Non-academic internet use in the classroom is negatively related to classroom learning regardless of intellectual ability

Susan M. Ravizza*, David Z. Hambrick, Kimberly M. Fenn

Department of Psychology, Michigan State University, East Lansing, MI 48824, USA

ABSTRACT

The use of laptops and cell phones in the classroom is increasing but there is little research assessing whether these devices create distraction that diminishes learning. Moreover, the contribution of intellectual ability to the relationship between learning and portable device use has not been thoroughly investigated. To bridge this gap, students in an introductory psychology class were surveyed about the frequency and duration of their use of various portable devices in the classroom. Internet use negatively predicted exam scores and added to the prediction of classroom learning, above a measure of intellectual ability. Furthermore, students discounted the effect of using portable devices on learning over time. Concomitantly, those with higher intellectual ability reported using the internet more in class over time. Thus, higher rates of internet use were associated with lower test grades and students' beliefs about this relationship did not reflect their ability to multi-task effectively.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Portable device use has become increasingly common in the classroom with 62% of students reporting the use of electronic media for non-academic purposes while in class, studying, or doing homework (Jacobsen & Forste, 2011). An estimated 95% of college students bring their cell phones to class every day (Tindell & Bohlander, 2012) and an estimated 29% bring laptops (Aguilar-Roca, Williams, & O'Dowd, 2012). The use of these devices in the classroom can have both positive and negative effects on classroom learning. On the positive side, survey data suggest that laptop use promotes participation in class (Samson, 2010; Trimmel & Bachmann, 2004) and increases students' motivation to learn (Barak, Lipson, & Lerman, 2006; Kay & Lauricella, 2011; Mouza, 2008; Samson, 2010; Trimmel & Bachmann, 2004). Moreover, in a well-controlled classroom setting, grades and test scores were higher for students using laptops than those not using laptops (Cengiz Gulek & Demirtas, 2005). Portable devices, however, can also serve as a distraction when used in uncontrolled and non-directed contexts (Fried, 2008). These devices allow students to send and receive messages with ease and also allow for other activities such as internet shopping, reading the news, watching sports, and checking email. The present study focuses on portable device use for non-academic purposes, during class.

While a few studies have reported negative effects on academic performance (e.g., lower exam scores) associated with the use of portable devices (Barks, Searight, & Ratwik, 2011; Clayson & Haley, 2013; Hembrooke & Gay, 2003; Jacobsen & Forste, 2011; Rosen, Lim, Carrier, & Cheever, 2011; Sana, Weston, & Cepeda, 2013; Wood et al., 2012), these findings are limited in their implications for classroom learning. For example, one study tested performance on only a limited amount of information on the order of 1–3 lectures (Clayson & Haley, 2013) and others used a simulated academic setting rather than a real classroom (Hembrooke & Gay, 2003; Sana et al., 2013). Finally, some of this work investigated the effect of learning with distraction using experimental paradigms that may not be ecologically valid (e.g., mandatory reading and responding to texts from research assistants; Barks et al., 2011; Risko, Buchanan, Medimorec, & Kingstone, 2013; Rosen et al., 2011; Wood et al., 2012).

The primary goal of the present study was to assess the relationship between natural portable device use in the classroom and performance in a real academic setting. With the rise in the use of cell phones and laptops in the classroom (Aguilar-Roca et al., 2012; Tindell &

Bohlander, 2012) students have the opportunity to use these devices at the same time that they attend to lectures. Essentially, some students are media multi-tasking in the classroom; that is, they are attempting to monitor auditory and visual classroom material while also processing visual (and tactile) information from their electronic devices.

