Reading interruptus! The effects of receiving and sending text messages on reading, learning, and metacognition

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Communication devices have better-enabled individuals to meet new people and to stay in contact with friends and family. We investigated the effects of sending/receiving text messages on learning. In Experiment 1, participants read a section of a chapter on texting or no texting condition. Reading comprehension was significantly lower in the texting condition. The two conditions differed significantly on the metacognitive measure of Prediction of Knowing but not on Ease of Learning, Judgment of Learning, or confidence levels. In Experiment 2, friends texted the participants during a 30-minute lecture or participants did not receive any texts. Significant differences occurred between the texting and no texting conditions, and accuracy was significantly correlated with Ease of learning, Delayed Judgment of Learning, Prediction of Knowing, and confidence levels. Both studies suggest that text messaging can impair students' ability to learn. Smartphone usage is only going to increase in our technological world. As university instructors must learn to change with the times, but at the same time, not contribute to smartphone addiction.

Keyword: confidence level; ease of learning; judgement of learning; metacognition; prediction of knowing; text messaging

During the past two decades, communication devices have better-enabled individuals to meet new people and to stay in contact with friends and family (Cummings et al., 2006). In the case of university students, these new communication technologies can have advantages in allowing people to easily stay in contact with friends and family while away at university. Unfortunately, there may be a cost to the users. For example, students may be distracted by receiving calls while in the classroom or by others receiving calls during a lecture. The purpose of the present research is to determine whether sending and receiving text messages interferes with learning. In the first study, we focused on the effects of texting while reading passages from a textbook, and in the second study, we tested the effects of sending and receiving text messages during a class lecture. Before discussing our two studies, we will briefly review past research on multitasking and learning, as well as research on how communication technology may affect student learning.

Ellis et al. (2010) defined multitasking as the "concurrent processing of two or more tasks through a process of context switching" (p. 2). This definition of multitasking fits well with students sending and receiving text messages or instant messages during a class lecture. Past research has shown that processing two independent thoughts (contexts) concurrently is not conducive to learning (Whitebread et al., 2005). Inhibitory models of attention and memory (i.e., Allport, 1989; Hasher & Zacks, 1988; & Navon,1988) suggest that to process relevant information and retain that information, irrelevant information must be inhibited. Hasher et al. (1999) proposed three functions of inhibitory mechanisms regarding working memory. First, inhibitory mechanisms restrict access to working memory focusing on only relevant items. Second, items no longer appropriate are deleted, and third, until the material can be evaluated, responses must be restrained. Therefore, we might expect that engaging in text messaging would prevent students from exercising the inhibitory control necessary to successfully process information from an assigned reading or a lecture.

Strategic use of communication technology can have beneficial effects on student behaviour (Bautista et al., 2018). There are several studies in the literature that support using instant messaging (IM) in the classroom for group projects. One study by Day and Kumar (2010) allowed students to use IM for the "Beer Game". Sterman 's (1989) Beer Game is widely used in operations courses as it engages students in a competitive supply chain simulation (Day & Kumar, 2010). The results showed that students in the IM group were more focused and engaged, made fewer errors, used better strategies, and incorporated more concepts than the groups not using IM. Joyce and Weibelzahl (2006) used IM to help to eliminate barriers to seeking help for depression for university students, and other studies have shown IM is beneficial to encourage interactivity in the classroom (Beauchamp et al., 2010). Text messaging outside of the classroom, but on campus, may help students stop smoking (Whittaker et al., 2008).

Past research has investigated different types of interference that can occur when students are studying, such as using messaging features on social network sites such as Facebook, Myspace, Yahoo, or AOL IM (Baron, 2010). According to Baron (2010), Instant Messaging on computers began in the 1980s but did not become popular until 1996 with ICQ, and then America Online Instant Messenger (AIM) in 1997, followed by MSN IM. IM was adopted by teenagers and young adults of university age in the late 1990s and early 2000s, and then in the workplace for both business and personal communication (Baron, 2010). Researchers have examined several dimensions of IM, from linguistic characteristics such as abbreviations and emotions (Randall, 2002) to social dimensions such as who uses IM, for what purpose, and how often is it used (Boneva et al., 2006). Quan-Haase (2007) found that university students were more likely to use IM than mobile phones for communication with close friends and relatives far away. Furthermore, Quan-Hasse (2007) found that university students used IM to keep close ties with friends from high school to share the university experience. One study examined the effect of IM on a computer while reading passages for later recall (Fox et al., 2009). Fox and colleagues (2009) manipulated whether students engaged in IM and tested recall for two levels of difficulty, low difficulty (SAT-level passages) and high difficulty (GRE-level passages). The results showed that the time to read and respond to questions was both longer in the IM condition than in the no-IM condition. Interestingly, their hypothesis that the more experienced IM users would be less affected by IM than less experienced IM users was not supported. Furthermore, the experience did not help the participants in avoiding the negative effects of IM on reading comprehension. Fox et al. (2007) also found that GPA was negatively related to the amount of time the participants spent using IM. Their results suggested that poorer students used IM more often than higher-performing students.

