Communication Education

Rethinking College Students' Self-Regulation and Sustained Attention: Does Text Messaging During Class Influence Cognitive Learning?

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First

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Rethinking College Students' Self-Regulation and Sustained Attention: Does Text Messaging During Class Influence Cognitive Learning?

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This study investigated whether texting during class influences students' cognitive learning. A theoretical model was proposed to study the relationships among college students' self-regulation, texting during class, sustained attention to classroom learning, and cognitive learning (i.e., grade-oriented academic performance and experience-oriented cognitive learning). Using a cross-sectional survey sample (N = 190), structural equation modeling analyses showed that texting during class partially mediates the effect of students' self-regulation on their sustained attention to classroom learning. In addition, students' sustained attention fully mediates the effect of their texting during class on experience-oriented learning. Thus, the results also suggest that self-regulated students are less likely to text during class and are more likely to sustain their attention to classroom learning, which, in turn, facilitates cognitive learning.

Given the prevalence of mobile phones, the 160-character short message service known as text messaging (Rosen, Chang, Erwin, Carrier, & Cheever, 2010) plays a significant role in college students' lives. In fact, approximately 97% of U.S. college students use texting more than e-mail or instant messaging (Kelly, 2010). Students text to engage in "quick communication with their peers" (Day & Kumar, 2010, p. 130), promote participation in social leisure activities (Campbell & Kwak, 2010), and nurture interpersonal relationships in social networks (e.g., Harley, Winn, Pemberton, & Wilcox, 2007; Jones, Edwards, & Reid, 2009).

Although mobile phones offer college students a way to gain autonomy about when and where to communicate with recipients in the public sphere (Ishii, 2006), their intensive use might cause "technological terror" (Gilroy, 2004, p. 56) for college professors during classroom instruction. For instance, using mobile phones during class might undermine teachers' authority (Nworie & Haughton, 2008) and disrupt teacher–student interactions (Campbell, 2006). However, whether texting during class influences students' cognitive learning rarely is examined.

In studying speed-response time and storage-memory as main factors that influence learning via information processing (see Wickens & McCarley, 2008), Rubinstein, Meyer, and Evans (2001) found that people take a longer period of time when they try to learn and perform other activities simultaneously, and that the outcomes are not as proficient compared to learning while not engaging in other activities. The prolonged response time (called *switch costs*) to complete multiple tasks might influence people's cognitive readiness to process information (Butler, Arrington, & Weywadt, 2011). Thus, with a similar tendency, texting potentially may undermine learners' attention from classroom instruction and adversely affect the capacity of short-term memory to process the multiple tasks in which students are engaging (texting and learning), leading to negative cognitive learning outcomes.

Effective cognitive learning also requires sustaining attention to learning tasks, which requires *self-regulation*, "the self-directive process through which learners transform their mental abilities into task-related academic skills" (Zimmerman, 2001, p. 1). *Self-control*, often employed interchangeably with self-regulation (Baumeister & Alquist, 2009), has been used to predict cognitive learning outcomes in school (e.g., grade point average; see Duckworth & Seligman, 2005; Tangney, Baumeister, & Boone, 2004). Based on the theory of self-regulated learning, self-regulated learners tend to block out distracters in a learning environment (Pintrich & De Groot, 1990) and actively engage themselves in cognitive learning (Zimmerman, 2001). If that is the case, students who employ a high level of self-regulation (self-control) during class are less likely to text and more likely to sustain their attention on classroom learning. Therefore, in this study we investigated whether college students' self-regulation predicts their text messaging during class, and whether students' text messaging during class negatively relates to their sustained attention and, in turn, their cognitive learning.

Review of the Literature

Self-Regulation

The foundation of self-regulation is derived from William James's self-awareness (see Forgas, Baumeister, & Tice, 2009). Volition (willpower) is a vital element to construct self-awareness, as Roeser and Peck (2009) explained:

> By *volition* we refer, for example, to individuals' capacity for the willful and conscious activation of particular plans and goals within the stream of consciousness, and for

willfully and consciously focusing and sustaining awareness on particular objects within the stream of consciousness for purposes of bringing goals to fruition in action. (p. 120)

Although humans can retrieve long-term memory and trigger habitual behaviors with minimum effort (Bargh, 1996), classroom learning demands that students use volitional control to fulfill academic demands, such as paying attention to lectures, comprehending new information, answering questions, and engaging in discussions with peers (Corno, 2001).

Zimmerman (2001) referred to such self-regulated actions or behaviors occurring in classrooms as *self-regulated learning*, and he identified seven theoretical approaches to such learning: operant, phenomenological, information processing, social cognitive, volitional, Vygotskian, and constructivist. In particular, volitional approaches, in which self-monitoring is employed to lessen interest shifts or interferences during the learning process, are most relevant to the present study because students' attention to classroom learning can be distracted by environmental or psychological "noise" (Corno, 2001, p. 196).