Research on the relationship of dual task performance and the frequency of media multi-tasking has been mixed. There is some evidence that individuals differ in the style in which they process multiple streams of information, based on the frequency with which they media multi-task (Ophir, Nass, & Wagner, 2009). For example, heavy media multi-taskers made more false alarms in a working memory N-back task and were slower to switch between tasks. This pattern of deficits suggested that heavy users were less able to filter out irrelevant information (Ophir et al., 2009). Similarly, another study reported that heavy media multi-taskers were less likely to use top-down information in an attention task suggesting that heavy users are biased to process more of the available visual information (Cain & Mitroff, 2011). In contrast, Alzahabi and Becker (2013b) found that heavy media multi-taskers were <u>faster</u> to switch between tasks than light users perhaps because of their greater experience in switching between multiple streams of information. Yet another study found no difference in task switching or filtering irrelevant information in working memory between heavy and light users (Minear, Brasher, McCurdy, Lewis, & Younggren, 2013). Given these conflicting results, there may be another factor mediating the relationship between media multi-tasking and cognition that was not considered in these studies; in particular, we suggest that general intellectual ability may moderate the ability to monitor multiple information streams.

Thus, a further goal of this study was to investigate whether the relationship between technology use and classroom performance was influenced by intellectual ability. Research on individual differences suggests that those with higher intellectual ability (e.g., working memory capacity) are better at filtering out distraction (Engle, 2002; Vogel, McCollough, & Machizawa, 2005; Poole & Kane, 2009). It is possible that higher-ability students will have a greater ability to regulate their use of portable technology. For example, high-ability students may be better able to inhibit their use of portable technology or assess when using such devices would be detrimental to learning. Furthermore, if intellectual ability reflects availability of attentional resources (e.g., Ackerman, 1987), then higher ability students may be able to multi-task more effectively and, therefore, may be able to use portable devices without harming their learning. That is, if the use of portable devices for non-academic purposes influences learning, this effect may be restricted to lower-performing students.

Although one study assessed the relationship of laptop use and classroom performance while controlling for ACT scores (Fried, 2008), we use structural equation modeling (SEM) to test for the effect of portable device use on classroom performance at the level of latent variables. A latent variable captures the systematic variance common to multiple measures of a construct and is therefore free of measurement error. Thus, we estimated the relationship between portable device use and classroom performance at the level of theoretical constructs rather than at the level of less reliable observed variables. We also used SEM to test whether the relationship between portable device use and classroom performance varied as a function of intellectual ability and included not only laptop use, but use of other devices such as smartphones.

We examined the relationship between classroom performance and use of portable technology and accounted for overall intellectuall ability and academic achievement using ACT composite scores, which correlate very highly with independent measures of general intelligence (Koenig, Frey, & Detterman, 2008). The specific question we addressed was whether portable technology use in the classroom would add significantly to the prediction of class grades, above and beyond intellectual ability. Further, the magnitude of the relationship was assessed for those with high and low intellectual ability.

2. Materials and methods

2.1. Participants

Five-hundred and eight students, enrolled in an Introductory Psychology class in Fall 2012, were asked to participate in this experiment. One-hundred and ninety-six students consented to participate in the experiment and ACT scores were available for 170 of those students. The majority of the students who participated were freshman (62%) or sophomores (24%) with only a small percentage of juniors (8%) and seniors (6%). This distribution was quite similar to the distribution of the entire class— 60% freshman, 25% sophomores, 9% juniors, and 6% seniors. Exam grades of the participants (81% averaged across all four tests) were somewhat higher than the class as a whole (78%). This may reflect the fact that lower-performing students are more likely to miss class (and were, therefore, not present on the day that consent forms were distributed).

With participants' permission, we obtained ACT scores from the university registrar. Thus, the ACT scores were accurate. Participants received no compensation for participation.

2.2. Materials

We created a 9-question survey to assess the frequency and duration of texting, accessing Facebook, checking email, and non-class related internet use during lectures. For each form of distraction (i.e. texting, Facebook, email, internet use), we first asked students to report how frequently they used the technology and then asked them to estimate the average amount of time spent on these activities during each lecture. Frequency of use was assessed using a 5-point scale corresponding to the following descriptions: Never, 1—3 times, 4—6 times, 7—9 times, Almost all class. Duration of use was also assessed on a 5-point scale: Zero minutes, 1—5 min, 6—15 min, 16—30 min, Greater than 30 min. A final question assessed the degree to which students thought that internet and phone use affected their learning of class material. It used a 5-point scale with the following descriptions: It has greatly impeded my learning, It has somewhat impeded my learning, It has no effect on my learning, It has somewhat improved my learning, It has greatly improved my learning.