Over the past 20 years, mobile phones have increased in popularity with university students, as evidenced by the observation that most students use mobile phones while on campus. Mobile phones are a means for university students to stay in close contact with both friends and relatives; however, mobile phones are often a distraction

to the student, classmates, and instructors if used during class time. A pilot study by Burns and Lohenry (2010) showed that instructors are concerned about mobile phone use in the classroom. The researchers found that students receive mobile phone calls and emails during class via their phones. Students reported receiving messages, emails, or texts, on their mobile phones during class time almost 35% of the time. Almost 73% of the students reported receiving a mobile phone call at some time during a class period. The researchers surmised that although mobile phone technology is a great communication tool, the use of mobile phones during class time is not conducive to teaching or learning. They recommended that faculty reinforce student mobile phone etiquette in the classroom. Hammer et al. (2010) found that 83% of students reported hiding the use of a mobile phone in class. Additionally, students responded that if they were bored in class, 97% used laptop computers, and 74% used mobile phones for non-related activities.

In addition to emailing and phone calls, text messaging has added another way for people to keep in constant contact with friends and family. Reid and Reid (2007) stated that text messaging is one of the fastest-growing modes of communication. The researchers stated that young people who use mobile phones prefer texting their friends over talking to them on the phone. If we also consider social networking applications, such as Facebook, Myspace, and Twitter, that allow people to follow a person of interest′s daily events, it is no wonder that university students, as well as others, are caught up in the convenience of using BlackBerrys, iPhones, and other high-tech communication devices, both inside and outside of the classroom.

Although research has already established distracting effects of IM while studying and having mobile phones ring while participants watch a video, research testing for similar effects of text messaging is just now appearing in the literature. It is important to explore whether text messaging while reading can interfere with reading comprehension so that students can be given appropriate advice to improve their learning. Based on previous research on distracting effects of similar technology, we hypothesise that the use of text messaging will result in decreased reading comprehension.

Recent studies on texting have reported both positive and negative correlates of texting in the classroom. For example, End et al. (2010) found a negative correlation between students′ GPA and the number of text messages per day; however, they found a positive correlation between GPA and students′ comfort texting in the classroom. A study conducted in 2014 by Gingerich and Lineweaver found in two studies that when university students are allowed to use their mobile phones during a class lecture the results on a quiz afterward were lower than those students not on a mobile phone or conversing in person with a classmate. Additionally, Bjornsen and Archer's (2015) results indicated that mobile phone use was "significantly and negatively associated with test scores regardless of student sex and grade point average" (p. 326). Early studies on mobile phone use during a university class by Massengill Shaw et al. (2007) on the relationship between the frequency of text messaging and literacy among university students indicated that the frequency of text messaging was not related to spelling ability. Later research by Kemp and Bushnell (2010) found that there were no significant differences between frequent and infrequent texters in measures of reading, spelling, or linguistic awareness; however, Rosen et al. (2010) found that the frequency of texting hurt student's formal writing, but not informal writing. Based on the writing required of university students in all areas of psychology, as well as other university disciplines, frequent text messaging may be a contributing factor to some students′ poor formal writing skills.

The use of texts (the informal, abbreviated words in texting) about literacy ability has been explored with schoolchildren as well as university students. Plester et al. (2009) found a positive relationship between literacy and the use of texts, showing those students (ages 10–12 years) who scored higher in their translation of texts translation exercises and who have a higher texts density in their text messages score better in spelling, reading, writing, phonological awareness, and vocabulary. Drouin and Davis (2009) explored these same questions with university students and found no significant differences related to literacy skills. Students reported that using texts was appropriate when used with friends and family, but not when communicating with professors. Quite interestingly, Drouin and Davis (2009) stated that university students reported some concern that using texts was having a detrimental effect on the use of their standard English (SE). Drouin (2001) found that university students reported using texts on SNS (social networking sites such as Facebook, and Myspace) and when text messaging on a mobile phone. The results showed that texts do not simply slip out everywhere in equal amounts. It is important to note that the data on using texts in other places than SNS or when IM or texting were self-reported.

