed, questions regarding our ability to engage in multi-tasking behaviors have become increasingly prevalent in both the popular press and in research (e.g., Eby, Vivoda, & St. Louis, 2006).

Although multi-tasking is not a new phenomenon, what is new, are the number and types of digitally based activities in which people can now engage in simultaneously. In addition, multi-tasking with technologies is perceived to be “easy”, especially among younger adults who are likely to be engaged in educational studies (Carrier, Cheever, Rosen, Benitez, & Chang, 2009). The combination of availability, perceived ease of use, and the wide range of activities that are available through portable digital technologies, increases the possibility that learners, especially young, adult learners, will engage in *off-task* behaviors in instructional contexts. The present study addresses learning performance when university students engage in multi-tasking with digital technologies while attending *real-time* classroom lectures.

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1.1. Background: understanding attention

In order to understand the implications of multi-tasking it is first important to understand attention. A precise definition of attention is challenging and depends to some extent on the nature of the task at hand. For example, Posner (1990) classified existing definitions of attention within three main categories. The first category acknowledged the importance of alertness or arousal to the task at hand. The second category noted the issue of selectivity, whereby, some stimuli would be acknowledged more so than others. The third category acknowledged limited processing based on competing demands within a limited system. Johnston and Heinz (1978) further characterized attention as flexible, such that individuals have voluntary control over what stimuli they choose to attend to at any given time. Each of these attributes seems necessary for understanding how learning occurs within classrooms and how learning occurs when multi-tasking is an option.

1.2. Multi-tasking: what is it?

As mentioned above, multi-tasking can be defined as doing more than one activity simultaneously (Pashler, 1994). Within the extant literature, multi-tasking is typically indirectly defined via the interference it produces. For example, the inability to simultaneously perform two or more overlapping tasks when each requires selecting a response (i.e., a decision task) due to a general slowing in the performance of the second task (Levy & Paschler, 2001; McCann & Johnston, 1992; Pashler, Harris, & Nuechterlein, 2008; Schumacher et al., 2001; Welford, 1952). This interference arises from a constraint in decision-making also referred to as Cognitive Bottleneck (Welford, 1967). Although there are several theories that propose the constraint of a cognitive bottleneck and they differ with respect to where in the process the bottleneck occurs (Deutsch & Deutsch, 1963; Norman, 1968; Solso, MacLin, & MacLin, 2007), generally, the effects of a cognitive bottleneck and the related slowing in the performance of the secondary task have been very well established.

However, some researchers have demonstrated conditions under which these effects can be overcome. For example, Meyer et al. proposed an alternate model of dual-task interference, called Executive-Process/Interactive-Control (EPIC), where practice plays an important role (Meyer et al., 1995). Specifically, skilled performance is accomplished by converting declarative knowledge into procedural knowledge through practice. Once this conversion has been accomplished, the processes required to complete two tasks at once can be performed simultaneously (Meyer et al., 1995; Schumacher et al., 2001). While acknowledging this finding, some researchers have argued that the removal of the slowing of performance associated with a cognitive bottleneck can only be circumvented in very simple and highly practiced tasks and not in more complex real-world situations (Pashler et al., 2008).

Some researchers also propose that different tasks produce different kinds of interference: general vs. specific (Brooks, 1968; Hirst & Kalmar, 1987). General interference occurs in dual-tasking situations in which a person performs two unrelated tasks, such as reading a sentence (a verbal task) and pushing a button in response to a certain word (motor task). On the other hand, specific interference occurs when a person performs two closely related tasks, such as listening to a message (verbal task) and producing a verbal response to that message (also a verbal task). When two tasks draw on the same overall resources, as well as the same processes, performance is expected to be especially low (Brooks, 1968; Hirst & Kalmar, 1987). In other words, the allocation of resources to a verbal and a motor task may be easier than the allocation of resources to two verbal tasks (e.g., writing and listening to a lecture). Although in both cases attempting to complete two tasks draws upon same limited available resources, the first draws on different processes and the second draws on the same processes (competing verbal), thus leading to a "double" interference. In terms of multi-tasking using a digital technology during a lecture, it should be easier to listen to a lecture (and process the meaning) while looking at pictures on Facebook™ (verbal/visual task) than it would be to listen to a lecture and type messages on MSN (verbal/verbal task).

Would multi-tasking with digital technologies elicit the slowing of tasks or interference typically associated with a cognitive bottleneck? If so, would the effects persist when individuals were experienced users of the digital technologies? In order to address these questions, it is first important to understand how individuals might use digital technologies in a multi-tasking situation. Posner (1990) identified two different kinds of attentional tasks that learners can employ: divided attention or rapid switching between tasks (Posner, 1990). Divided attention is synonymous with dual-tasking and refers to attending to more than one stimulus at a time. When this form of attention is used, the selection of information is imperfect, and therefore, subject to dual-task slowing (Smith & Kosslyn, 2007). Rapid Attention Switching refers to shifting attention from one stimulus to another stimulus in a rapid succession, but only one stimulus is attended to at any given time (Posner, 1990) and information from one task may be undetected while attending to the other task.