2.3. Procedure

Participants were recruited from a large lecture course (original enrollment was 523 and 508 students completed the course). Four exams were given throughout the course and were composed of 50—51 multiple choice questions each worth 2 points. The first three exams tested

Table 1
Self-reported use of each type of distraction on a 0-8 scale summing across frequency and duration ($n = 170$).

Score (range = 0–8) Mean (SEM)	Facebook	Email	Internet	Texting
	1.87 (.14)	1.26 (.08)	2.9 (.19)	3.3 (.15)

course material from one-third of the course and the final exam was cumulative. The class met two times a week for 15 weeks from 10:20–12:10 with a 10-min break beginning at approximately 11:20.

The survey was administered during class time using Microsoft PowerPoint on three occasions in the semester, approximately one week prior to each exam. Consent forms were only offered during the first assessment so students who were not present in class that day could not participate in the experiment. Students were told to answer the questions according to their typical classroom use throughout the semester and not restricted to that particular day. Moreover, students were asked to respond about usage concerning non-classroom based activities rather than portable device use for class-related purposes. Students responded to the questions using iClicker response devices. Participants registered their clickers for class because they were also used to assess attendance and class participation. This allowed us to link their responses on the survey with their test scores. They were assured that none of the data would be examined until grades were submitted at the end of the course.

3. Results

3.1. Portable device use

The values on the frequency and duration scales for each type of technology use were summed for each of the three assessment points. We scored responses on a 0-4 scale such that higher numbers indicated more technology use. For example, for frequency of use, a response of "Never" would be assigned a value of "0", "1–3 times" would be assigned a value of "1", etc. We first assessed which form of technology students used most often in class. A repeated measures ANOVA on technology use, averaged across three sessions, indicated that students reported spending the most time texting in class followed, in descending order, by using the internet, accessing Facebook, and checking email $F_{3, 480} = 80.13$, $p < .05$, partial eta$^2 = .33$) (Table 1). Planned comparisons indicated that all differences in technology use were statistically significant (all ts > 2.33, all ps < .05).

The relationship between the use of portable devices and classroom performance was assessed by correlating self-reported ratings of technology use with scores on the cumulative final exam, using a Bonferroni adjusted p-value of .01 to account for the number of tests performed (.05/4 = .01). All four types of technology use were negatively correlated with final exam score, however, only non-class internet use showed a significant relationship (texting: $r(167) = -.07$, $p = .39$; internet use: $r(162) = -.22$, $p = .005$; Facebook: $r(167) = -.10$, $p = .212$; email: $r(169) = -.07$, $p = .388$)[1]. Thus, lower test scores were related to higher ratings of using the internet for non-classroom purposes.

3.2. Structural equation modeling

This analysis focused on ratings of non-classroom internet use given that this was the only form of portable technology use that was correlated with test performance. Ninety-five participants had 1-2 missing values for internet use; these values were estimated in the SEM using the expectation maximization (EM) procedure in SPSS (v. 21). There was one outlier (>3.5 SDs from mean on Exam 3), which we replaced with a value corresponding to 3.5 SDs from the mean.

The relationship between internet use, ACT scores, and classroom performance was assessed using structural equation modeling (SEM). The latent variable representing internet use was estimated based on the three measures of internet use from the semester, and the latent variable representing classroom performance were estimated based on the three exams during the semester and the cumulative final exam. The model also included ACT scores as a measure of general intellectual ability, which was allowed to correlate with internet use. As can be seen from Fig. 1, internet use negatively predicted classroom performance ($-.30$, $p < .01$), above and beyond the effect of ACT on classroom performance (.42, $p < .01$). Moreover, ACT and internet use correlated near zero ($-.02$, $p = .79$). Model fit was excellent: $\chi^2(18) = 25.73$, $p = .11$, CFI = .99, NFI = .96, RMSEA = .05.

