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# Interest level improves learning but does not moderate the effects of interruptions: An experiment using simultaneous multitasking

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ABSTRACT

It has become common practice for people to multitask with electronic devices in everyday situations. We examined the effects of interrupting participants with instant messages while they watched a video presentation in a situation that resembled commonplace events such as a business meeting, a training presentation, or a classroom lecture. We compared them to participants who were not interrupted. We also investigated how interest in the topics presented affected learning. Results showed that interruptions reduced learning, by a small but statistically significant margin, which is consistent with the findings of similar studies. Importantly, interest level was as strong a predictor of learning as being interrupted, although interest did not moderate the effect of interruptions. Results showed that interruptions are disruptive but perhaps not as much as is commonly believed. The results also highlight the importance of studying individual difference factors, such as interest levels, in conjunction with experimental manipulations, when assessing the effects of multitasking.



## 1. Introduction

### 1.1. Overview

Understanding the effects of interruptions or distractions is an important goal of attention researchers, with implications for a wide variety of situations. Interruptions can take many forms. For example, imagine that you received a text or instant message (IM) during a lecture or presentation. Should you attend to it or ignore it? People in a wide variety of occupations and circumstances encounter such situations daily. Although distractions could impact knowledge acquisition, and possibly subsequent performance, people often do attend to such interruptions, perhaps believing in their ability to multitask, or perhaps because the interrupting message is more important than the ongoing presentation.

Understanding the role of individual differences is central in many psychological domains, and is also important to understanding the effects of interruptions. Interest level is one individual difference that could play a role in learning, and could mitigate the effect of interruptions. The present study examined the effects of interruptions and interest level on learning, and investigated whether interest could moderate the effects of interruptions in a simultaneous multitasking situation.

### 1.2. Theoretical background

Single channel (or resource) theories of working memory and attention postulate that performing two tasks simultaneously will result in a competition for central attentional resources, reducing recall, performance time, and accuracy (Parasuraman, 2011; Tombu et al., 2011). However, theories such as the multiple component theory of attention and working memory postulate that individuals process information through a variety of cognitive components, each with its own functions and workload capacity. In addition, individuals can opt to use a variety of strategies for processing information, some of which are more effective than others (Hambrick, Oswald, Darowski, Rench, & Brou, 2010; Logie, 2011). Similarly, the executive attention theory of working memory postulates that individuals have the ability to keep information "in mind" in a way that is active and easily retrievable, and that working memory is also involved in concentrating attention in order to avoid distractions (Engle, 2002; Meyer & Kieras, 1997). The multiple component and executive attention theories propose that individuals can process, store, and retain information while performing multiple tasks. Any performance deficits due to multitasking would depend on the extent to which those tasks required use of the same channels or cognitive components, as well as the individual's working memory capacity.

Research results across decades have supported both kinds of theories, with some findings of negative interruption effects (Schiffman & Greist-Bousquet, 1992; Schuh, 1978), some findings of negligible effects (O'Conaill & Frohlich, 1995), and some findings of positive and negative effects depending on factors such as task complexity (Burmistrov & Leonova, 2003; Speier, Valacich, & Vessey, 1999; Tétard,

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1999). More recently, Trafton and Monk's (2008) review concluded that interruption complexity, similarity of the primary and secondary tasks, control over interruption engagement, and availability of retrieval cues were the most consistent predictors of disruptiveness. Specifically, simple, brief interruptions were less disruptive than complex, long ones. Dissimilar interruptions were less disruptive than when both tasks were similar. Negotiated interruptions (for which a response could be postponed) were less disruptive than non-negotiated interruptions. The availability of retrieval cues aided recovery time after an interruption, thus making it less disruptive.