Given that some college students do not control their texting behaviors during classroom instruction, texting might distract those students from learning. At the macro level, the volitional approach might explain why students with a high level of self-regulation, compared to those with a low level, are more likely to sustain their attention to classroom learning (using their willpower to stay away from this distraction of texting). At the micro level, this study also partially relies on the information-processing approach because attention is the main gateway to influencing the entry, maintenance, format, and retrieval of information (Craik & Lockhart, 1976), which might contribute to variation in students' cognitive learning outcomes.

Furthermore, research on the relationship between self-regulation and cognitive learning has found a positive correlation between these variables. For instance, Pintrich and De Groot (1990) found that students with a high grade point average (GPA), compared to those with a low GPA, were more likely to use self-regulatory strategies. Tangney et al. (2004) also showed that students' grades positively related to their self-regulation. Duckworth and Seligman (2005) found that standardized test scores, GPA, and attendance were positively related to self-regulation, such that students with high self-control consistently engaged in the learning process. Therefore, studies suggest that students with a high level of self-regulation not only can sustain their attention on assigned learning tasks during class, but they also can control themselves not to perform off-task behaviors (in this case, texting). Because texting during class seems to be a dynamic phenomenon, it is important to understand college students' texting behaviors.

College Students' Texting

According to Ling (2010), young adults 19 to 21 years of age have reached the peak of using text messaging in their life phases. More than any other social groups, college students prefer to use text messaging primarily to maintain copresent friendships (see

Lin & Tong, 2007) and to enjoy the feeling of "control over social interaction" (Madell & Muncer, 2007, p. 138). Given this motivation to communicate, text message users tend to access this medium ubiquitously across public settings (Leung, 2007).

Although text messaging might help college students to gain social support outside of class (Harley et al., 2007; Naismith, 2007), it also leads to an unexpected social consequence: Despite teachers' level of immediacy (verbal and nonverbal behaviors that motivate students' classroom participation) during classroom instruction, students who are regular text users habitually engage in text messaging during lectures (Wei & Wang, 2010). Such users may demonstrate difficulty sustaining their learning attention because they are multitasking during the information-processing process, and as Small and Vorgan (2008) found, switching tasks back and forth potentially reduces task efficiency.

However, as Braguglia (2008) discovered, 77% of college business students believe that cell phone use seldom or never interferes with classroom learning, although 76% also believed that it seldom assists classroom learning. Hence, whether students' text messaging during class negatively relates to their cognitive learning remains unanswered. If learning requires attention (see Wickens & McCarley, 2008), whether texting and listening to lecture simultaneously can influence students' cognitive learning seems to be another vital concern to teachers.

Attention

When people cannot distinguish relevant from irrelevant information, such mistakes, referred to as "failure of attention" (Broadbent, 1952, p. 428), might occur easily in the selective process. Thus, selective attention is similar to a filtering system. Broadbent's filter model, as Wickens and McCarley (2008) pointed out, is comparable to "an information-processing bottleneck," suggesting that humans "can only process one stimulus or piece of information at a time" (p. 10). However, depending on the nature of the tasks being performed, the question is whether multitasking behaviors influence performances.

Kahneman's (1976) view of information processing did not exclude all multi-tasking; instead, the model suggests that a highly demanding performance is influenced by the capacity to provide sufficient attention. Due to insufficient capacity, people's abilities to perform multitasking can be limited. For example, in comparison to focused attention, Ninio and Kahneman (1974) found that divided attention might delay response time to an assigned task because concurrent signals might interfere with one another; thus, multitasking might be hindered by a limited attention capacity. Wickens and McCarley (2008) illustrated Kahneman's concept by saying that "it's hard to try hard on an easy task but easy to try hard on a hard task" (p. 115). In contrast, Shiffrin and Schneider (1977) argued that the limited capacity approach emphasizes controlled attention because it depends on "the limited-comparison rate and the limited amount of information that can be maintained without loss" (p. 160). Automaticity depends on habitual practice through intensive

training and the speed of processing tasks; consequently, learners require minimum attention to retain the capacity.

However, neither controlled nor automatic attention functions alone (Wickens & McCarley, 2008); consequently, Hofmann, Friese, Schmeichel, and Baddeley (2011) used a "tug-of-war" (p. 214) metaphor to describe the relationship between controlled attention and automaticity. According to Hofmann et al., bottom-up allocation of attention tends to be automatic, meaning that it is a stimulus-driven reaction, as opposed to a top-down allocation of attention, which is driven by self-regulatory goals. To stay focused on goal-oriented tasks, it is important to "prevent attentional capture by distracting or irrelevant cues" (Hoffman et al., p. 214). Even though automatic attention might not necessarily affect the memory capacity, irrelevant stimuli might interfere or compete with controlled attention. Thus, if learners cannot resist irrelevant stimuli during information processing, such as text messaging, their attention to learning might be disrupted.

Moreover, as Wickens and McCarley (2008) noted, attention-related mistakes and delays seem to be associated with task switching. Most researchers (e.g., Baddeley, Chincotta, & Adlam, 2001; Gopher, Armony, & Greenshpan, 2000; Rogers & Monsell, 1995) have cited Jersild's (1927) experimental study to demonstrate that costs take place during task switching, such as prolonged response time when people switch back and forth between two tasks. In particular, Rogers and Monsell (1995) found that the stimuli in the irrelevant task can increase switch costs in performing tasks.