Studies exploring the effects of texting during the classroom experimentally have increased as the number of students owning and using a phone has increased. One early study by Ellis et. al. (2010) randomly assigned 62 university students into two conditions: a texting condition and a control condition. All of the participants attended a class lecture and were given a quiz after the lecture. The students who were in the texting condition were instructed to text the instructor three times at any time during the lecture. The results showed that the participants in the texting condition scored significantly lower than those in the non-texting condition. The overall results of their study suggest that texting in a learning environment can be detrimental to learning university students for both men and women and students with high or low GPAs. Flanigan and Kiewra (2018) coined the term cyber-slacking after their study where the researchers found that mobile technology use has become second nature for most university students (Flanigan & Babchuk 2015; Roberts et al. 2014), and cyber-slacking has permeated university students' academic activities. Inside the classroom, cyber-slacking hinders student learning (Kuznekoff et al., 2015), and instructors have struggled to minimise the problem (Barks et al., 2011; Berry & Westfall, 2011).

The efficacy of learning new mnemonics in heavy texters compared to low texters was investigated by Ryker et al. (2011). They found that low texters were more confident in learning new mnemonics and more successful than high texters. The researchers suggest several possible explanations for the results: 1) due to their heavy use of text speak, which uses acronyms and mnemonics, the new acronyms and mnemonics may not be interesting enough for them to use as an effective memory aid; 2) the researchers suggested that perhaps there is a text limit speak vocabulary and the heavy texters have reached their limit, or 3) living with high technology is altering our brains. Carr (2010), cited by Ryker et al. (2011) stated that "frantic superficiality is destroying our powers of concentration" (p. 31).

In the present research, we focus on the potential for disruptive effects on the learning of students engaging in text messaging. The premise is that engaging in text messaging requires attention, therefore reducing the cognitive resources available for comprehending information presented in a reading assignment or a lecture. Baddeley's (2000) model of working memory indicates that attention is necessary to coordinate the processing of information. Thus, we would expect text messaging to make it less likely that students could efficiently process information from a lecture or book in working memory and ultimately recall the material when tested.

Text messaging may also affect students' ability to monitor how well they comprehend the material. The literature on text messaging lacks research on the effects of sending and receiving text messages on students' metacognitive abilities. Metacognition broadly defined is the knowledge people have of their cognitive functions and how these functions are regulated (Flavell, 1979). Metacognition allows us to know what we know or perhaps even more important, to know what we do not know. For example, if a student is studying passages in a test book in which they will be tested over the material, it is advantageous for the student to realize what material he/she comprehended and what material needs further studying. Nelson and Narens (1990) created a framework that involves both prospective and retrospective judgements related to metamemory, which is the monitoring system for these judgements. Prospective judgements of memory, according to Nelson and Narens (1990), include three main categories: (a) Ease-of-Learning (EOL), (b) Judgements-of-Learning (JOL), and (c) Feeling-of-Knowing. Retrospective memory judgements include confidence levels and Prediction-of-Knowing (POK), in which participants are asked to briefly look at the multiple-choice questions and predict how well they would score on a future test over the material. Prediction-of-Knowing is made before retrieving the material that is studied. For example, Schreiber and Nelson (1998) used POK in a paired associate's paradigm in which participants viewed a list of words followed by an extra list of semantically related cue words and gave a POK, rating how whether they believed each of the cue words would help them recall the target word. Following the POK, the participants saw each cue word and attempted to recall the target word. In the present study, POK was used to determine whether participants could predict which questions they could answer correctly.

These metacognitive measures have not yet been tested about the effects of sending and receiving text messages, or about learning material in a classroom setting while sending and receiving text messages, which makes the present two studies unique in the literature. Moreover, our study is the first study to include friends of the participants as senders and receivers of the text messages while their friends were in the research study, and we use the ecologically valid practice of having the participants in the texting condition does not know when they will be asked to send or receive text messages during a class lecture.

We conducted two experiments to determine the effects of sending and receiving text messages on learning. The purpose of Experiment 1 was to determine whether sending and receiving text messages while reading passages from a textbook would interfere with reading comprehension. To extend the ecological validity of the effect, we conducted Experiment 2 in a classroom setting where participants were either in a texting or no-texting group. Both groups listened to a 30-minute lecture and completed a comprehension test. For both experiments, we hypothesized that performance on a comprehension test would be lower in texting than in non-texting conditions. We also expected that texting would disrupt metacognition, resulting in reduced performance on metacognitive measures in the texting conditions.