### 1.3. Types of multitasking

In addition to aspects of tasks and interruptions, the type of multitasking also plays a role. Sequential multitasking, also called parallel multitasking and task switching, refers to switching back and forth from a primary to a secondary, interrupting task. Sequential multitasking research results were mixed. Some results sequential multitasking increased the time to perform a task (Conard & Marsh, 2010; Leroy, 2009; Welford, 1952). Other studies showed that brief interruptions (3 to 18 s) increased the time it took to resume a primary task (Hodgetts & Jones, 2006; Monk, Trafton, & Boehm-Davis, 2008; Trafton & Monk, 2008). Altmann, Trafton, and Hambrick (2013) found that interruptions averaging 4.4 s increased response latencies, but interruptions of 2.8 s did not. Importantly, both categories of interruptions considerably increased sequence errors (i.e., resuming the task at an incorrect step in a series of steps) but not other errors. Still other studies found that for simple, boring, or repetitive interruption tasks, participants worked faster after switching back to the primary task, resulting in no net increase in time to complete the primary task (Mark, Gudith, & Klocke, 2008; Ratwani & Trafton, 2006; Speier et al., 1999; Speier, Vessey, & Valacich, 2003).

Simultaneous multitasking differs from sequential multitasking in that it involves performing two tasks at once, such as walking and talking, or listening to a conversation and texting. Single channel theories would predict large deficits in performing these tasks, because it is not possible to truly do two tasks at once. Rather, task performance that appears to be simultaneous is actually task switching at the cognitive level. Alternately, multiple component theories predict that the level of resulting deficits, if any, would depend on the extent to which performing two tasks required shared cognitive components. Conjugate tasks require at least some shared components and more sharing leads to larger deficits. Disjoint tasks don't share components and should have little or no deficit due to simultaneous multitasking. Texting and listening to a conversation are conjugate tasks because both require language processing. Walking and talking are disjoint tasks because they require different cognitive components. Meyer and his colleagues found that simultaneous multitasking with conjugate tasks showed bigger deficits in performance than with disjoint tasks. Practice improved performance for both types of tasks (Meyer & Kieras, 1997).

Many multitasking studies (in non-dangerous situations) were based on purely cognitive tasks such a counting back by threes from 1000, or cognitive and psychomotor tasks such as identifying geometric shapes on a computer screen and pressing a button. Relatively few studied multitasking in everyday tasks. Two studies of sequential multitasking, where participants read a passage and took a comprehension test afterwards, found that participants interrupted with instant messages (IMs) during reading took longer to finish reading than those not interrupted. However, there were no significant differences on test scores (Bowman, Levine, Waite, & Gendron, 2010; Fox, Rosen, & Crawford, 2009).

Conversely, studies employing simultaneous multitasking found differences in grades and test scores. Fried (2008) found a negative correlation between self-reported level of laptop use during classes and final grades. However, Grace-Martin and Gay (2001) found that only long browsing sessions during class were associated with lower final grades. Frequent, short browsing sessions were associated with higher final grades. In a follow-up experiment, Hembrooke and Gay (2003) found that students who were allowed to use laptops during a lecture scored significantly lower on a test than those who did not use laptops, and that the difference was associated with free recall (fill-in) items, not multiple choice items. Although the difference was statistically significant, in practical terms it was equivalent to getting one more item incorrect on the 20 item test, a 5% decrease. Similarly, Rosen, Lim, Carrier, and Cheever (2011) found that participants who received and sent a large number of text messages (more than 16 total received and/or sent, $M = 19$) while viewing a videotaped lecture scored significantly lower on a test than those who received few or no text messages (seven or fewer). In that case, experimenters sent zero, four, or eight text messages. Additional messages were from contacts outside the experiment. Rosen et al. also noted that the size of the difference was equivalent to about one more item incorrect on the 18 item test, a 5.5% decrease. When multitasking required extensive web browsing (approximately 33% of lecture time spent browsing) multitaskers scored 11% lower than non-multitaskers (Sana, Weston, & Cepeda, 2013).

Overall, the evidence from studies using everyday tasks such as reading suggests that sequential multitasking increases time to complete tasks, but does not affect test scores, when completion time was not limited. However, the evidence also suggests that simultaneous multitasking during tasks, such as attending a class or listening to a lecture, there is a small but significant decrease in test scores with brief interruptions (e.g., IMs or text messages), and a somewhat larger deficit with extensive interruptions.