Although distinctions between these two types of attention are important for understanding basic cognitive functions, the present study did not directly manipulate or control attention. However, the present study did ensure selection of competing activities that would require multi-tasking. Specifically, in three conditions learners were required to use digital technologies that employed verbal information (e.g., texting, emailing, MSN) as a secondary task while the primary task required attention to a verbally based lecture with pictorial supports. An additional condition (Facbook™) combined verbal and pictorial information as the secondary task during the lecture. Attempting to attend to these competing forms of information would be understood as forms of multi-tasking, where one task is a primary task (the learning task) and the other task is secondary (using digital media), and would be expected to impair performance.

1.3. Real world applications of multi-tasking: multi-tasking and learning

Consistent with theories of attention, Rubinstein, Meyer, and Evans (2001) found that people who were required to multi-task took longer to finish their two tasks, than it would take them to finish both tasks if they concentrated on one task at a time. The increase in time for multi-tasking was attributed to lost time from switching back and forth between the tasks, especially when the tasks became more complex (Rubinstein et al., 2001). A neuro-imaging study on learning while multi-tasking supported this finding (Foerde, Knowlton, & Poldrack, 2006). Specifically, participants who learned without distractions were able to correctly learn information presented to them, and apply it flexibly to new situations, On the other hand, participants who multi-tasked were not able to apply this information flexibly to new contexts, though they were still able to correctly learn factual information. The authors concluded that while multi-tasking did not seem to affect rote memorization, it might hamper higher-order tasks that involve understanding material and application of the material to novel situations. Together, the results of these studies are consistent with both the cognitive bottleneck theory of multi-tasking and provide evidence that attention, especially for complex tasks, can be impaired when multi-tasking is involved.

Interestingly, a recent study examining the impact of instant messaging while reading also found that students took longer to read when messaging than those who read without messaging, however, comprehension performance, which would be considered a complex task, did not differ between the two groups (Bowman, Levine, Waite, & gendron, 2010). The authors suggested that learners who multi-tasked may have required additional time in order to review previously read material and re-engage on-task behaviors. In this case, additional time could compensate for the disruptions from instant messaging and hence, no performance differences were found. When additional time is not available, however, it may be more likely to find performance decrements. In summary, the results of the above studies suggest that off-task use of digital technologies while learning might be especially harmful to performance in a *real-time* classroom context.

1.4. Multi-tasking with digital technologies and learning

Within the University setting, initiatives, often referred to as Anywhere Anytime Learning (AAL) (Milrad & Spikol, 2007), promote the use of digital technologies, especially personal use technologies such as laptops, as a complement to more traditional teaching and learning tools. The newest addition to personalized digital technologies is mobile technologies (e.g., Blackberrys, iPhones, Smartphones, iPads and cell-phones). These devices, when connected to wireless access to the Internet, offer the promise of shifting learning into even more environments than had been envisioned with laptops.

Although many educational systems have quickly embraced digital technologies, the effective inclusion of these technologies into teaching practice has encountered, and continues to encounter, practical and pedagogical barriers (e.g., Wood, Specht, Willoughby, & Mueller, 2008). In addition, the limited extant research provides contradicting evidence regarding the outcomes associated technology use (Wainer et al., 2008). With respect to multi-tasking, several studies show that when students have access to laptops in the classroom, they often engage in distractive multi-tasking behaviors, which is associated with a decrement in performance (Fried, 2008; Grace-Martin & Gay, 2001; Hembrooke & Gay, 2003; Junco & Cotton, 2011; Kraushaar & Novak, 2010; Wainer et al., 2008; Wurst, Smarkola, & Gaffney, 2008). For example, research examining use of instant messaging as an instructional tool found that students engaged in off-task messaging in addition to the expected instructional use and the off-task messaging impacted negatively on the teaching environment (Murphy & Manzanares, 2008). A recent study with mobile technologies also found that students self-reported engaging in off-task activities with these devices when the technology was supposed to be used for instructional purposes (Mueller, Wood, & De Pasquale, in press). In addition, distraction from multi-tasking need not be firsthand as research indicates that using laptops in classrooms can distract not only its users, but also other students in close proximity to the laptops (Fried, 2008).

Off-task multi-tasking, in particular, poses concerns for learning. Consistent with cognitive load theory (Sweller, 2003) when learners engage in activities that are not directly related to the goals of the instructional task at hand, then learning becomes less effective (Chandler & Sweller, 1991). Cognitive load theory identifies three types of load; intrinsic, germane, and extraneous. The first two types of load are related to the learning task and activities which facilitate these benefit learning. Extraneous load is associated with activities not directly contributing to learning. Multi-tasking with off-task activities increases extraneous load which would be expected to interfere with learning as was noted in the studies above.