However, the cost of task switching is greater than just the increased response time for completing tasks, for as Wickens and McCarley (2008) suggested, "The phenomenon of task-set inertia implies that even after an interrupting task has been completed, the act of having performed it may continue to hinder the ongoing task, contributing to general switch costs of the form just described" (p. 150). Applying these findings to text messaging, if learners switch their attention back and forth between texting and classroom material, they might have a hard time learning that material because they might have to prolong their response time to process that information. Due to such attention shifting during class, it is crucial to understand the potential impact of learners' sustained attention on learning.

In examining effortful attention, Schmeichel and Baumeister (2010) classified attention into three categories: (a) *selective attention*, paying attention to one stimulus and avoiding other competing stimuli simultaneously; (b) *divided attention*, dealing with multiple tasks or attending to different information at the same time; and (c) *sustained attention*, "focusing attention on a stimulus or activity for an extended period of time" (p. 31). Sustained attention has been found to be one of the major variables affecting academic achievement (Steinmayr, Ziegler, & Träuble, 2010). For example, the NICHD Early Child Care Research Network's (2003) survey of 1,002 young children found that sustained attention positively predicts social competency and academic achievement in school. More important, as the NICHD Early Child Care Research Network concluded, "Sustained attention and inhibition of impulsive responding" (p. 589) is crucial for successful learning. A study conducted by Steinmayr et al. (2010) also showed a positive relationship between adolescents'

sustained attention and academic performance. Hence, if attending to content is essential to classroom learning, students who shift their attention might lose their readiness and responsiveness in following through on classroom instruction; in such cases, texting behaviors might result in lowered cognitive learning via insufficient sustained attention. Although the positive relationship between students' sustained attention and academic performance has been examined by scholars, it is also important to address the variation of approaches to cognitive learning.

Cognitive Learning

Bloom (1956) divided learning into cognitive, affective, and psychomotor domains. *Cognitive learning* is described as a hierarchical order of instructional objectives comprising knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; for detailed discussion, see Jonassen & Grabowski, 1993). Although Bloom's taxonomy of cognitive objectives is not the only one, as King and Witt (2009) noted, it is the most common approach to cognitive learning. Cognitive learning traditionally has been measured by students' overall GPA (Walker, 2008) or course grade (Harper & Hughey, 1986). However, a course grade or final examination grade alone undoubtedly does not best reflect cognitive learning outcomes. Moreover, other factors, such as attendance or differential levels of effort put into an assigned group project, easily can bias cognitive learning outcomes (see Richmond, McCroskey, Kearney, & Plax, 1987). To broaden the measurement of cognitive learning, Richmond et al. (1987) assessed students' *learning loss* via self-reports to two questions, "How much did you learn in this class?" and "How much do you think you could have learned in the class had you had an ideal instructor" (p. 6), using a 10-point scale (0 = *Nothing*, 9 = *More than any class I have ever had*). Though the validity of the learning loss measure has been questioned (Hess, Smythe, & Communication 451, 2001), the measure has been employed widely in instructional communication scholarship to study the relationship between teacher immediacy behavior and an aspect of student learning termed by Witt, Wheeless, and Allen (2004) as *perceived* cognitive learning. To measure the concept of perceived cognitive learning, Frymier and Houser (1999) developed a revised cognitive learning indicators scale to assess whether students believe that they learned a lot in a course and whether that learning extends outside the classroom. Although many factors, such as teacher immediacy (Richmond et al., 1987) can influence students' perceived cognitive learning outcomes, texting during class has not been examined thoroughly in the learning process.

Rationale and Hypotheses

Grounded in the theory of self-regulated learning, studies (e.g., Duckworth & Seligman, 2005; Pintrich & De Groot, 1990; Tangney, Baumeister, & Boone, 2004) have shown that self-regulation is positively related to students' cognitive learning, meaning that self-regulated (self-controlled) students not only cognitively engage in

the learning process (Zimmerman, 2001) but also effectively block internal or environmental distracters during information processing (Corno, 2001). Thus, in line with the volitional approach (Corno, 2001), it is possible that self-regulated (self-controlled) learners are less likely to text during class and are more likely to sustain their attention on learning-oriented tasks. Consequently, students with a high level of self-regulation would be less likely to shift their attention to other irrelevant behaviors during class compared to students with a low level of self-regulation.

Because attention is the main gatekeeper to processing, storing, and retrieving information (e.g., Craik & Lockhart, 1976; Wickens & McCarley, 2008), learning cannot proceed in its absence. Of the types of learning attention (see Schmeichel & Baumeister, 2010), *sustained attention* has been identified as a vital predictor of academic learning outcomes (NICHD Early Child Care Research, 2003); in particular, Steinmayr, Ziegler, and Träuble (2010) found a positive relationship between students' sustained attention and their cognitive learning of math. Hence, when students sustain their attention in classroom learning, they should learn the information presented more effectively.