### 1.4. Interest level

In addition to external factors such as types of multitasking or interruptions, there are internal, individual factors that also merit attention from researchers. Level of interest is one of those individual differences that could affect attention and learning, and has not been explored in the multitasking literature. Interest can be categorized as either individual or situational (Krapp, 2002). Situational interest is specific to a topic or situation, and is positively related to intrinsic motivation to learn, academic achievement and coping, and long-term retention of information, (Müller & Louw, 2004). Nye, Su, Rounds, and Drasgow's (2012) meta-analysis of vocational interests showed that when specific interests matched specific characteristics of academic majors or occupations, (analogous to high situational interest) those interests were substantially correlated with grades and job performance. The Nye et al. findings underscore the importance of situational interest to learning. If situational interest is high, it might motivate the activation of more cognitive resources, particularly in working memory, which could allow the individual to better attend to the content being learned in spite of interruptions. Therefore, it is important to investigate interest and interruptions together.

### 1.5. The present study

The present study assessed the effects of interruptions and situational interest on learning during simultaneous multitasking with conjugate tasks (Meyer & Kieras, 1997). We operationalized learning as performance on a test of information from a videotaped business presentation. Instant messages (IMs) interrupted participants as they watched the presentation. Half of the interruptions were timed to coincide with information that was on the test, and half were at other times. This method simulates interruptions in everyday situations, which do not always occur at critical times. Further, in addition to comparing mean differences between interrupted and uninterrupted groups, we compared the relative contributions of interruptions and situational interest, and tested whether interest would moderate the effect of interruptions, in a multiple regression framework. The conjugate tasks involved viewing a videotaped presentation, and noticing, reading, and typing responses to IMs, which involve at least some of the same cognitive channels. Both single channel and multiple component theories would predict a deficit in learning, although single channel theories would predict larger deficits. Therefore, we hypothesized that interrupted participants would learn less than uninterrupted participants (H1). Further, we hypothesized that compared with uninterrupted participants, interrupted participants would do more poorly on test items concerning information presented simultaneously with an interruption than on items concerning information presented at other times (H2). Lastly, we hypothesized that interest would predict learning (H3) and that interest would compensate for (moderate) the effect of interruptions (H4).

## 2. Method

### 2.1. Participants

Undergraduate business students participated ($N = 110$, $M$ age = 21.3, $SD = 2.4$; 62 men, 48 women; 1 sophomore, 40 juniors; 69 seniors; 56 in the interrupted condition, 54 in the uninterrupted condition). Each participant received course credit. Nonparticipants could choose an alternate assignment.

### 2.2. Materials and procedure

Materials consisted of a pre-experiment survey, a videotaped presentation regarding social networking (Contee, 2007), a 22-item test that measured learning of information presented in the videotape, and a post-experiment survey. Survey and test materials were developed by the researchers, were reviewed by undergraduate research assistants for clarity and accuracy for the intended participants, and were pretested with two groups of undergraduates.

Participants chose a time block to participate from among several scheduled blocks, in a conference room with space for up to 12 participants. Because participants were free to choose when they participated, the number per group varied between 6 and 12. Experimental conditions were randomly assigned by time block. Therefore, participants in each group experienced the same condition, either interrupted eight times, or not interrupted.

Participants reported to a conference room with their own laptops and were seated around a U-shaped conference table so that each participant had a clear view of the elevated video screen. Researchers instructed them to close all applications, to turn off their cell phones and any other electronic devices, to open AOL Instant Messenger (AIM) and their course site on Blackboard, and that there would be a test on information presented in the video that they would watch. Researchers issued a code number to each participant so that the survey and test data could be matched, and to preserve participants' anonymity. Participants then signed on to AIM using unique screen names and passwords that were created specifically for the experiment, so that all IM communication could be controlled by the experimenters. We chose IM rather than texting to have that level of control. Next they followed a link to a survey that assessed demographic information, IM experience, social networking experience, attitudes toward interruptions in general, and their typical multitasking behavior during classes (with a three-item scale, I pay attention to my professors in class — reverse scored, how often do you use IM/Facebook/other internet in class, I respond right away when receiving an IM in class). Some of these measures were used as a randomization check, to assess the similarity of participants assigned to the two conditions on factors that might affect the results. Survey items used a five point Likert scale (where 1 = strongly disagree or never, 5 = strongly agree or always).

Once the pre-experiment survey was completed, participants watched a 16 min video of a business presentation regarding internet social networking in venues that were not widely known at the time (Contee, 2007). The presentation was similar to what one might experience in a business meeting, a training presentation, or a classroom lecture. The video was chosen from YouTube with the help of undergraduate research assistants, who judged it to be interesting, and sufficiently novel, so that participants would be willing to attend to it, and they would be unlikely to have previous knowledge of the topics presented.