METHOD (Experiment 1)

Participants

Sixty undergraduate university students from an upper level (junior/senior), Southeastern University volunteered to participate in our study. All participants had texting capabilities on their mobile phones. There were 42 women and 18 men who ranged in age from 18 – 54 years of age, with a mean of 25.6 years (*SD* = 5.32). The sample included 31 Caucasian students, 28 African American students, and 1 Native American student. The participants all earned extra credit for participating in the research study. At this campus, Motivational Psychology had never been available as an elective, therefore, none of the students had formal exposure to the reading material.

Materials

The reading material was six pages from a Motivational Psychology Textbook (Petri & Govern, 2004). The answer sheet consisted of an Ease-of-Learning (EOL) scale with a range from 0-100% for the participants to report how easy the passages were to learn, a Delayed Judgment-of-Learning (DJOL) scale with a range from 0-100% for participants to report how well they comprehended the material, and a Prediction of Knowing (POK) for each of the multiple-choice questions. Participants were asked to predict how many of the 15 multiple-choice questions they expected to answer correctly. Each question had a space provided for participants to mark their prediction of whether they would answer the question right or wrong. Fifteen multiple-choice questions with four alternative answers were used to test the participants' reading comprehension. We provided a piece of white paper to the participants so they to cover the passages as they read them. We used a word search game as a distractor task to prevent the information from being in working memory. Lastly, after answering the multiple-choice questions, the participants indicated how many of the multiple-choice questions they thought they had answered correctly (confidence level). We also asked how many texts they sent per day and received per day, whether they sent and received texts in class, and whether they sent and received texts at home while studying.

Procedure

We randomly assigned participants to two conditions. In both conditions, the participants read the instructions for the study which included explicit definitions of the terms EOL, JOL, and POK. In both conditions, the participants read each of the passages (total time of approximately 20 minutes). We instructed the participants to use the white sheet of paper to cover the sections of the passages as they read the material, and at no time to refer back to the passages. In the Texting condition, we asked the participants to cover the passages when they received a text message. The participants then provided metacognitive judgements on EOL, JOL, and POK. For EOL, the participants responded to the statement: "On a scale of 0-100, how easy did you find the reading material (0 indicating very difficult – 100 meaning you found the material very easy to learn)." After providing the EOL judgements, the participants provided the JOL: "On a scale of 0–100 how well do you think you comprehended the material? " Next, the participants provided a POK score after they briefly looked over each of the 15 multiple-choice questions. They predicted how many of the questions they thought they would get correct.

The metacognitive measures of EOL, JOL, and POK took approximately 5 minutes. After reading the section in the Motivational Psychology textbook, (about 20 minutes) the participants were allowed to play a short word-finding game as a distractor task for about 10 minutes. The word search was completely unrelated to the material in the reading assignment and was used to make it unlikely participants could hold information from the text in working memory. After the distractor task participants responded to the multiple-choice

comprehension questions. At no time were the participants allowed to look back at the material in the book. After answering each multiple-choice question, the participants reported whether they believed that they got the answer right or wrong and how confident they were in their response. At the end of the study, which took approximately 40 minutes, the participants responded to questions about their texting habits. We then debriefed and dismissed the participants.

In the Texting condition, the participants read the same material, but we randomly interrupted them 10 times with text messages from a research assistant located in a different room. We instructed the participants to respond to each text message immediately. It typically took approximately 5-8 seconds to respond to a text message. Reading time for the participants in the texting time averaged 25 minutes. When the participants received a text message, they used a blank sheet of paper to cover the already-read portion of the passage and continue reading from that point in the passage after receiving and sending the text message. We adopted this procedure based on responses to a question in a pilot study. We found that students typically reported that they did not go back and reread what they had been reading when receiving a text on the phone; rather, they typically marked the spot and continued reading where they had left off due to the time that they had allotted to study the material. Based on the pilot study responses, we opted to prevent all participants from re-reading so that this behavior would not be an extraneous variable.

RESULTS (Experiment 1)

Descriptive statistics for accuracy, JOL, EOL, POK, and confidence in each condition are shown in Table 1. We compared the conditions on each measure using an independent samples *t*-test. Students in the control condition answered significantly more questions correctly than students in the texting condition. The difference between conditions on POK was marginally significant with a trend toward higher predictions in the control condition than in the texting condition. The two conditions did not significantly differ on JOL ratings, EOL ratings, or confidence ratings.

We computed correlations among the dependent variables (see Table 2) to determine whether accuracy on the comprehension test was related to metacognitive measures or the number of text messages sent per day. Correlations among the dependent variables are shown in Table 2. The number correct was not significantly correlated with any of the metacognitive measures or with the number of text messages sent per day. We found several significant positive correlations among the metacognitive measures: JOL with EOL, JOL with POK; EOL with POK, EOL with confidence, and predicted number correct with confidence. The number of text messages sent per day was significantly correlated with confidence but not with any of the other measures.