Together the correlational and self-report studies above suggest that off-task multi-tasking in the classroom is most likely detrimental to learning. One purpose of the present study therefore, was to directly test the impact of multi-tasking in a *real-time* classroom context for learning.

1.5. Summary of the present study

The present study extended current multi-tasking research by directly assessing the learning outcomes following off-task multi-tasking in when learning from *real-time* classroom lectures. In addition, the study contrasted the relative impact of differing digital technologies when multi-tasking. Technologies included the use of laptops for conducting Facebook™ searches, or for communicating (email/MSN messenger) and the use of cell-phones for responding to social messages (i.e., texting). Performance in these groups was compared to a variety of controls. Specifically, a paper-and-pencil control, a word-processing note-taking only control and a natural use control (in which participants were allowed to use technology in an unlimited manner, if they chose to do so, as they normally would during lectures). The natural use control group was included in order to determine the proportion of students who use digital media in a classroom and in what way they use the technology. To test the impact of familiarity with technologies, the study required students to use the same technologies over three consecutive lectures.

1.6. Hypotheses

In total, two main hypotheses and one methodological issue were addressed.

1) Given the potential for multi-tasking to tax the resources and distract the learner, it was expected that learning performance would be lower for the multi-tasking conditions when compared with the note-taking conditions.
    i) It was expected that participants in the natural condition who chose not to multi-task, would score higher on learning performance than those who chose to multi-task.
2) If practice facilitated the ability to multi-task, it was expected that performance in all multi-tasking conditions would increase over the three sessions.
3) As a result of access to technologies, it was anticipated that students might engage in multi-tasking beyond what was instructed. To determine whether this occurred, a fidelity measure was included where participants indicated what multi-tasking activities they engaged in during the lecture. This measure was an exploratory measure to allow an estimate of how many multi-tasking activities

students engaged in when given the opportunity. In addition, the results of the fidelity measure were utilized for reassigning participants to conditions based on the modal behavior indicated by each participant.

2. Method

2.1. Participants

All 145 participants (116 females and 29 males) were randomly assigned to one of seven conditions (with $n = 21$ in Facebook™, Texting, Natural Technology Use, Word Processing only and paper-and-pencil conditions and $n = 20$ in the MSN and email conditions). Approximately equal proportions of males ($M_{age} = 20.67$, SD $= 2.33$) and females ($M_{age} = 19.56$, SD $= 1.19$) were represented within each condition. Participants were recruited from 2nd year research methods and statistics courses. The participants selected either 1.5 course credits or $15 as compensation. Participants were treated in accordance with APA/CPA ethical guidelines.

2.2. Materials and procedure

The study was comprised of three sessions. In all three sessions students were given a 20-min lecture presentation on research methods, followed by a 15-item quiz and a fidelity measure. Before session 1, students completed a pre-test survey assessing demographic variables (e.g., age, gender, and ethnic/racial background).

2.2.1. Instructional sessions

Participants attended the 3 consecutive lectures that were actual course material presented during class instructional time. The topics of the lectures focused on research methods topics, including; a) definitions and types of reliability and validity, b) experimental designs and validity, and c) internal and external validity and threats to validity. Lectures were developed by the course instructor and reflected the textbook content for each respective component of the course. Each lecture was constructed to contain approximately the same number of main ideas and subsidiary points and examples. All lectures were accompanied by PowerPoint slides (developed by the instructor) that presented each main and subsidiary idea. Both verbal (text) and visual (images) information supported the points. The assigned instructor for the course (a teaching excellence award winner) presented all lectures and was blind to student conditions. The majority of the lectures occurred in large classroom context for two sections of a medium sized methods course. In addition, students recruited from another statistics course and students who missed a class were taught in a smaller classroom context. Assignment of the students from the statistics course was balanced across all conditions. Procedures, content, materials, lecturer, and research assistants were identical across the two contexts. Order of lectures was fixed due to the progressive nature of the lecture content. The three experimental sessions occurred within a two-week period for all students.

2.2.2. Experimental conditions

Participants received instructions for their randomly assigned condition a week before the sessions began and were reminded of their instructions at the beginning of the first experimental session. They were introduced to the study as an investigation of technology use while learning. Participants remained in their assigned conditions throughout each of the 3 consecutive sessions. All conditions were conducted simultaneously during the lectures. Participants in the four multi-tasking conditions were required to use one of 4 social networking tools; texting via cell-phones, Email, MSN or they used Facebook™. Participants in the MSN, texting and email conditions exchanged messages with research assistants. Research assistants, located in a separate room, initiated contact at the outset of the lecture and maintained contact until cued to terminate the interactions at the end of the lecture. All research assistants followed prepared scripts for the interactions as well as responding to spurious or unplanned messages from the target recipient. Scripted questions were presented in a pre-selected order. Although the scripts changed across the three sessions, they shared a similar format (e.g., book a follow-up review appointment for the lecture, followed by open ended questions involving school issues, such as current courses and exams, followed by other current events exchanges such as Halloween). Spurious questions posed by participants were always answered in order to continue the exchange of messages and were then followed by the next question in the script.