We performed a multiple-groups SEM to test for whether the relationship between internet use and classroom learning was stronger for those with lower ACT scores than for those with higher ACT scores. We divided the sample into low-ability ($n = 73$) and high-ability ($n = 97$) groups based on a median split on ACT score (see Kline, 2011). Model fit was not significantly different across the groups, $\Delta\chi^2 < 1$, indicating that the negative effect of internet use on classroom learning was not significantly different across the high ability ($-.33$, $p < .01$) and low ability ($-.28$, $p < .05$) groups.

3.3. Beliefs about portable device use

Students also rated how they thought the use of portable devices affected their learning of classroom material. Beliefs changed over time as indicated by a significant repeated-measures ANOVA with time as a within-subject factor and intellectual ability as a between-subject factor (97 students participated in all 3 belief assessments; $F(2, 190) = 58.6$, $p < .05$, partial eta$^2 = .38$). The main effect of time was primarily due to a difference between the first session which occurred before the first exam and the last two assessments (time 1 vs. 2: $t(96) = 8.34$, $p < .05$; time 1 vs 3: $t(96) = 8.11$, $p < .05$; time 2 vs. 3: $t(96) = .49$ $p = .62$). Before taking the first exam, participants were more likely to think that their portable device use was negatively impacting their learning (avg. rating: 1.72), but ratings changed after the first

---

[1] The sample size for correlations varies because some students did not complete every survey question.
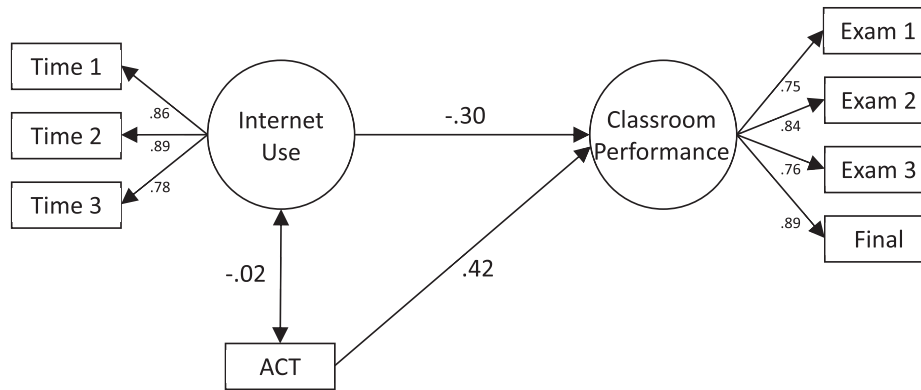
Fig. 1. SEM model with Internet use and ACT-composite scores as factors predicting classroom performance.

exam, and students were more likely to believe that their learning was unaffected by internet use (time 2: 2.72; time 3: 2.69). The main effect of group, $F(1, 95) = 1$, $p = .32$, partial eta$^2 = .01$, and the interaction of time and group was not significant, $F(2, 190) = .45$, $p = .64$, partial eta$^2 = .01$.

Correspondingly, a repeated-measures time × group ANOVA indicated that ratings of internet use also changed over time (78 students participated in all 3 internet use assessment times; $F(2, 152) = 4.58$, $p < .05$, partial eta$^2 = .06$); namely, internet use was reported to be higher after the first exam at assessments 2 and 3 compared to assessment 1 (Fig. 2). However, the effect of time was modulated by ACT scores, $F(2, 152) = 3.4$, $p < .05$, partial eta$^2 = .04$. Those with higher ACT scores reported using the internet more after the first test (time 1 vs. 2: $t(42) = 3.15$, $p < .05$; time 1 vs 3: $t(42) = 3.4$, $p < .05$; time 2 vs. 3: $t(42) = .71$, $p = .48$) whereas those with lower ACT scores showed no change (all $ts < .6$, all $ps > .55$). There was no main effect of group indicating that ratings of internet use during class were similar $F(1,76) = 1.23$, $p = .27$, partial eta$^2 = .02$. Thus, all students tended to discount the impact of portable device use over time, while, at the same time, those with higher ACT scores reported that they used the internet more during class.