All of the students reported that they had sent texts and received texts while studying at home. The majority of the students reported that they had sent texts while in class (83%) and that they had received texts while in class (95%). The majority of the students (65%) either strongly agreed or agreed that texting interfered with their reading comprehension, while 20% either disagreed or strongly disagreed with that statement. The mean number of text messages sent in for the sample was 115.56 text messages per day, with a minimum of two texts per day and a maximum of 800 texts per day.

The results supported the hypothesis that text messaging while reading would interfere with reading comprehension. Performance on the multiple-choice comprehension test was significantly lower in the texting condition than in the control condition, with Cohen′s *d* of .64 indicating an effect size between medium and large (Cohen, 1992). Receiving and sending text messages while reading did not appear to influence metacognitive judgments, suggesting that students in the texting condition were unaware of how much their comprehension was affected by text messaging. If the students had been accurately monitoring their comprehension, their metacognitive judgments should have been lower in the texting condition. In other words, texting appeared to create two problems for students: lower comprehension and a lack of awareness that their comprehension was low.

The present study provides evidence that sending and receiving text messages while reading a textbook passage can impair university students ' reading comprehension. University students should be advised that their ability to learn may be at risk if they are not able to put aside their mobile phones while reading. The convenience of being able to easily communicate with friends and family members also carries potential costs, and students should be aware of those costs.

Table 1
Experiment 1: Descriptive statistics by condition for number correct on the comprehension test and metacognitive measures

	Condition						
	Control		Texting				
Dependent Variable	*M*	*SD*	*M*	*SD*	*t*	*p*	*d*
Number Correct	8.07	2.38	6.80	1.52	2.46	.017[a]	.64
Judgment of Learning	59.33	23.18	51.33	25.01	1.28	.204	.33
Ease of Learning	60.67	22.58	62.67	27.66	0.31	.760	.08
Prediction of Knowing	8.53	3.22	6.83	3.35	2.00	.050	.52
Confidence Rating	9.93	2.98	9.57	3.72	0.42	.421	.11

[a] p-value corrected for unequal variances.

Table 2
Experiment 1: Correlation matrix for number correct on comprehension test, metacognitive measures, and number of text messages sent per day

Measure	1	2	3	4	5	6
1. Number Correct	---	.03	-.20	-.12	-.01	-.19
2. Judgment of Learning		---	.40**	.48**	.22	.05
3. Ease of Learning			---	.26*	.26*	.10
4. Predicted Number Correct				---	.32*	.23
5. Confidence Rating					---	.30*
6. Number of Messages/Day						---

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

An interesting correlational finding was the significant positive correlation between how often students reported texting and their confidence ratings of how many comprehension questions they thought they had answered correctly. Although this correlation was moderate, the pattern suggests that students who engage in frequent texting may be more confident in their reading comprehension. It is important to note that self-reported frequency of text messaging was not correlated with how well students actually performed on the comprehension questions. Thus, higher confidence in their performance was not warranted.

In the present experiment, students were texted by a person they did not know in a room separate from where the participant was reading the passages for reading comprehension. It is also important to note that the text messages for this study were artificial in the sense that they were generated by a researcher rather than by a friend or family member of the participant. It seems plausible that exchanging text messages with a close contact rather than with a researcher might be even more distracting, as the messages to and from personal contacts would likely have more personal relevance to the student. Additionally, it would be interesting to determine whether sending and receiving text messages from a friend instead of one of the experimenters during a class lecture would interfere with the learning of the concepts presented in the lecture.

To increase the ecological validity of the research study, we conducted a second experiment to determine if there would be an effect on comprehension of receiving text messages from friends. The second experiment was more realistic in that the participants in the texting condition knew the person texting and texted about topics that they would normally discuss (i.e., what they were doing that weekend, what they thought about a movie they had talked about seeing, relationships).

Experiment 1 investigated the effects of receiving text messages on reading comprehension. It is also worthwhile to investigate how the use of texting might affect comprehension of a lecture. Therefore, in Experiment 2, we examined the effects of sending and receiving texts on comprehension of the material presented in a lecture.

We hypothesized that participants in the texting condition would score significantly lower on a test given after the lecture than those participants who were in the no texting condition. Additionally, we predicted that the metacognitive measures, as well as accuracy, would be negatively affected by sending and receiving text messages during a lecture class.