During the video presentation, research assistants sent a different IM question at eight carefully selected times throughout the presentation based on a video time code. Four were intentionally timed to occur when the speaker was presenting information that corresponded to a test item. Those simultaneous interruptions were sent approximately two seconds before presented information began, in order to allow for transmission time. The to-be-tested information occurred within the presenter's next one or two sentences. The interrupting IMs were: What was the last thing you watched on TV? What is your favorite sport? What is the name of the last movie you saw in a theater? What month is your birthday? Four IMs were sent at other times, when information would not be tested (non-simultaneous interruptions).

Immediately after the presentation, participants were directed to their class Blackboard site where they completed a 22-item multiple choice test that measured learning from the presentation. They then followed a link provided on Blackboard to a post-experiment survey that assessed reactions to the experiment. Because situational interest must be measured specifically for the event, we designed a five-item scale to measure it. Cronbach's alpha reliability analyses showed that a three-item scale had higher reliability, therefore it was used in subsequent analyses. Those items were: the video was interesting, the speaker was engaging, I learned something from the video. Lack of attention was assessed with a three-item scale (e.g., I was impatient with the video, my attention wandered, it was easy to focus on the video — reverse scored). For those in the interrupted condition (N = 56), level of distraction was measured with a four-item scale (IMs caused me to miss things, IMs distracted me, other computers distracted me, I was able to concentrate on the video — reverse scored). The scales showed acceptable levels of reliability. Cronbach's alpha values are presented in Table 1.

## 3. Results and discussion

### 3.1. Randomization check

As a randomization check, we compared the interrupted and uninterrupted groups on a priori individual difference variables that could affect the results. We did not have direct measures of working memory or cognitive ability, however, the groups were not significantly different on GPA or SAT, which are correlated with working memory capacity (Logie, 2011) and cognitive ability. Further, the groups were not different in how much time they spent weekly on such activities as instant messaging, Facebook, the internet in general, video games, television, and reading, nor on multitasking during classes, use of instant messaging, and attitudes toward interruptions. Therefore, the groups were not different in capabilities or experience. (These independent $t$-test results are available on request from the authors.)

### 3.2. Manipulation check

Because participants who received IMs could choose to ignore them in spite of the experimenter's instructions, or might not notice them immediately, it was important to assess whether the IM interruptions were actually attended to. Upon examination of the AIM logs, out of 448 total IMs sent (eight each to 56 participants), 441 responses were received (98%). Participants also answered quickly. Mean time elapsed between sending the IM and receiving a response, which would include reading the IM, thinking of a response, and typing the response, was 12.6, 10.5, 15.5 and 19 s for the four simultaneous IMs, and the range

**Table 1**
Means, standard deviations, alphas, and intercorrelations for major study variables.

| | Mean (SD) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Test performance (22 items) | 15.8 (2.1) | – | | | | | | | | |
| 2. GPA | 3.2 (0.4) | .17 | – | | | | | | | |
| 3. Total SAT (N = 92) | 1117.4 (170) | .07 | .25* | – | | | | | | |
| 4. Situational Interest (3 items) | 10.1 (2.3) | .24* | −.04 | .01 | (.70) | | | | | |
| 5. Attention not focused (3 items) | 10.6 (2.3) | −.14 | .17 | .17 | −.49** | (.78) | | | | |
| 6. IMs Distracted (4 items, N = 55) | 12.5 (3.5) | −.15 | .08 | .09 | .19 | .42** | (.75) | | | |
| 7. Simultaneous items (4 items) | 73.9 (19.6) | .48** | .09 | .08 | −.02 | −.07 | −.03 | – | | |
| 8. Non-simultaneous items (18 items) | 66.9 (10.1) | .90** | .14 | .02 | .27** | −.10 | −.10 | .09 | – | |
| 9. In-class multitasking (3 items) | 8.1 (2.4) | −.08 | −.18 | −.10 | −.04 | .03 | −.19 | .01 | −.05 | (.78) |

N = 110, except where noted. Simultaneous items are quiz items that coincided with an IM interruption. Non-simultaneous items are quiz items that did not coincide with an IM interruption. For number 7 and 8, means are percent correct. Cronbach's alphas are reported in parentheses along the diagonal.
* $p < .05$.
** $p < .01$.

was 90–98% of responses received within 30 s. Further, in the post experiment survey, interrupted participants indicated that they found the IMs to be moderately distracting ($M = 12.5$, $SD = 3.5$ out of a possible 20). Mean time elapsed for the four non-simultaneous IMs were 16.2, 18.2, 11.6, and 23.1 s. Overall, the mean time to respond was 15.9 s ($SD = 6.3$). These statistics clearly indicate that the interruptions did work as intended.