While beliefs and internet use seemed to plateau after the first test, differences in actual test performance continued to change throughout the semester. For this analysis, we looked at the three interim exams which were given a week after each survey and excluded the cumulative final exam given a week after the third exam. A main effect of time was observed in a repeated-measures ANOVA in performance on the three exams, $F(2, 336) = 13.33$, $p < .05$, partial eta$^2 = .07$, but the interaction of time and group was not significant, $F(2, 336) = 2.15$, $p = .12$, partial eta$^2 = .01$. The worst performance was on Exam 1 (mean = 78%), followed by Exam 3 (80%) and then Exam 2 (82%). Paired t-tests showed significant differences between all test scores (Exam 1 vs 2: $t(169) = -5.24$, $p < .05$; Exam 1 vs 3: $t(169) = -2.35$, $p < .05$; Exam 2 vs 3: $t(169) = 2.5$, $p < .05$). Thus, test performance did not plateau after Exam 1 as did beliefs about internet use and test performance and self-reported internet use.

4. Discussion

Using the internet for non-classroom purposes was related to classroom performance; higher rates of internet use were associated with lower exam scores. Moreover, internet use was a significant source of the variance in test scores that was independent from overall intellectual ability as indexed by ACT composite scores. These results are consistent with the possibility that students are not efficient multitaskers when browsing the internet during class, and that this is true regardless of intellectual ability.

We found no evidence that those with higher ACT scores (reflecting higher intellectual ability) were able to multi-task more efficiently; that is, the correlations between classroom performance and portable device use were similar for those with lower and higher ACT scores. This was surprising given that variables that are strongly related to intelligence, such as working memory capacity, are related to the ability to filter out irrelevant information in studies using paradigms such as the Stroop and flanker tasks (Engle, 2002; Poole & Kane, 2009; Vogel et al., 2005). Moreover, general intelligence is related to lower rates of goal neglect in which task requirements are remembered but ignored (Duncan, Emslie, Williams, Johnson, & Freer, 1996, 2008). These data suggest that using portable devices during class may be different from multi-tasking in general. For example, students voluntarily attend to portable devices by logging into an instant message or Facebook account, responding to text messages, or opening internet browsing windows. In contrast, irrelevant information captures attention automatically and involuntarily in tasks such as the Stroop. Intellectual ability may be more related to resisting attentional capture from irrelevant information than deciding whether to voluntarily attend to irrelevant information. The latter may be influenced by how well the student perceives he/she is doing in the class ("I don't have to pay attention") or interest in the material. Indeed, intelligence was not associated with the frequency of multi-tasking with electronic media in another study (Alzahabi & Becker, 2013a). How these and other factors are related to portable device use is an important avenue for further inquiry.