METHOD (Experiment 2)

Participants

Sixty undergraduate university students participated in our study using an upper-level (juniors and seniors) psychology course at a Southeastern University. All participants had texting capabilities on their mobile phones. There were 36 females and 24 males who ranged in age from 20 – 36 years of age, with a mean of 23.8 years (*SD* = 6.34). The sample included 43 Caucasian students and 17 African American students. The students were not eligible to participate in the study if they had taken the Experimental Psychology course due to the terminology presented in the lecture that would later be part of the testing materials. A short quiz was given over the material before the test to determine if any of the participants were familiar with the research design. We eliminated three participants from the study because of prior knowledge of the material learned in another course.

Materials

We used a PowerPoint presentation, consisting of 15 slides, with three slides per page including the note-taking lines next to each slide. PowerPoint handouts were given to all of the participants before the lecture began with the important terminology missing from the handouts. Each participant had a friend who agreed to text the participant at specific times during the PowerPoint presentation. The friend in the study had the same PowerPoint handout as the participant, except that the friend′s PowerPoint included prompts of when to text their friend, and prompts showing when to stop texting. A friend was used in Experiment 2 to increase realistic texting, versus canned questions from a stranger. A word search game was used as a distractor task, and we used a 30-question test consisting of 20 multiple-choice questions, five matching, and five fill-in-the-blank questions to measure comprehension. We provided a debriefing form to the participants upon completing the study which was also read by the researcher to assure that the students would not talk about the study until all data had been collected.

Procedure

We recruited the participants through announcements in class and a psychology research sign-up board. We randomly assigned participants to one of two conditions: texting or no texting. All participants attended a lecture on Experimental Design. The lecture included a PowerPoint with the important points in bold print as well as additional emphases by the instructor on the point. Students were encouraged to fill in the blanks on their PowerPoint handout in the spaces provided on the handout. After the lecture, the participants provided Ease-of-Learning (EOL) ratings to indicate how easy the participant found the material to learn. The scale ranged from 0% (meaning extremely difficult to learn) to 100% (meaning extremely easy to learn). We instructed the participants to briefly look over the test and to predict (POK scale) how many of the questions the participant thought they would answer correctly if asked to take the test in the future. The participants then engaged in a word search as a distractor task for 15 minutes to prevent participants from retaining information from the lecture in working memory. Unlike Experiment 1, participants in Experiment 2 provided the JOL following the distractor task. This is referred to as Delayed Judgment of Learning (DJOL). The DJOL indicated well the participant believed he/she learned the material as in Experiment 1, however, at least 15 minutes had elapsed before making the DJOL. The scale ranged from 0% (I did not learn anything from the material) to 100% (I believe I know the material well). The participants responded to a 30-question test consisting of 20 multiple-choice questions, five matching, and five fill-in-the-blank questions. After completing the test we debriefed the participant. The entire experiment took approximately 60 minutes of the participants′ time.

In the texting condition, the procedure was the same with the following exceptions. We asked participants to bring one a friend whom they typically texted frequently. The friends did not take the test. Rather, we gave the friends instructions on their duties before the study began in a separate room from their partners. We then seated the friends in the back row of the class and the participants in the first two rows of the class. Each session consisted of five participants and one friend of each participant. We gave the friends a version of the PowerPoint

presentation that alerted them when to start and end texting their partner. One slide before an important concept was presented in the lecture, the friend began texting the participant and kept the participant texting back and forth until the particular important section had been covered, which was indicated on the friend's PowerPoint handout. There were 10 text messages sent and received throughout the 30-minute lecture. All mobile phones were set on vibrate so that the noise would not interfere with learning. After the lecture was complete, the friends left the testing room, and the participants provided the same metacognitive measures and distractor tasks as in the control condition. After completing the test, we debriefed the participants and both friends were asked to delete the questions sent and received during the research study to help ensure that the questions were not shared with any future participants in the study.

RESULTS (Experiment 2)

We compared the texting and no-texting groups on each dependent variable using an independent samples *t*-test. Dependent variables included accuracy on the comprehension test, DJOL, POK, EOL, Confidence Ratings, and gamma correlations between right-wrong ratings for each question and question accuracy and between confidence ratings for each question and question accuracy. We calculated gammas to measure how well participants' ability to answer the questions correctly was related to their metacognitive ratings. Gamma is a commonly used statistic in the metacognition literature (Dunlosky & Lipko, 2007). Positive values of gamma indicate that individuals who answered correctly also provided higher metacognitive ratings (e.g., a greater confidence rating). Higher gamma values indicate better metacognition, as they indicate strong correspondence deviations are shown in Table 3. As indicated in Table 3, students in the texting condition had significantly lower levels of accuracy as well as lower ratings on each of the metacognitive measures (DJOL, POK, EOL, confidence ratings, and right-wrong gammas) except for the confidence gammas. Cohen's *d* indicated large effects on accuracy, DJOL, POK, EOL, right-wrong gammas, and a medium-sized effect on confidence ratings. Intercorrelations among accuracy, metacognitive measures, and participant ages are shown in Table 4. Accuracy was significantly correlated with DJOL, EOL, POK, and confidence ratings; more accurate individuals tended to provide higher metacognitive ratings. Participant age was not significantly correlated with any of the dependent variables.