### 3.3. Prior IM use and multitasking

Not surprisingly, results indicated that participants were highly involved in electronic multitasking, in general. On a five point Likert scale, (where 1 = strongly disagree or never, 5 = strongly agree or always), the mean for "I usually keep IM and email running and my phone on when I do school work" was 4.2 ($SD = 1.1$). For "When your computer is on, how often do you have your IM software on?" $M = 4.3$ ($SD = 1.0$). For "Do you generally respond right away when you receive an IM?" $M = 3.6$ ($SD = 0.9$). Participants averaged 9.9 ($SD = 14.3$) hours per week instant messaging. These results showed that instant messaging was a common part of the participants' daily lives and was an appropriate type of interruption to use.

### 3.4. Interruptions, situational interest, and learning

Table 1 presents descriptive statistics, correlations for major study variables and Cronbach's alpha reliabilities for multi-item scales. The four scales that were created (in class multitasking, interest, lack of attention, distraction) showed acceptable levels of reliability, particularly since they were relatively short (3 or 4 items each). The pattern of correlations indicates acceptable levels of multicollinearity. Examination of the correlations indicates that test performance was modestly but not significantly correlated with GPA. Test performance was positively correlated with interest in the video, and negatively (but not significantly) correlated with inability to focus attention on the video, and level of distractions.

Similar to the Fox et al. (2009) results, participants' habits of in-class multitasking were generally negatively correlated with other study variables, particularly GPA, and also (for those who were interrupted) the extent to which they felt distracted during the study, however those correlations did not reach significance at the $p < .05$ level. For all participants, interest in the presentation was negatively correlated with inability to focus (which would be expected). For those who were interrupted, interest was significantly positively correlated with feeling distracted by the IM interruptions. The more they were interested in the presentation, the more they felt distracted. Regarding participant reactions, the interrupted and uninterrupted participants were not different on level of interest in the video or the scale that measured lack of attention to the video. Table 2 also presents those results.

To test H1 and H2, independent sample *t*-tests were computed and are presented in Table 2. Regarding test performance, the interrupted group scored significantly lower than the uninterrupted group, which supported H1. This finding is consistent with previous findings that interruptions had deleterious effects for reading comprehension tasks, as well as attending to information in a presentation (e.g., Bowman et al., 2010; Hembrooke & Gay, 2003; Monk et al., 2008; Rosen et al., 2011).

Subsamples of test items were divided into those that were simultaneously interrupted (in the interruption condition; four items) and those that were not interrupted (non-simultaneous; 18 items). Compared to uninterrupted participants, interrupted participants performed worse on the simultaneous items. There was no difference in performance on the non-simultaneous items, so there does not appear to be a generalized interruption effect. These findings support H2. Because of the one-item effect size for the simultaneous interruptions, we performed *t*-tests on each of those four items. The results showed that it was one of the four simultaneous interruptions that accounted for the difference ($t\ (108) = 2.5$, $p = .005$). Conversely, three out of four items with simultaneous interruptions showed no significant differences. Taken together, these results indicate that the difference in test performance can be attributed to getting one more item wrong, when the information was presented simultaneously with an interruption.