Participants in the Facebook™ condition completed a prepared information “scavenger hunt”: an instruction sheet asking them to visit the Facebook™ profiles of several people to find specific pieces of information in those profiles. The “scavenger hunt” was different for each of the three sessions. The participants in the Facebook™ condition did not exchange responses with the research assistants.

Of the 3 control conditions, the natural use of technology group was allowed to use any technology they wished throughout the experimental session. The purpose of this control was to determine the number of participants who naturally chose to engage in off-task multi-tasking behaviors which off-task activities were engaged and how many multi-tasking behaviors were used. Another control group used a laptop word-processing application for note-taking and the last group only used paper-and-pencil for note-taking.

All of the participants who were required to use a laptop used their own personal laptops (except for 4 participants who used laptops provided by the researchers) and as such, the type of laptop, and any programs (such as the Internet browser, word-processor, and email), were not controlled. Finally, students used their own cell-phones in the texting condition (except for 3 participants who used phones supplied to them). All participants were instructed to attend to the lecture while engaged in their assigned activities.

Given that students required this material as part of their course, follow-up review sessions for each of the three topics were provided after the experiment was complete.

2.2.3. Learning task

Following each lecture, students completed one, 15-item multiple-choice test. All questions pertained to material presented in the lecture for that session. Consistent with course expectations, the multiple-choice questions reflected factual, application and synthesis level demands. Participants were aware of the upcoming multiple-choice test and that the material being presented would be on their final exam. Therefore, participants would have a natural incentive to attend to the material being presented.

2.2.4. Fidelity measure

After completing the multiple-choice test, participants completed a 26-item fidelity measure, assessing the participants' compliance to instructions and authenticity of technology use during the lecture.

3. Results

Two sets of analyses were performed. The first set of analyses examined learning performance in class as a function of assigned condition. The second set of analyses examined fidelity to instructions and a reanalysis of data as a function of fidelity outcomes.

3.1. Memory for information presented in class

A 3 (session) × 7 (condition) repeated measures ANOVA was conducted to assess performance on the multiple-choice tests for each of the three sessions as a function of experimental condition (See Table 1 for means). There were significant main effects for both condition, $F_{(6,\ 138)} = 2.53$, $p = .02$ and for session $F_{(2,\ 276)} = 97.28$, $p < .001$. The interaction of condition by session was not significant, $F_{(12,\ 276)} = 0.97$, $p = .48$. To examine the main effect for condition, Dunnett's post hoc comparisons were conducted with the no technology paper-and-pencil condition set as the control condition. Participants in the Facebook™ condition scored significantly lower on the multiple-choice tests than those in the paper-and-pencil condition, $p = .05$. In addition, there was a strong trend for participants in the MSN condition to score significantly lower than the participants in the paper-and-pencil control condition, $p = .059$. This outcome provided partial support for the hypothesis that participants engaged in multi-tasking would score less well than those in the paper-and-pencil control condition.

To examine the main effect for session, three paired samples *t*-tests were conducted. Performance in Session 2 ($M = .73$) exceeded performance in Session 1 ($t_{(144)} = -11.74$, $p < .001$) and Session 3 ($t_{(143)} = 12.06$, $p < .001$). Session 1 ($M = .53$) and 3 ($M = .51$) did not differ from one another. Instead of the expected continuous increases in performance over time, memory performance did not systematically improve in the present study. This suggests that performance did not increase with increasing practice.

In summary, overall, not all multi-tasking conditions yielded poorer performance than the traditional paper-and-pencil condition as predicted. However, it appears that Facebook™ and MSN were more likely to serve as distractions that impact negatively on learning when used during lectures. It also appears that repeated practice with the technologies did not systematically improve performance over time in any condition.

3.1.1. Natural use of technologies in the classroom

The natural use condition was included in order to determine whether or not students chose to use technology when attending lectures, what technologies they employed, and how the choice to employ technology impacted on learning. A frequency analysis revealed that 9 out of 21 participants in Session 1, 10 out of 21 participants in Session 2, and 9 out of 21 participants in Session 3 indicated they did not use any technologies while attending to the lecture. Across all three sessions, only 7 participants did not use technology at all and an additional 2 participants reported using some form of technology for only one of the three sessions. Nine participants used technology during every session. In summary, almost half of the participants used technology for every class when allowed to use technologies as they normally would during lectures, while approximately one third of students elected to use only paper-and-pencil during lectures. The remaining students were inconsistent in their choices regarding technology use.