The magnitude of the correlation between internet use and test performance is probably an underestimate of the true magnitude of this relationship. First, students are likely to be under-reporting their use of portable devices (Kraushaar & Novak, 2010). Although we assured students that their survey answers would not be examined until grades had been submitted to the registrar, it is possible that some students may have worried about the confidentiality of their responses. Second, we focused on portable device use during the encoding of information presented in the classroom, but students also use portable devices while studying this information as well beyond the classroom. For example, one study reported that high school and university students who accessed Facebook while studying had lower GPAs than those who avoided Facebook (Rosen, Carrier, & Cheever, 2013). While it seems likely that students who use the internet in the classroom are also more likely to do so while studying, there may be students who have access to portable devices while studying at home, but not in the
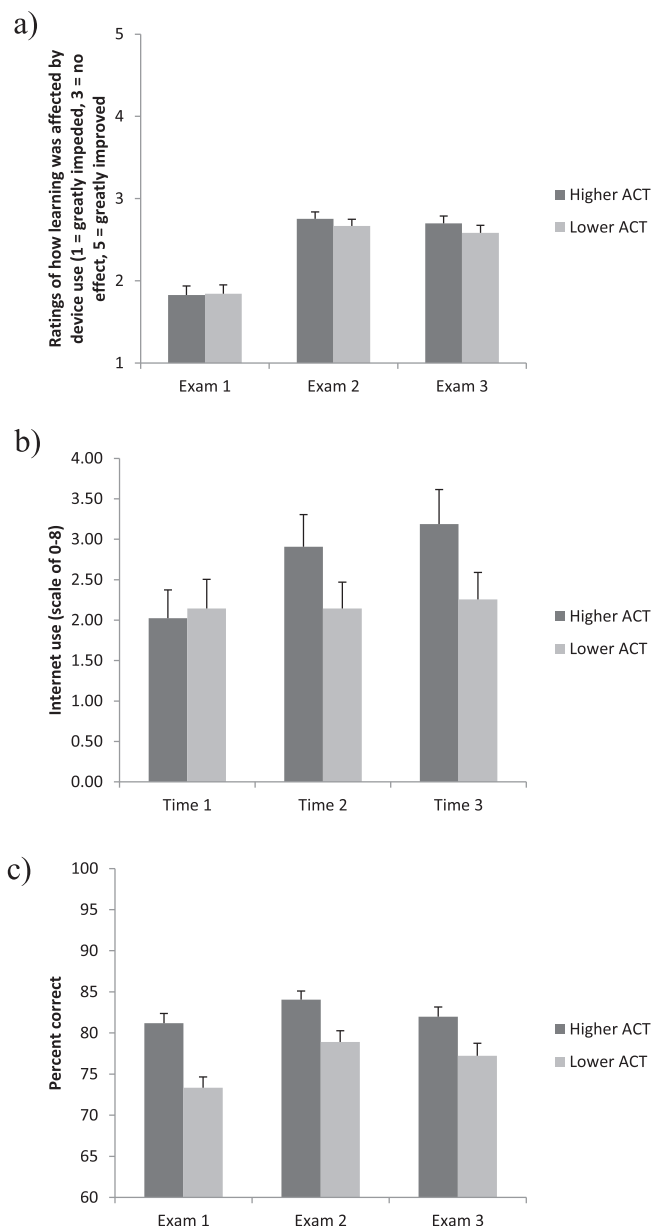
Fig. 2. Self-reported a) beliefs about portable device use and learning and b) internet use at the 3 assessment times for groups with higher and lower ACT scores. Accuracy on the three interim exams is also shown (c). The three interim exams were given about 1 week before each of three surveys.

classroom. Even without factoring in internet use while studying, however, a significant association between classroom internet use and test performance was observed.

Students discounted the effects of using portable devices on their learning over time. This finding is consistent with other studies reporting that students show poor awareness of how their use of portable devices affects their learning (Clayson & Haley, 2013; Rosen et al., 2011). Our results also suggest that internet use concomitantly increases over time, but only for students with higher intellectual ability. Given that greater internet use is associated with lower classroom performance, those with higher intellectual ability may be more vulnerable to these effects as the class progresses.

Accessing Facebook, checking email, and texting were not significantly related to test scores, although previous studies have reported relationships between texting and Facebook use and classroom learning (Barks et al., 2011; Clayson & Haley, 2013; Rosen et al., 2011; Wood et al., 2012). The null result is unlikely to be due to be an artifact of the absolute differences in the frequency or duration of use, however. Students reported texting more often than any of the other types of portable device use, but the relationship of texting to classroom performance was still weak. One possibility is that texting, checking email, and Facebook are more transient activities while using the internet to read news or shop is more involved and requires sustained attention. Consistent with this proposal, the duration spent browsing the internet was reported to be higher than texting whereas students reported texting more frequently that browsing the internet. The null result should be interpreted cautiously, however, and it should be noted that all types of computer and phone use were negatively related to performance on the final exam.