Table 3
Experiment 2: Mean accuracy and metacognitive measures for the no texting and texting conditions

	Condition						
	No Texting		Texting				
Variable	*M*	*SD*	*M*	*SD*	*t*		*d*
Accuracy	93.40	7.47	70.60	17.09	6.70	<.001[a]	1.73
DJOL	85.77	16.58	68.00	20.75	3.66	.001	0.95
POK	92.60	13.39	54.00	25.27	7.39	<.000[a]	1.91
EOL	84.00	14.29	64.67	23.30	3.87	<.001[a]	1.00
Confidence	86.00	11.92	64.67	20.81	4.87	<.001[a]	0.71
Right-Wrong Gamma[b]	.98	0.03	-.14	0.60	9.73	<.001[a]	2.65
Confidence Gamma[c]	.10	1.68	-.01	0.41	0.22	.832[a]	0.07

[a] *p*-value corrected for unequal variances.
[b] *N* = 44; gamma could not be computed for the remaining participants.
[c] *N* = 46; gamma could not be computed for the remaining participants.

Table 4
Experiment 2: Correlations of accuracy, metacognitive measures, and age

Measure	1	2	3	4	5	6	7	8
1. Accuracy	---	.58**	.60**	.82**	.43**	.29	.00	-.09
2. DJOL		---	.30*	.44**	.25*	.35*	-.05	-.05
3. EOL			---	.52**	.36**	.24	.08	-.02
4. POK				---	.44**	.37*	-.03	-.11
5. Confidence Rating					---	.43**	-.01	-.06
6. Right-Wrong Gamma[a]						---	-.06	.04
7. Confidence Gamma[b]							---	-.14
8. Age								---

* $p < .05$
** $p < .01$
[a] $N = 44$; gamma could not be computed for the remaining participants.
[b] $N = 46$; gamma could not be computed for the remaining participants.

DISCUSSION

The purpose of Experiment 2 was to determine whether students who received and sent text messages to a personal friend during a PowerPoint lecture would score differently on a test over the material than a control group who did receive any text messages. The results supported our hypothesis that sending and receiving text messages during a classroom lecture interferes with learning; students who received text messages performed significantly worse on the comprehension questions than students who did not receive texts, and the effect size for this difference was large.

We also found a large difference between the texting and no texting groups on gamma correlations between accuracy and right-wrong predictions made by the participants. Students in the texting condition were very poor at knowing whether they got the question right or wrong, as their mean gamma was close to zero. In fact, the mean gamma for the no texting condition was weakly negative, indicating a slight tendency for students who believed they answered a question correctly to be incorrect in answering the question, and *vice versa*. In contrast, students in the texting condition had a very high, positive mean value of gamma, indicating that they could reliably judge whether they had responded to the question correctly. Thus, texting appears not only to reduce performance on a comprehension test but to reduce students' ability to monitor how well they know the material.

The present results are important from both the student's perception and the instructor's position. From a student's perspective, it is important to realize that having a mobile phone on while studying or while in class could hurt later recall of the material. From an instructor's perspective, we may need to rethink the rules in our classrooms concerning allowing students to send and receive texts, other than for emergencies. Students who have their heads down and mobile phones under their desks trying to conceal the phone may suffer more interference than those outwardly using texting during a lecture. Additionally, students who are doing group work and have one or more members of the group texting, rather than contributing to the group work, may be not only harming themselves by not learning what the group is discussing, but also may be causing indirect harm to their fellow students by not participating. Social loafing may become more prominent in groups in which one or two members insist on texting rather than participating. Furthermore, some students are not so courteous and do not put their mobile phones on vibrate and disrupt the class with a variety of loud ringtones. Then some text chooses to have a tone for their key press, which is annoying and distracting.