Participants were grouped into two groups based on whether they did or did not use technology. Although sample sizes were unequal and relatively low (7 versus 14), an exploratory 2 (technology vs. no technology) × 3 (session) ANOVA was performed to test whether the self-selected use of technology impacted on performance in the Natural Use condition. There was a significant main effect for technology use, $F_{(1,\ 19)} = 8.42$, $p < .01$. Participants who did not use technology ($M = .76$) outperformed technology users ($M = .59$) suggesting that multi-tasking with technology negatively impacted on performance in this condition when compared to non-technology use. Consistent with previous analyses, there was also an effect of session, $F_{(2,\ 38)} = 15.148$, $p < .001$, such that Session 2 yielded higher performance than Session 1 or Session 3, and Session 1 and Session 3 did not differ from one another.

Given that the overall analysis above indicated that use of MSN and Facebook™ in particular, had negative consequences for learning, a count was conducted to examine how many participants in the Natural Use condition used Facebook™ and/or MSN, the two most distracting technologies. For Session 1, 4 participants used MSN and 3 of these participants also used Facebook™. For Session 2, two of these participants continued to use both Facebook™ & MSN and 1 new participant used both sites/programs. For Session 3 only one participant used Facebook™ and/or MSN. Overall, in the Natural Use condition, few participants self-selected to use the two most detrimental technologies.

Table 1
Summary of means and standard deviations for multiple-choice proportion scores by condition and session.

	Session 1		Session 2		Session 3	
	M	SD	*M*	SD	*M*	SD
Texting	.57	(.17)	.75	(.11)	.56	(.16)
Email	.52	(.11)	.69	(.14)	.50	(.12)
MSN	.48	(.15)	.71	(.16)	.42	(.22)
Facebook™	.50	(.19)	.68	(.17)	.43	(.18)
Natural use control	.50	(.15)	.78	(.24)	.58	(.17)
Word-processing control	.55	(.15)	.75	(.12)	.57	(.21)
Paper-and-pencil control	.60	(.16)	.74	(.17)	.53	(.20)

3.2. Fidelity in the conditions

Fidelity measures were used to determine:

1. Compliance: Whether or not students had adhered to instruction.
2. Technology Use: Whether or not students had used any technologies.
3. Amount of Multi-tasking Activities: If students had used technologies, in how many multi-tasking activities had they engaged?
4. Type of Multi-tasking Activities Chosen: Preferred extra technology activities engaged in by participants.

Compliance: Overall, only 57% of the participants self-reported completely adhering to their instructions for the use of technology in their assigned condition across all three sessions (see Table 2 for a count of non-compliance as a function of condition and session). The remaining participants deviated from instructions either by engaging in one or more activities than they were instructed to *or* by not using technologies/not engaging in multi-tasking activities when instructed to do so. To determine whether simple compliance with instructions yielded significant differences in performance, a 2 (compliant vs. non compliant) $\times$ 7 (condition) univariate ANOVA was conducted to compare performance for compliant versus non-compliant participants. Compliance was defined as full compliance to instructions in all 3 sessions and non-compliance was defined as deviating from instructions in at least one of the three sessions. The average multiple-choice score across all sessions was the dependent variable. There were no significant main effects nor was there a significant interaction, largest $F_{(6,\ 144)} = 2.56$, $p < ns$ for condition, suggesting that simple compliance versus non-compliance with instructions did not yield systematic differences in performance.

Given the substantial amount of non-compliance, a separate set of analyses was conducted to explore performance outcomes with compliance taken into account. These analyses are explained in the following sections.

3.2.1. Technology users versus non-users

Independent of assigned condition, participants were divided into two groups based on whether or not they had indicated in the fidelity measure that they had used technology at all during the three sessions. In total, only 23.5% (34 out of 145 participants) self-reported not using any technologies in any of the three sessions. The remaining 76.5% (111 participants) self-reported using at least one type of technology/engaging in a multi-tasking activity in at least one session. To determine the impact of using technology on total performance across all three sessions, an independent *t*-test was conducted. There was a significant difference, $t(143) = 4.61$, $p < .001$, with non-users ($M = .67$) outperforming users ($M = .57$) on learning performance.

3.2.2. Amount of multi-tasking activities

Participants were only ever instructed to engage in one competing multi-tasking activity (except for those in the natural use condition). However, the fidelity measures clearly indicated that some participants engaged in more than one alternative technology activity when they had access to technology. It is possible that the number of alternative activities engaged in during the lecture might have an increasingly negative impact on learning. Participants were divided into 4 categories, depending on the amount of self-reported multi-tasking with technology: non multi-taskers, low, medium and high multi-taskers. Non multi-taskers were defined as not having used any technologies or engaged in any multi-tasking behaviors in any of the three sessions, low multi-taskers were defined as having an average of 1 multi-tasking activity over the three sessions, medium multi-taskers averaged more than 1 or equal to 2 activities, and high multi-taskers averaged more than 2 multi-tasking activities across the three sessions. There were 34 non multi-taskers, 67 low multi-taskers, 31 medium multi-taskers and 13 high multi-taskers. The impact of amount of multi-tasking behaviors on performance was assessed using a univariate ANOVA. There was a significant main effect for the amount of multi-tasking, $F_{(3,\ 144)} = 8.23$, $p < .001$). Tukey b post hoc comparisons revealed that non multi-taskers ($M = .67$) outperformed low ($M = .57$), medium ($M = .58$) and high ($M = .51$) multi-taskers, and participants in any of the multi-tasking categories did not differ from one another. These outcomes are consistent with the above comparison of technology users and non-users in the natural use condition and suggest that engaging in distracting technology use per se, rather than number of different technologies engaged in is the important issue in understanding what impacts negatively on learning.