Our results support other studies showing a negative relationship between portable device use and classroom learning (Barks et al., 2011; Clayson & Haley, 2013; Hembrooke & Gay, 2003; Jacobsen & Forste, 2011; Rosen et al., 2011; Sana et al., 2013; Wood et al., 2012). Concluding

that the use of portable devices during class leads to lower levels of learning, however, is not warranted on the basis of these results - the results are only *consistent* with this possibility. First, we relied on self-reported use which is likely to contain more error than directly observing actual use (Kraushaar & Novak, 2010). Students may under-report portable device use if anxious about the confidentiality of their responses or may not be able to recall how often they used portable devices during the past few weeks. Second, we only measured the relationship of portable device use and test scores. Test scores are one measure of learning, but may not measure the full extent of learning, particularly in students who suffer from high levels of text anxiety (see Speilberger & Vagg, 1995). Third, other variables may be mediating the relationship between portable device use and test scores. For example, interest in the material may determine both whether students decide to use portable devices and how well they perform on exams. More information on these and other variables will help in determining why students decide to use portable devices in class and whether these factors are more critical in determining classroom learning than portable device use per se.

In sum, higher rates of internet use for non-classroom purposes throughout the semester were related to lower test scores. This relationship held even when accounting for intellectual ability. Students seemed unaware of the degree to which their internet use was related to classroom learning after the first test and were not making effective decisions about the use of portable technology in the classroom. Results such as these should be translated by academics for students such that they become aware of the ramifications of their study techniques (in and out of the classroom) on their learning and assessment performances. In this way, such research might ultimately encourage meta-cognition in students and higher performance.