Furthermore, even though scholars have found that self-regulation is positively related to attention (Schmeichel & Baumeister, 2010) and cognitive learning (Steinmayr et al., 2010), it remains unclear how texting relates to sustained attention during class. For instance, text messaging may be a distracter (internal noise) that grabs students' attention away from lectures and other learning activities (Corno, 2001); consequently, such task switching might cause a delay in response to the main task and may cause task-set inertia to influence sequential task quality (Wickens & McCarley, 2008). Thus, to understand the potential effects of text messaging on students' cognitive learning as a process, it is important to determine whether self-regulation relates to students' text messaging, whether frequent texting during class is associated with a lower level of students' sustained attention, and whether the effects of text messaging on cognitive learning are mediated by sustained attention. Therefore, based on research revealing positive relationships among self-regulation, sustained attention, and cognitive learning (Schmeichel & Baumeister, 2010; Steinmayr et al., 2010), we proposed a model of the potential effects of text messaging during class with regard to its positive or negative relationships among these four variables (see Figure 1).

We first hypothesized that college students' text messaging during class would partially mediate the effect of their self-regulation on their sustained attention to classroom learning, and that direct and indirect effects of self-regulation would be statistically significant. Second, college students' sustained attention was hypothesized to mediate the effects of their self-regulation and text messaging during class on their cognitive learning outcomes, and that such indirect effects of self-regulation and text messaging during class would be statistically significant, whereas the direct effects of self-regulation and text messaging during class would be statistically nonsignificant after controlling for the effect of students' sustained attention.
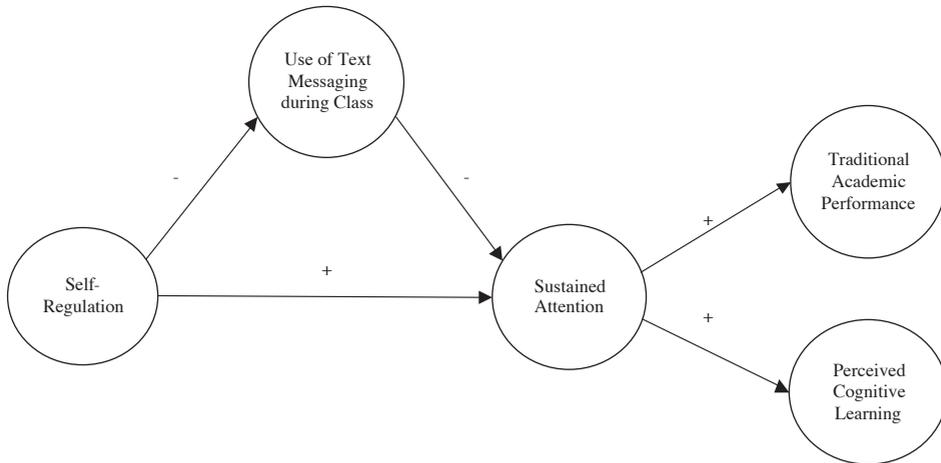
Figure 1.　Hypothesized research model including latent constructs: self-regulation (SR), use of text messaging during class (TM), sustained attention (SA), grade-oriented academic performance (AP), and experience-oriented perceived cognitive learning (CL).

Method

Participants

The sample consisted of 190 undergraduate college students recruited from a small-sized university in the Northeast United States. Participants (97 women, 93 men, $M_{age} = 22$ years, age range: 18–49 years) completed a cross-sectional questionnaire. Approximately 83.2% of the participants were Caucasian, 8.9% were African American, 3.2% were Hispanic, 2.1% were Asian, and 2.6% were Other. Participants came from a variety of disciplines, including anthropology, biology, business, chemistry, communication, computer science, criminal justice, economic, education, English, engineering, mathematics, music, physics, psychology, sociology, and sport management. Like most U.S. universities, the institution employed a 50-, 75-, or 150-minute class meeting time for undergraduate courses, with the average class size being between 15 and 25 students. With the exception of courses pertaining to laboratory, physical education, nursing practice, and internships, all of the under-graduate courses at the university primarily are taught in a lecture-oriented format. The university from which the sample was drawn did not employ a zero-tolerance policy of banning mobile phones during class, and participants had been using a text-messaging service for an average of 5.32 years.

Procedures

After gaining Institutional Review Board approval, 238 college students enrolled in 10 undergraduate general education classes listed in the 2010 spring semester course catalog were contacted by their instructors to voluntarily complete at the end of the semester an anonymous questionnaire, with no extra credit given to entice

participation. The questions assessed participants' recall of their most recent midterm examination score, assignment grade, and overall cognitive learning experience. Administers asked participants not to complete the questionnaire more than one time. Participants answered all questions based on "the class which you attended immediately before this class" (Richmond, 1990, p. 183). Furthermore, administers also requested students to report the class meeting time and title that they attended immediately before the class in which the questionnaire was completed, with responses removed for nonlecture-oriented classes or for class meetings that exceeded 75 minutes. In total, 190 completed questionnaires were coded and analyzed using SPSS 19 and M-Plus 5.2 software.