It was also important to determine whether any of the required technology conditions encouraged the use of more multi-tasking than others. To examine this issue, a comparison was made among all of the non-compliant participants to assess whether they tended to use more or less technologies as a function of the initial technology assigned. Unlike participants in the natural use condition, participants in all other conditions made a conscious decision to ignore instructions in favor of another technology. A ONEWAY ANOVA was conducted to compare the number of multi-tasking activities engaged in as a function of assigned condition for non-compliant participants. There was a significant main effect for condition, $F_{(5,\ 66)} = 4.15$, $p = .003$. Post hoc Tukey b comparisons indicated that participants in the paper-and-pencil condition ($M = 2.00$; SD $= 1.41$) and word-processing condition ($M = 2.50$; SD $= 3.59$) engaged in less multi-tasking than participants

Table 2
Number of non-compliant participants by condition for each session.

	Session 1	Session 2	Session 3	Average
Texting	4	6	3	4.33
Email	8	8	7	7.66
MSN	13	8	9	10
Facebook™	14	11	10	11.6
Natural Use Control	–	–	–	–
Word-processing Control	6	6	5	5.66
Paper-and-pencil Control	4	5	5	4.66
Total of Non-Compliant Participants	49/144	44/105	39/103	

Note. The “out of” number is the number of participants with available fidelity data for each session. The dash indicates “not applicable”.

in the email ($M = 7.64$; SD = 3.56) and Facebook™ ($M = 7.69$; SD = 6.02) conditions, but MSN ($M = 4.93$; SD = 2.69) and texting ($M = 4.22$; SD = 2.44) conditions did not differ from any other conditions. In summary, when participants were not compliant, those in the Facebook and email conditions engaged in the greatest number of alternative technologies during the lectures.

3.2.3. Types of multi-tasking activities

The types of multi-tasking activities that non-compliant participants engaged in (i.e., activities above and beyond those expected in the condition) were identified in order to determine what additional activities were engaged in across the three sessions (see Table 3 for a summary of the most frequent additional technologies). For participants in the texting condition, the most frequent additional multi-tasking activities reported were emailing and using the Internet for entertainment purposes. Participants in the email condition checked their own accounts/schedule online, and used MSN, texting and Facebook™. Participants in the MSN condition used the Internet for entertainment purposes, texting, email and Facebook™. Participants in the Facebook™ condition engaged in texting, using the Internet for entertainment purposes and MSN. Participants in the Word-processing condition mostly used texting, MSN, Facebook™ and email, but the relative number of participants engaging in these activities was low. Lastly, participants in the paper-and-pencil control condition, who engaged in multi-tasking engaged mostly in texting. A descriptive comparison of participants across conditions suggests that participants in the Facebook™, MSN and email conditions engaged in additional multi-tasking activities more so than participants in the texting or control conditions.

4. Discussion

The primary purpose of the present study was to examine the relative impact of multi-tasking with various digital technologies while attempting to learn from a real-time classroom lecture. A summary of outcomes is presented below.

4.1. Memory for information presented in class

Overall, memory performance for the information presented in class was consistent with expectations projected by the cognitive bottleneck theory (Welford, 1967). That is, when two cognitive tasks were being performed simultaneously there were decrements in performance in at least one of the tasks, namely memory performance in the present study. Interestingly, results contrasting performance across assigned multi-tasking conditions only provided partial support for the cognitive bottleneck theory because only off-task use of Facebook™ and MSN messaging negatively impacted on learning when compared to on-task note-taking with paper-and-pencil. These outcomes, however, needed to be interpreted with caution given the amount of non-compliance to instructions in the present sample. Nonetheless, the outcomes are important as they raise two important questions; why did Facebook™ and MSN serve as particularly salient multi-tasking distractors? and why did cell-phone texting and email messaging not pose as a great a problem?

With respect to the first concern, clearly both MSN and Facebook™ are attractive, engaging interactive activities. Facebook™ offers a variety of intrinsically interesting activities to perform, such as viewing pictures of friends, chatting with friends, playing games, posting status updates etc, that can all be performed within a single site. As such, the structure of Facebook™ provides users with a multitude of stimuli to explore and act on (Junco & Cotton, 2011: Nosko, Wood, & Molema, 2010). These interesting features also may make Facebook™ particularly distracting, especially when compared to less dynamic or interesting platforms that may rely mainly on verbal information presented in a plain background such as text messages or email.