The results may be understood from a working memory perspective. In Baddeley's model of working memory, the central executive component coordinates the storage and processing of newly presented information by determining how to direct attention (Baddeley, 1986). If text messaging diverts attention, then the information presented in a lecture or reading assignment is less likely to be stored in long-term memory, i.e., less likely to be learned. Further, metacognitive monitoring processes require attention (Nelson & Narens, 1990); thus, text

messaging may reduce the ability to monitor comprehension by diverting attention to the content of the text messages.

It is important to note that not all research on using mobile phone use in the classroom is negative. For example, Lindquist and colleagues (2007) conducted a study in which students were asked to use Short Message Sending (SMS, meaning text messages, and picture text messages) to answer multiple-choice and short essay questions. At the time of the study, the students did not have unlimited minutes, therefore, the main objection to using mobile phones for answering questions in class was due to the extra cost students would have to pay per text sent. The researchers stated that if phone companies would create packages for unlimited texting that cellphone use could replace clickers in the classroom. It was also noted that if students already owned mobile phones and the majority do, it would be less expensive than buying and using clickers in the classroom.

Mobile phones and text messaging are here to stay. New technology such as smartphones allowing email and internet surfing may entice students to not only bring the phones to class but to use them for purposes other than learning (i.e., Facebook, Myspace). We believe that as researchers and psychologists we need to take the lead in educating our students about the harmful effects their texting can have on their academic performance. Further research should address the effectiveness of allowing students to use mobile phones in the classroom in a positive, contributing rather than an annoying, negative interfering manner. Furthermore, if students used mobile phones in the classroom to look up information on the internet and to respond to in-class questions as Lindquist et al. (2007) indicated, then mobile phones would more likely be accepted in the classroom by instructors. Classroom policy using mobile phones in the classroom may need to be rewritten if cellphone use has a positive effect on learning. Lindquist et al. (2007) noted that using mobile phones as an active learning technique may become more common in the future.

CONCLUSION

The present findings are subject to several limitations. First, the study was conducted on samples of university students, so it is not clear whether the results can be generalised to other populations. However, we were primarily interested in how texting might affect the comprehension of university students. Secondly, in Experiment 1, the results are limited to one particular type of reading material (a passage from a Motivational Psychology textbook). Further research on individual differences in the frequency of text messaging is necessary to determine whether this pattern is generalizable and whether there may be other measures of learning that are correlated with text messaging frequency. Experiment 2 also had some limitations that must be mentioned. The participants in the texting condition were texted by their friends during the most important parts of the lecture. Realistically, a student would probably not receive text messages during all of the important parts of a lecture, but those who are avid texters may miss a significant number of important points by being distracted by either sending or receiving text messages. The possibility that the Experiment 2 results could have been affected by students' prior familiarity with the lecture content was minimal, as we used a quiz to screen students for familiarity with the material. Future studies may explore how many students are distracted by using devices that allow students to check their email, chat on Facebook, or work on assignments for other classes while the instructor is teaching or during group work assignments.

New technology will constantly be invented that will make our lives easier and allow us to communicate with our friends and family. University students need to embrace new technology and discover how they can utilize technology to their advantage, such as keeping in touch with friends and family, surfing the internet for useful materials for their class assignments, or using technology as a networking tool. There are multiple reasons why students should have and use smartphones, iPads, and other tools for communicating and gathering knowledge, but there is often a price to pay for inappropriately using technology in the classroom. Smartphones are nearly ubiquitous among younger adults, with 92% of Americans aged 18- to 29-year-olds owning one (Pew Research Center, 2017) however, the number is now at 97% (Pew Research Center, 2021). Although we do not believe smartphones in general cannot be used as a teaching tool, students' grade point averages in classes where smartphones are not restricted are being negatively affected. The question many instructors struggle with is restricting smartphone usage in the classroom which can result in negative course evaluations. We suggest there could be a compromise between students and instructors that smartphone usage is allowed only when allowed by the instructor to use the mobile phone as a means of educational research (e.g., Google Scholar for research articles). More research needs to be conducted to find amiable ways for students to have some smartphone usage during classes without negative consequences to the student's grades. Sahlström, et al. (2019) suggested that perhaps delaying smartphone use can be trained. These interventions should focus on self-regulation of

smartphone usage. In a 2020 survey by the Pew Research Center, 60% of children were exposed to smartphones before the age 5. In that group, 31% had been introduced to phones before age 2. Based on these findings it is easy to see why some university students demonstrate addiction to smartphone usage. By focusing on self-regulation of smartphone usage before children enter grade school perhaps not as many students will exhibit negative responses when asked to put their phones away during class. Smartphone usage is only going to increase in our technological world. As university instructors must learn to change with the times, but at the same time, not contribute to smartphone addiction.

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