Measurement

The questionnaire measured the following constructs: (a) self-regulation, (b) sustained attention during classroom learning, (c) text messaging during class, and (d) cognitive learning, which consists of self-reported grade-oriented academic performance and experience-oriented cognitive learning outcomes. Demographic information such as gender, age (used as the control variable), ethnicity, and the year of experience with texting was requested in the last section of the questionnaire.

Self-regulation. The self-regulation (SR) scale from Pintrich and De Groot (1990)'s Motivation Strategies for Learning Questionnaire (MSLQ) was used to measure students' self-regulation. Participants employed a 7-point Likert-type scale ($1 = Not$ *at all true of me*, $7 = Very true of me$) to respond to the 9-item construct of self-regulation as measured by statements such as, "Even when study materials are dull and uninteresting, I keep working until I finish" and "I find that when the teacher is talking I think of other things and don't really listen to what is being said." Reverse coding was employed for statements phrased in a negative manner. Cronbach's alpha for the measurement of self-regulation was .71 ($M = 4.55$, $SD = .90$).

Sustained attention. A 6-item scale of sustained attention to classroom learning (SA) was created for this study. Prior to data collection, two independent external reviewers were invited to examine the face validity of the scale and all items were adopted. Participants responded to statements such as, "I never shift my attention to other nontask-oriented learning activities in this class," "I can sustain my attention to learning activities throughout the class," and "I pay my full attention to classroom discussions in that class," using the same 7-point Likert-type scale described for self-regulation. An item analysis excluded one item, and Cronbach's alpha for the 5-item CA was .87 ($M = 4.41$, $SD = 1.09$).

Text messaging during class. To assess students' use of text messaging during class (TM), they were asked to respond to two closed-ended questions used previously by Wei and Wang (2010): "Based on the class which you attended immediately before this class, how many text messages do you, on average, read in that class" ($M = 2.59$, $SD = 4.55$) and "Based on the class which you attended immediately before this class,

how many text messages do you, on average, send in that class? ($M = 2.37$, $SD = 5.01$).

Cognitive learning. In line with a dual-process approach to grade-oriented and learning experience-oriented cognitive evaluations, students' perceived cognitive learning was measured in two separate variables—one by traditionally measured self-reported grades for academic performance (AP) and the other by Frymier and Houser's (1999) revised cognitive learning indicators scale for perceived cognitive learning outcomes (CL). With respect to traditionally measured academic performance, using a 100% assessment scale, participants wrote down their most recent midterm examination grade ($M = 84.13$, $SD = 10.39$), most recent assignment grade ($M = 89.62$, $SD = 10.57$), and final grade ($M = 84.33$, $SD = 12.21$) for the course that they attended immediately before the course being surveyed. For learning experience-oriented cognitive assessment, participants used a 5-point Likert scale ($0 = Never$, $4 = Very often$) to respond to seven statements, such as "I feel I have learned a lot in that class." Cronbach's alpha for the scale was .84 ($M = 2.47$, $SD = .85$).

Data Analysis

Given that the data were collected from a mixture of 50-minute and 75-minute classes, pretests on sample differences for students' texting and sustained attention from these two groups were performed. A mean comparison of students' sustained attention indicated no significant difference between the data collected from the 50-minute ($M = 21.52$, $SD = 6.08$) and from the 75-minute classes ($M = 22.22$, $SD = 6.51$), $t(188) = -.76$, $p > .05$. The other test of students' sent and read messages also indicated no significant difference for students' text messaging during class between the 50-minute ($M = 4.46$, $SD = 8.44$) classes and the 75-minute classes ($M = 5.36$, $SD = 10.11$), $t(188) = -.65$, $p > .05$.

A regression analysis was performed to test for possible influences of users' age on their use of text messaging during class (see Ling, 2010). The result indicated no significant difference in the extent of text messaging during class ($F = 2.865$, $p > .05$) across age groups. Participants' age subsequently was loaded as a control covariate to the model to explain the relationship between text messaging and sustained attention during class. The result showed no significance ($\beta = -.124$, $p > .05$), further confirming that age difference did not affect the SEM.

A multivariate normality check was performed on all variables before entering them into the model to minimize potential threats to the violation of the normality assumption of standard maximum likelihood estimation. The check revealed that, except for the text messaging during class, all other variables demonstrated acceptable departure from normality. The two positively skewed items on text messaging during class were normalized to z-scores before loaded into the model.

Structural equation modeling (SEM) technique with maximum likelihood (ML) estimation was employed to test the proposed research model. Pursuant to the procedures suggested by Kline (2005), a confirmatory factor analysis (CFA) was

conducted to assess the measurement model, with the indicators loaded to underlying latent constructs (Park, Dailey, & Lemus, 2002). The purpose of the measurement model is to evaluate the loadings of the indicators as well as the relationships among latent constructs. The proposed research model contained five latent constructs: self-regulation (SR), text messaging during class (TM), sustained attention (SA), self-reported graded-oriented academic performance (AP), and experience-oriented cognitive learning (CL). Two latent constructs (TM and AP) were identified by using the observed variables; the other three latent constructs (SR, SA, and CL) were identified by aggregating observed variables into three *parcels* to reduce the number of parameter estimates and to improve reliability (see Schrodt et al., 2009).