MSN relies primarily on simple exchanges of text-based information. Although the page template presents users with stimuli, such as visual and auditory emoticons, perhaps the most salient features of MSN is that the program is constantly running when the user is online, regardless of other activities in which the user may be engaged, and this allows messages to be immediately accessible and in real-time. Such perceived synchronicity of communication and ease has been associated with increased use (Bowman et al., 2010; Jones & Madden, 2002). In addition, the user is provided with an instant notification (i.e., in the form of an auditory signal) when a message has been received which

Table 3
Most frequent multi-tasking activities for non-compliant participants by condition and session.

	Session 1	Session 2	Session 3
Texting	Internet for Entertainment (1) Games (1)	Email (3) Internet for Entertainment (2) MSN (1)	Internet for Entertainment (2) Games (1) MSN (1)
Email	Checked Own Student Account (4) MSN (3) Facebook™ (3)	MSN (5) Texting (2) Internet for Entertainment (2)	Texting (3) Facebook™ (2) Checked Student Schedule Online (2)
MSN	Internet for Entertainment (5) Texting (4) Email (4) Facebook™ (4)	Internet for Entertainment (2) Texting (1) Facebook™ (1)	Internet for Entertainment (3) Email (3) Games (1)
Facebook™	Texting (7) Internet for Entertainment (6) MSN (6)	Texting (5) Internet for Entertainment (4) MSN (3)	Texting (5) MSN (2) Email (2)
Word-processing Control	Texting (2) Facebook™ (1) MSN (1)	Texting (4)	Texting (3) Email (1) MSN (1)
Paper-and-pencil Control	Texting (4) MSN (1) Games (1)	Texting (5)	Texting (5)

orients the user to the new message. These features could encourage users to attend more regularly and immediately to the incoming information.

Although email messages also have the potential to alert users to incoming messages if the computer is set to allow this function, it could be expected that emailing would have a similar impact as MSN on performance. In the context of the present study, however, email messages were not automatically signaled. Also, email typically requires the user to open and close the program between uses, as timed lock-outs can occur. Therefore, users have to open the program each time to search to see if new messages have arrived before viewing them. Hence, participants may have been more strategic in their use of email as they waited for appropriate breaks before checking for new messages and responding to existing messages. The asynchrony and additional steps required to execute a response to email may have made it less distracting as learners selected when to use it and had fewer activities within the program in which to engage.

It could also be argued that cell-phone text messages, which either employ a vibration or sound to indicate incoming messages, also would incur an immediate response such as in MSN. However, with cell-phones, participants may have been interested to see the received message but may have delayed before answering, as the immediacy of response may not be as characteristic of this device as it is with MSN. In addition, whereas MSN is directly in front of the person, logged in at all times, users often put aside their cell-phones between messages especially if they needed to use alternate media to write notes. With the cell-phone being put aside between uses, it is conceivable that cell-phones may have been less distracting as they were not constantly present in the learner's field of vision and actively running, such as is the case with MSN.

Overall, although the type of display and multitude of information in a single location, in addition to the synchrony and immediacy of notification in MSN, may be features that make Facebook™ and MSN particularly engaging, these features alone do not separate these two digital technologies from other technologies. Clearly, more intensive examination of the specific features of technologies that cause users to be distracted needs to be conducted in order to understand whether some devices or platforms promote greater attention and engagement.

An important outcome in the present study was that participants in both the MSN and Facebook™ conditions engaged in more than the two tasks assigned to them as a function of their condition. They truly engaged in *multi*-tasking. That is, participants in the Facebook™, and MSN conditions engaged in many more off-task activities than participants in any other condition except for those in the email condition. That is, participants in all three of these conditions searched the internet for entertainment purposes and engaged in other activities in addition to their instructions In part, the poorer performance of participants in the Facebook™ and MSN conditions in the initial analyses may be a reflection of how attractive and engaging the assigned off-task activities were in addition to being distracted because their attention was spread across many more activities. This distribution of attention across more tasks places an increased load on available cognitive resources (e.g., Levy & Paschler, 2001; Pashler et al., 2008: Sweller, 2003), much more so than participants in the other conditions who engaged in fewer additional distracting activities. Therefore, it would be expected that the amount of multi-tasking rather than the intrinsic distracting factors of each technology may be partially responsible for the increased decrements in learning performance in the Facebook™ and MSN conditions in particular.

Support for distraction for *multi*-tasking rather than "*dual*-tasking", however, was not confirmed when number of multi-tasking activities was examined in the comparisons of technology users and non-users. Indeed, any distraction, regardless of number, resulted in poorer performance than the no distraction condition. In addition, participants in the email condition engaged in more multi-tasking activities than did participants in the MSN condition, but emailing was not found to be detrimental to performance. The pattern of outcomes suggests that compliance to instruction and the amount of multi-tasking activities were not the only issues affecting learning performance. The type of activity itself seems to play an important role, and hence, further study of the features of the most distracting activities is warranted.