Single channel theories of working memory would predict severe deficits in this simultaneous multitasking scenario, even to the extent that it would not be possible to do both tasks at the same time. However, multiple component and executive attention theories would predict some deficits, corresponding to the extent to which each task required the same cognitive channels, and the extent to which individuals can keep information from one task "in mind" and retrievable while performing another task. Multiple component and executive attention theories of working memory appear to explain the present results better because there was some deficit, but not as severe as single channel

**Table 2**
Descriptive statistics and *t*-test results.

| | Not Interrupted | Interrupted | |
|---|---|---|---|
| | Mean (*SD*) | Mean (*SD*) | *t* (108) |
| Test score (22 items) | 16.3 (2.0) | 15.3 (2.1) | 2.40* |
| Test percentage | 74.1% | 69.5% | |
| Simultaneous items correct (4 items) | 85.2% (14) | 74.6% (18) | 3.42*** |
| Non-simultaneous items correct (18 items) | 71.5% (10) | 68.7% (9) | 1.51** |
| In-class multitasking (3 items) | 8.5 (2.8) | 7.9 (2.3) | 1.36 |
| Interest (3 items) | 10.4 (2.4) | 9.8 (2.3) | 1.49 |
| Attention not focused (3 items) | 10.4 (2.8) | 10.7 (1.9) | −0.74 |

* $p < .05$.
** $p < .01$.
*** $p < .001$.

theories would predict (Engle, 2002; Logie, 2011). Further, Klingberg (2010) summarized studies that demonstrated that people who practiced specific working memory tasks improved their working memory capacity for those particular tasks. It may be that participants, who indicated that they practiced computer based multitasking frequently using IM, may have become fairly skilled at it, and perhaps have improved their working memory capacity (Dux et al., 2009) and therefore their ability to multitask and retain information in this particular situation (Hambrick et al., 2010).

Another possible explanation is that participants didn't notice or attend to the IMs immediately, so they weren't actually simultaneous interruptions, and therefore were not disruptive. However, analysis of the AIM logs showed that mean time elapsed between sending the IM and receiving a response ranged from 10.5 to 19 s for the four simultaneous IMs. Further, all IMs were timed to be sent corresponding to the video time code, either when tested information was presented, or at other times.

It is possible that participants treated the IMs as a negotiated interruption, in that they could decide to respond immediately or to delay responding and continue attending to the presentation, and therefore were able to learn the information presented (Trafton & Monk, 2008). However, the mean elapsed times between sending the IMs and receiving responses indicate that there was little or no delay, and for the four simultaneous IMs, the vast majority of responses were received within 30 s. It does not appear that participants were systematically delaying responses.

To test the effects of interest on test scores (H3 and H4) a series of multiple regression equations were estimated and are presented in Table 3. First, to improve interpretability in a continuous variable when zero is not a meaningful score, situational interest scores were centered by subtracting scores from the mean (Cohen, Cohen, Aiken, & West, 2003). Then experimental condition (interrupted vs. not, coded 1 and 0 respectively), and interest were regressed on test score. Interruptions and interest predicted test score independently. Therefore, H3 was supported. The β-weights indicate that both interruptions and situational interest contributed equally, in opposite directions, to predicting test score. Examination of $R^2$ and $\Delta R^2$ showed that experimental condition accounted for 5.0% of the variance in test scores, and situational interest accounted for an additional 5.0%. Interpretation of the β-weights in Table 3, step 1 indicates that in practical terms, when interruption condition is held constant, there was a 0.57 point (2.6%) increase in test score for *each one point increase* in interest. Conversely, when interest is held constant, those in the interrupted group averaged −.86 points lower (3.9%) than the interrupted group.

Moderator effects can happen in several ways. Because there was no extant literature that suggests how interest might moderate the effect of interruptions, we tested both linear (interaction) and quadratic (curvilinear) moderation effects (Baron & Kenny, 1986). The results in Table 3, Steps 2a and 2b show that neither moderator effect was significant. Therefore H4 was not supported. Taken together, these findings are important because they show that interruptions and interest independently affect learning, however the effect of interruptions does not change at different levels of interest, and the effect of interest was the same for uninterrupted and interrupted groups.

**Table 3**
Summary of hierarchical regression analysis for variables predicting test performance.

| Variable | B | SE B | β |
|---|---|---|---|
| *Step 1* | | | |
| Interruption (I) | −.86 | .39 | −.21* |
| Situational interest (SI) | .57 | .25 | .21* |
| *Step 2a (linear moderation)* | | | |
| I | −.86 | .39 | −.21* |
| SI | .53 | .36 | .20* |
| I × SI | .08 | .50 | .02 |
| *Step 2b (quadratic moderation)* | | | |
| I | −1.04 | .52 | −.25* |
| SI | .52 | .36 | .20 |
| $SI^2$ | −.26 | .46 | −.11 |
| I × $SI^2$ | .31 | .58 | .11 |

Note. *N* = 109. $R^2$ = .05 for interruption condition; $R^2$ = .10 for Step 1; $\Delta R^2$ = .00 for step 2a; $\Delta R^2$ = .00 for step 2b.
* $p < .05$.