For the measurement and structural models, fit indices that included the model χ^2, degrees of freedom (*df*), comparative fit index (CFI), and root mean square error of approximation (RMSEA) were examined to evaluate the model fitness. As suggested by Hu and Bentler (1999), models with CFI greater than .90 whereas RMSEA less than .05 are considered to be a close fit with the data.

Results

The Pearson product-moment correlations for all variables are reported in Table 1, and the measurement and structural models are reported below.

Measurement Model

The CFA measurement model indicated a good model fit, χ^2 (*df* = 67, $N = 187$) = 90.581, $p = .029$; CFI = .981, RMSEA = .043 (90% CI: .015—.065). The fit indices suggest a good fit of the model with the data, with the loadings for the indicators and the corresponding residuals reported in Figure 2. All indicator loadings ranged between medium and high, which suggests acceptable convergent validity. The estimated factor correlations ranged between low and moderate in size, suggesting acceptable discriminant validity.

Structural Model

The structural model also indicated a good model fit, χ^2 (*df* = 71, $N = 187$) = 96.606, CFI = .980, RMSEA = .044 (90% CI: .017 − .065). The model accounted for substantial variance in students' cognitive learning ($R^2 = .39$), but only accounted for a little of the variance in their academic performance ($R^2 = .07$). Self-regulation and text messaging during class accounted for a substantial portion of the variance in sustained attention ($R^2 = .53$).

The path model indicated that college students' self-regulation has a direct positive relationship with their sustained attention ($\beta = .65$, $p < .001$) and an indirect negative relationship with texting during class ($\beta = -.30$, $p < .01$), with texting during class subsequently being negatively related to sustained attention ($\beta = -.18$, $p < .01$). A bootstrapping test (see Hayes, 2009) employed to examine the indirect

Table 1   Correlations Among Latent Constructs

	Variables	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1	TM—read in class	2.585	4.550	–												
2	TM—sent in class	2.373	5.013	.927**	–											
3	SR—Parcel 1	3.416	1.927	−.103	−.103	–										
4	SR—Parcel 2	4.868	1.655	−.194**	−.181*	.456**	–									
5	SR—Parcel 3	4.447	1.602	−.268**	−.286**	.490**	.580**	–								
6	SA—Parcel 1	3.821	1.752	−.270**	−.233**	.203**	.440**	.489**	–							
7	SA—Parcel 2	4.584	1.484	−.323**	−.354**	.212**	.507**	.493**	.582**	–						
8	SA—Parcel 3	4.605	1.521	−.300**	−.314**	.236**	.457**	.519**	.639**	.773**	–					
9	AP—Midterm	84.132	10.393	−.044	−.086	.195**	.314**	.364**	.277**	.326**	.263**	–				
10	AP—Assignments	89.617	10.566	−.037	−.054	.100	.293**	.262**	.206**	.289**	.149*	.543**	–			
11	AP—Final	84.758	10.618	−.014	−.056	.150*	.236**	.283**	.239**	.307**	.225**	.654**	.414**	–		
12	CL—Parcel 1	2.253	1.154	−.140	−.147*	.234**	.248**	.236**	.240**	.352**	.322**	.286**	.194**	.350**	–	
13	CL—Parcel 2	2.489	1.167	−.085	−.092	.241**	.323**	.371**	.248**	.366**	.372**	.337**	.209**	.342**	.481**	–
14	CL—Parcel 3	2.847	1.128	−.082	−.076	.193**	.302**	.318**	.299**	.449**	.439**	.384**	.222**	.365**	.469**	.559**

Note. TM, use of text messaging during class; SR, self-regulation; SA, sustained attention to classroom learning; AP, traditional academic performance (grade-oriented learning); CL, perceived cognitive learning (experience-oriented learning). *$p < .01$. **$p < .05$.
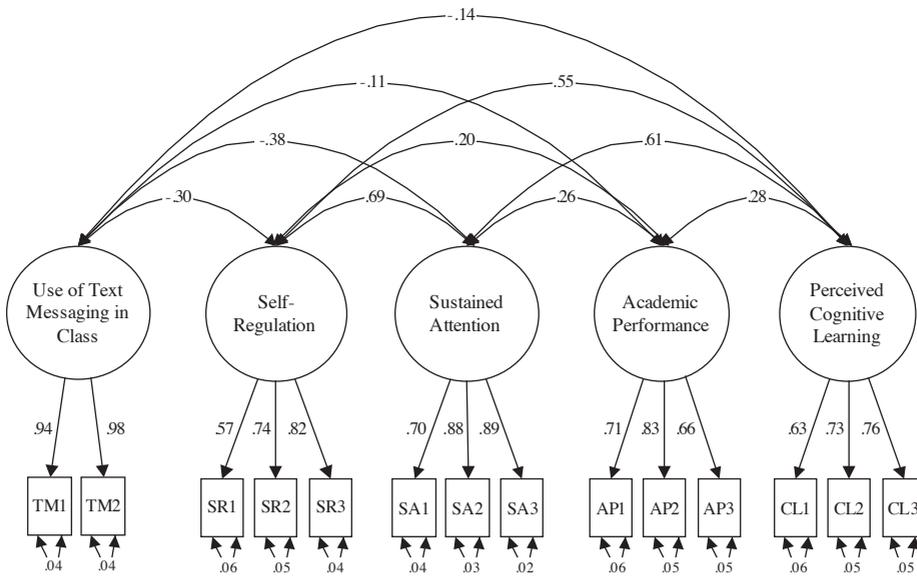
Figure 2.   Measurement model of self-regulation (SR), sustained attention (SA), use of text messaging during class (TM) and cognitive learning, including grade-oriented academic performance (AP) and experience-oriented perceived cognitive learning (CL).