It was expected that those participants who chose not to use technology, or used minimal amounts of technology, would outperform those participants who chose to engage in multi-tasking activities to a greater extent. This hypothesis was supported. Specifically, participants in the natural use condition who did not use any technology outperformed technology users, and a comparison of the technology users versus non-users yielded the same outcome. This is consistent with previous research that shows that technology used in a classroom can serve as a distraction rather than an important instructional tool (Fried, 2008; Grace-Martin & Gay, 2001; Hembrooke & Gay, 2003; Kraushaar & Novak, 2010; Wainer et al., 2008; Wurst et al., 2008). However, it must be noted that in the present study, only in the word-processing condition, was the technology offered as a potential learning tool.

4.2. Fidelity in the conditions

Overall, compliance with instructions was low, only 57% of the participants self-reported fully adhering to instructions on each of the three sessions. This finding is intriguing because it suggests that having access to Internet-based technologies may be too inviting for many learners. Much research has begun to explore the power of multi-media as an instructional tool (Barak, Lipson, & Lerman, 2006; Fried, 2008; Grace-Martin & Gay, 2001; Liao, 2007; Lowther, Ross, & Morrison, 2003; Siegle & Foster, 2001; Wainer et al., 2008; Wurst et al., 2008) but the findings of the present study suggest that the very features that make multi-media platforms attractive as learning tools may also make them distractors. This is an important consideration for educational practice.

4.3. Examining effects of practice

The results of the present study did not reveal increasing performance with increased practice with the multi-tasking activities, either among the conditions where multi-tasking was assigned or in the natural use study condition. This is contrary to previous research, which has shown that under some circumstances people may become better at multi-tasking given sufficient practice (Spelke, Hirst, & Neisser, 1976). It is possible that three sessions was simply not enough exposure or practice to allow participants to acquire fluency with their assigned multi-tasking activity. If this was the case, the results obtained in this study were insufficient to provide evidence to assess the EPIC model of multi-tasking (Meyer et al., 1995) and in order to properly test this model, practice effects would need to be measured only after a specified mastery criterion had been attained.

However, within the constraints of the present study it could also be argued that participants were already fluent and comfortable with the available technologies. Indeed, almost all of the students had their own digital devices. Also, these participants, given their age, would be considered *digital natives* (Prensky, 2001) in that they likely would have exposure and experience with computer (including laptop) technologies for all of their lives. As such it is probable that these students represented very fluent and flexible technology users and that multi-tasking would not be unfamiliar but instead be commonplace for this group. Hence, being able to use the technologies should not have been a challenge in the classroom context.

In addition, considering that the learning assessed in this study did not involve any purposeful studying per se, such as in a preparation for an examination, the students performed reasonably well on the learning tasks (53.2% in session 1, 72.8% in session 2, 51.3% in session 3) and particularly well in session 2 suggesting that the difficulty level of content material rather than multi-tasking practice was explaining differences in performance over time.

Consistent with this interpretation, it could be argued that the static order of presentation might have caused the effects. Given that the material was drawn from the same textbook and that the topics built upon each other, if familiarity with the concepts were to account for outcomes, lecture 3 should have been recalled best as students would have had more exposure to the concepts by this lecture. Since the second lecture was recalled best, it does seem that the content in this lecture was less difficult.

4.4. Limitations and directions for future research

The present study provided an initial experimental examination of the impact of off-task multi-tasking for classroom-style lecture contexts. The findings provide a foundation from which ongoing research can be planned. Most notably, the findings clearly indicate that further investigation of the impact of multi-tasking using each of the technologies on learning is needed. Immediate extensions of the current work could involve examination of the use of the various technologies under more controlled conditions, ensuring fidelity to instruction and greater power for subsequent analyses. In addition, the present study introduced multi-tasking and the use of technologies as a distracting task. It would be useful to examine how these same technologies would be used if users were already engaged with the technologies for task-relevant activities.

Future research might also focus on individual differences to determine how these interact with decisions to engage in off-task technology use. For example, in the present study some students in the natural use condition and some assigned to use technology chose not to use any technology or used technology only for note-taking. It would be useful to investigate what accounts for these types of choices. Similarly, exploration of gender and age may also prove useful in determining the generalizability of the present findings.

In summary, the results of the present study provide a provocative set of findings regarding the negative impact of off-task use of technologies in the classroom. Given that many technology users use technology despite the distraction it poses to other students (Lowther et al., 2003) and, apparently the negative consequences it has for themselves, their use of technology for off-task activities may increase as mobile technologies become more widely available. Knowledge of the detrimental impact on learning has important implications for educators and policy makers especially since digital technologies have become standard teaching and learning tools at all levels of education. In order to maximize the educational benefits associated with technology, we must also fully identify, understand and overcome potential shortcomings resulting from inappropriate use of technology in the classroom.

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