Acknowledgments

References

Ackerman, P. L. (1987). Individual differences in skill learning: an integration of psychometric and information processing perspectives. *Psychological Bulletin, 102*(1), 3–27.
Aguilar-Roca, N. M., Williams, A. E., & O'Dowd, D. K. (2012). The impact of laptop-free zones on student performance and attitudes in large lectures. *Computers & Education, 59*(4), 1300–1308.
Alzahabi, R., & Becker, M. W. (May 2013a). *The influence of media multitasking on cognitive control*. Poster presented at the Midwestern Cognitive Science Conference, Columbus, OH.
Alzahabi, R., & Becker, M. W. (2013b). The association between media multitasking, task-switching, and dual-task performance. *Journal of Experimental Psychology Human Perception and Performance, 39*(5), 1485–1495.
Barak, M., Lipson, A., & Lerman, S. (2006). Wireless laptops as means for promoting active learning in large lecture halls. *Journal of Research on Technology in Education, 38*(3), 245–263.
Barks, A., Searight, H. R., & Ratwik, S. (2011). Effects of text messaging on academic performance. *Journal of Pedagogy and Psychology "Signum Temporis", 4*, 4–9.
Cain, M. S., & Mitroff, S. R. (2011). Distractor filtering in media multitaskers. *Perception-London, 40*(10), 1183–1192.
Cengiz Gulek, J., & Demirtas, H. (2005). Learning with technology: the impact of laptop use on student achievement. *The Journal of Technology, Learning and Assessment, 3*(2), 4–20.
Clayson, D. E., & Haley, D. A. (2013). An introduction to multitasking and texting: prevalence and impact on grades and GPA in marketing classes. *Journal of Marketing Education, 35*, 26–40.
Duncan, J., Emslie, H., Williams, P., Johnson, R., & Freer, C. (1996). Intelligence and the frontal lobe: the organization of goal-directed behavior. *Cognitive Psychology, 30*(3), 257–303.
Duncan, J., Parr, A., Woolgar, A., Thompson, R., Bright, P., Cox, S., et al. (2008). Goal neglect and Spearman's g: competing parts of a complex task. *Journal of Experimental Psychology General, 137*(1), 131–148.
Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11*, 19–23.
Fried, C. B. (2008). In-class laptop use and its effects on student learning. *Computers & Education, 50*(3), 906–914.
Hembrooke, H., & Gay, G. (2003). The laptop and the lecture: the effects of multitasking in learning environments. *Journal of Computing in Higher Education, 15*(1), 46–64.
Jacobsen, W. C., & Forste, R. (2011). The wired generation: academic and social outcomes of electronic media use among university students. *Cyberpsychology, Behavior, & Social Networking, 14*(5), 275–280.
Kay, R. H., & Lauricella, S. (2011). Exploring the benefits and challenges of using laptop computers in higher education classrooms: a formative analysis. *Canadian Journal of Learning & Technology, 37*(1), 1–18.
Kline, R. B. (2011). *Principles and practice of structural equation modeling*. Guilford Press.
Koenig, K. A., Frey, M. C., & Detterman, D. K. (2008). ACT and general cognitive ability. *Intelligence, 36*, 153–160.
Kraushaar, J. M., & Novak, D. C. (2010). Examining the affects of student multitasking with laptops during the lecture. *Journal of Information Systems Education, 21*(2), 11.
Minear, M., Brasher, F., McCurdy, M., Lewis, J., & Younggren, A. (2013). Working memory, fluid intelligence, and impulsiveness in heavy media multitaskers. *Psychonomic Bulletin & Review, 20*(6), 1274–1281.
Mouza, C. (2008). Learning with laptops: implementation and outcomes in an urban, under-privileged school. *Journal of Research on Technology in Education, 40*(4), 447–472.
Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences, 106*(37), 15583–15587.
Poole, B. J., & Kane, M. J. (2009). Working-memory capacity predicts the executive control of visual search among distractors: the influences of sustained and selective attention. *The Quarterly Journal of Experimental Psychology, 62*, 1430–1454.
Risko, E. F., Buchanan, D., Medimorec, S., & Kingstone, A. (2013). Everyday attention: mind wandering and computer use during lectures. *Computers & Education, 68*, 275–283.
Rosen, L. D., Carrier, L. M., & Cheever, N. A. (2013). Facebook and texting made me do it: media-induced task-switching while studying. *Computers in Human Behavior, 29*(3), 948–958.
Rosen, L. D., Lim, A. F., Carrier, L. M., & Cheever, N. A. (2011). An empirical examination of the educational impact of text message-induced task switching in the classroom: educational implications and strategies to enhance learning. *Psicología Educativa, 17*, 163–177.
Samson, P. J. (2010). Deliberate engagement of laptops in large lecture classes to improve attentiveness and engagement. *Computers in Education, 20*(2), 27–38.
Sana, F., Weston, T., & Cepeda, N. J. (2013). Laptop multitasking hinders classroom learning for both users and nearby peers. *Computers & Education, 62*, 24–31.
Speilberger, C. D., & Vagg, P. R. (Eds.). (1995). *Test anxiety: Theory, assessment and treatment* (pp. 3–14). Bristol, UK: Taylor & Francis.
Tindell, D. R., & Bohlander, R. W. (2012). The use and abuse of cell phones and text messaging in the classroom: a survey of college students. *College Teaching, 60*(1), 1–9.
Trimmel, M., & Bachmann, J. (2004). Cognitive, social, motivational and health aspects of students in laptop classrooms. *Journal of Computer Assisted Learning, 20*(2), 151–158.
Vogel, E. K., McCollough, A. W., & Machizawa, M. G. (2005). Neural measures reveal individual differences in controlling access to working memory. *Nature, 438*(7067), 500–503.
Wood, E., Zivcakova, L., Gentile, P., Archer, K., De Pasquale, D., & Nosko, A. (2012). Examining the impact of off-task multi-tasking with technology on real-time classroom learning. *Computers & Education, 58*, 365–374.