effects for self-regulation found a significant indirect effect ($p < .05$) from self-regulation to sustained attention via texting during class. Thus, texting during class partially mediated the effect of students' self-regulation on their sustained attention.

The path weights between students' sustained attention and their grade-oriented academic performance ($\beta = .26$, $p < .01$) and experience-oriented cognitive learning outcomes ($\beta = .62$, $p < .001$) were both positively significant. Again, a bootstrapping test was employed to test the indirect effects among students' self-regulation, texting during class, and their academic performance and cognitive learning. Significant indirect effects were found: (1) from students' self-regulation to their sustained attention to classroom learning via use of text messaging during class (point estimate of .170 with 95% confidence interval between .023 and .317 based on 1,000 bootstrap samples, $p < .05$), (2) from self-regulation to experience-oriented perceive cognitive learning via sustained attention (point estimate of .405 with 95% confidence interval between .279 and .531 based on 1,000 bootstrap samples, $p < .001$), and (3) from students' texting during class to their experience-oriented perceived cognitive learning via sustained attention (point estimate of $-.107$ with 95% confidence interval between $-.179$ and $-.035$ based on 1,000 bootstrap samples, $p < .05$).

Both direct and indirect effects of self-regulation and texting during class on academic performance and cognitive learning outcomes also were tested. After controlling for sustained attention, the direct effects of texting during class and self-regulation on academic performance and cognitive learning outcomes became
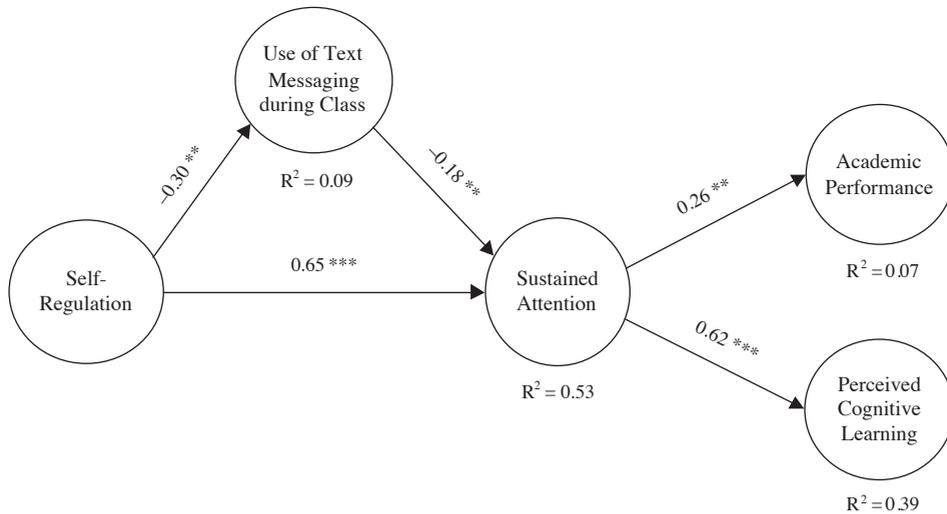
***$p < .001$, **$p < .005$, *$p < .05$

Figure 3.   Path model.

statistically nonsignificant. Thus, sustained attention fully mediated the effect of students' self-regulation and texting during class on their academic performance and perceived cognitive learning.

Discussion

The goal of this research was to investigate whether text messaging influences college students' cognitive learning. A path model was proposed regarding relationships among students' self-regulation, texting during class, sustained attention, and cognitive learning (i.e., grade-oriented academic performance and experience-oriented cognitive learning). Overall, the model was supported by the collected data.