*3.5. Limitations*

The present study included eight interruptions which could be dealt with in relatively short periods of time. Therefore the results pertain to relatively brief, dispersed interruptions and not interruptions such as lengthy conversations or internet browsing.

Learning was measured with a multiple choice test, which is a recognition task, rather than free recall such as an essay or fill-in-the-blanks. Hembrooke and Gay (2003) found that recall items showed decrements after interruptions, but multiple choice items did not. It is possible that the multiple choice items made it easier to retrieve information from memory than free recall items would have.

The study design involved a realistic situation where participants would have to notice and respond to IMs on their laptops. Instructions to participants were that they immediately respond to any IMs received. Research assistants sent IMs at exact times corresponding to video time codes. Further, analysis of the AOL logs indicated that interruptions occurred in a timely fashion. However, it does not eliminate the possibility that some participants may not have noticed the arrival of some IMs immediately, or may have delayed responding for some other reason, and managed to attend to the relevant information.

The participants were from a generation that grew up with access to computers, and they were experienced with multitasking using IM. Less experienced participants might have greater decrements to learning.

## 4. Conclusions and implications

The present study makes several important contributions to our understanding of multitasking. First, the results showed that interruptions affected learning, and the effect was significant but relatively small (4.5% of test score) and it was due to information presented simultaneously with an interruption. Interestingly, similar effect sizes were also found in two additional studies (Hembrooke & Gay, 2003; Rosen et al., 2011) so there appears to be a pattern emerging in the literature. In a practical sense, a 4–5% decrease in test scores could represent a drop in one half of a letter grade in a college course, so it is not trivial. However, the deficit is not enormous. It is important to note that the experimental situation did not involve danger. A 5% deficit in learning tasks or skills that involve potential for harm, such as driving or air traffic control, could be catastrophic.

Second, the experimental situation was very similar to a business meeting, a training presentation, or a classroom lecture. This verisimilitude increases the likelihood that results will generalize outside of the laboratory situation. Studies such as this can inform the debates surrounding laptop use in college classrooms (see Fried, 2008) or the use of electronic devices at work, and in everyday life. Overall, the evidence supports multiple component and executive attentional theories of working memory (Engle, 2002; Logie, 2011) and indicates that interruptions had a significant but small effect on learning. Three of four simultaneous interruptions did not affect learning. Perhaps participants have well developed working memory capacity for this particular task, possibly influenced by practice, or they may have used some effective multitasking strategies or both (Hambrick et al., 2010; Meyer & Kieras, 1997). Future studies could examine those factors together.

Third, situational interest was as important to predicting learning as were interruptions and the effects were in opposite directions. This result adds to previous studies which showed that interest was correlated with intrinsic motivation to learn, long-term retention of information, coping with academic demands, academic achievement, and job performance (Müller & Louw, 2004; Nye et al., 2012). It was expected that high interest might motivate the activation of additional mental resources, which could mitigate the effect of interruptions. However, interest did not moderate the interruption effect.

Fourth, the widespread method of statistically comparing group-level mean differences in performance on dependent variables such as learning or speed of response in experimental studies of multitasking gives us limited information, in that it overemphasizes the importance of the experimental manipulations and ignores important individual factors. Using multiple regression and causal modeling frameworks, as in the present study, as well as in Fox et al. (2009) and Hambrick et al. (2010), expands our understanding of the role of individual differences in multitasking. The present results showed that situational interest is one of those important predictors. Other individual level factors such as working memory capacity (Conway, Cowan, & Bunting, 2001; Engle, 2002; Hambrick et al., 2010; Parasuraman, 2011) have shown similar effects. Additionally, Dux et al. (2009) showed that training with multitasking improves information processing speed, indicating that training and expertise are factors that also merit further investigation. Due to the ubiquitous nature of multitasking, the fact that in some situations it is unavoidable, and the likelihood that the future will include it, we need to change the question of whether multitasking is deleterious, to when, how, and for whom does multitasking work, and to understand when to use it and also when to avoid it.

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