Students' texting during class emerged as a partial mediator of the effect of self-regulation on sustained attention. The results showed that college students' self-regulation was negatively related to their text messaging use during class, which in turn was negatively related to their sustained attention to classroom learning, meaning that college students who possess a high level of self-regulation are less likely to text during class and are more likely to sustain their attention to classroom learning. When students text during class and simultaneously listen to lectures, their limited information-processing capacity (see Ninio & Kahneman, 1974) requires that they have to concentrate on one of those tasks and not the other. Thus, in line with research about switch costs and task-set inertia (Wickens & McCarley, 2008), one possible reason for this finding is that those students who text during class may need more time to process lecture notes (new information) or even be unable to comprehend the content well due to the interference of irrelevant tasks (see Rubinstein et al., 2001). In the particular case of students texting during class, they have to make frequent switches between two information-processing tasks (e.g.,

texting vs. listening to the lecture), and the accumulated switch costs signify the magnitude of distraction to sustained attention. This finding is consistent with Corno's (2001) view that self-regulated learners effectively control their attention in a learning environment, using their willpower and learning strategies to block irrelevant stimuli, and, in turn, they can perform more fully on-task learning behaviors. Sustained attention appeared to mediate the effect of students' self-regulation on both grade-oriented academic performance and experience-oriented cognitive learning. Students with a high level of volitional power were more likely to sustain their attention on classroom learning (to stay on task-oriented behavior), which, in turn led to positive cognitive learning. This finding was in line with the volitional and information-processing approaches to self-regulated learning and provided support to other findings (e.g., NICHD Early Child Care Research, 2003; Steinmayr et al., 2010).

Sustained attention was also found to mediate the effect of students' texting during class on their experience-oriented cognitive learning. Frequent texting during class reduces students' sustained attention to the material being covered and further decreases their perceived cognitive learning. Therefore, this study suggests that frequent texting during class might reflect students' low self-control in classroom learning, and it might jeopardize students' sustained attention on the in-class tasks and, in turn, might significantly influence students' perceived cognitive learning.

It is worth noting that the relationship between students' sustained attention to classroom learning and their grade-oriented academic performance was stronger than that between sustained attention and experience-oriented perceived cognitive learning. The strong path weight between students' sustained attention and their perceived cognitive learning suggests that those who sustained their attention during class tend to believe that they have learned more from the classroom instruction. Sustained attention, thus, appears to be a type of controlled (effortful) attention (Schmeichel & Baumeister, 2010). In other words, students with a high level of sustained attention to classroom learning might not only care about examination and assignment grades but also care about whether the content being discussed is useful. In comparison, students' sustained attention demonstrated a low positive association with grade-oriented academic performance, perhaps because those who failed to sustain attention during class had sought alternative ways to learn classroom materials (e.g., copying notes from classmates after class). Hence, examination and assignment grades might have been influenced by efforts outside of class (e.g., the amount of time preparing for a test).

Implications

Because this study showed that sustained attention is a vital variable that mediates the relationship between texting during class and cognitive learning outcomes, it is important for teachers to help students maintain their sustained attention on learning and to lessen unrelated classroom activities via effective instructional strategies, such as by employing hands-on activities or clickers during lectures to sustain students'

attention during class and to prevent them from texting. Additionally, displaying a visible countdown watch on the lecture screen (setting up a limited time) for a classroom activity may pressure students who text during class to limit unnecessary task switching and to keep the same pace with other students on the assigned learning task. Furthermore, although teachers have the authority to completely ban texting during class, there may be alternatives to such an extreme practice without compromising students' learning effectiveness. Strategies for promoting students' motivation and self-regulated learning may engage students' sustained attention more effectively than simply banning text messaging. For instance, because the ultimate goal is to maintain students' attention on course-related content, some universities, such as the University of Michigan, have begun to use smart phones or mobile devices to facilitate students' classroom discussion (Sohn, 2011).

Limitations and Future Studies

Although this study enhances understanding of the potential influences of students' in-class texting on their cognitive learning, the findings must be interpreted in light of at least four limitations. First, the survey method employed only allowed for correlations to be obtained among the investigated variables. To demonstrate causal relationships between texting and switch costs (delay of the responses), experimental studies need to assess differences between students who do and do not text during a (simulated) class with respect to, for instance, their response time to teachers' questions. Second, although the theory of self-regulated learning explains how students' proactive efforts (e.g., self-control and self-efficacy) contribute to their cognitive learning outcomes (Zimmerman, 2001), it may exclude the potential effects of teachers' instructional interventions. To assess students' proactive efforts and teachers' interventions simultaneously, researchers might investigate the interaction between students' texting during class and teachers' strategies of preventing texting. Third, whereas texting during class was measured in terms of average use, students' examination and assignment grades were cumulative measures of how much they learned throughout the course rather than their learning on an average day in that course. Such a conceptual discrepancy in measurements might slightly influence the preciseness of traditionally measured academic performance. Finally, the results from the anonymous survey questionnaire came from students who attended different courses; thus, the types of examinations and assignment formats, levels of difficulty, and grading methods could not be controlled, which might be factors that produced the small path weight between students' sustained attention and traditionally measured academic performance. Future studies should collect data from larger universities where the same course is taught in multiple sections and use the same pedagogy.

Conclusion

This study showed that self-regulated students were more likely to sustain their attention on classroom learning, and, therefore, less likely to text message during

class. Subsequently, these students perceived themselves to have achieved better cognitive learning outcomes, whereas students who frequently texted during class had difficulty maintaining their sustained attention during classroom learning and, in turn, potentially sacrificed cognitive learning outcomes. These results suggest that each time students send or read text messages during class, their focus is interrupted and diverted from the main learning task. Thus, students should consider limiting their texting during class because learning requires their sustained attention.

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