International Journal of Teaching and Learning in Higher Education 2020, Volume 32, Number 1, 64-72
http://www.isetl.org/ijtlhe/ ISSN 1812-9129

Persistence of Multitasking Distraction Following the Use of Smartphone-based Clickers

Sihui Ma, Daniel G. Steger, Peter E. Doolittle, Andrew H. Lee, Laura E. Griffin, and Amanda Stewart
Virginia Tech

Clickers are used to improve student learning, motivation, and engagement. Smartphones can serve as clickers; however, instructional use of smartphones may lead to students multitasking between instructional and alternative media. This study investigates whether students are distracted after instructional use of smartphones in a lecture-based classroom. Outcomes were assessed through both self-reported smartphone use and in-class observations of actual smartphone use. Students were observed covertly for 5 minutes following instructional use of smartphones to determine whether multi-tasking distraction occurred and/or persisted following the instructional use of smartphones. Even though the self-reported data indicate that students disagreed to somewhat disagreed that smartphone use was a distraction, our findings show that 42% of students began to use their smartphones for non-instructional purposes immediately following the instructional episode, and 28% of students persisted in this behavior five minutes after the instructional episode ended. The observations contradicted the students' self-reported survey responses, thus emphasizing the need to critically consider self-reported outcomes related to multi-tasking distraction in the classroom. Policies or practices to limit multi-tasking distraction due to non-instructional use of smartphones in the classroom should be considered in cases where smartphones are being used for instructional purposes.

In pursuit of active learning strategies to deploy in college classrooms, personal response systems, typically called "clickers", have increased in use over time (Hunsu, Adesope, & Bayly, 2016; Sun, 2014). Traditional clickers involve the use of a handheld infrared or radio-frequency system that allows students to respond to instructor questions, while smartphone-based clickers allow students to use their personal phones to respond to instructor questions via cloud or web-based computing. In either case, student responses can be automatically summarized and displayed (if desired) in a slide-based presentation, such as PowerPoint (Banks, 2006). Clickers, traditional and smartphone-based, are tools to create an active learning environment within the classroom in the form of engagement and active cognitive/social processing (Mayer & Chandler, 2001) through question responding (Beatty, Gerace, Leonard, & Dufresne, 2006), feedback use (Mostyn, Meade, & Lymn, 2012), knowledge reactivation (Shapiro & Gordon, 2012), social exchange (Filer, 2010), just-in-time-teaching (Caldwell, 2007), and question-based teaching (Anderson, Healy, Kole, & Bourne, 2013).

That said, as clicker use transitions, at least in part, from using traditional clickers to smartphone-based clickers, an issue arises: Does the use of smartphone-based clickers for instructional purposes lead to an increase in student multitasking, with potential negative impacts on academic performance? Existing research is clear that the off-task multitasking use of laptops and smartphones leads to decreases in academic performance (Watson, Terry, & Doolittle, 2012). Does the use of smartphones as clickers then exacerbate this?

Traditional Clickers for Instructional Purposes

In 2016, three meta-analyses were conducted to examine the impact of traditional clicker use for non-cognitive and cognitive purposes (Castillo-Manzano, Castro-Nuño, López-Valpuesta, Sanz-Díaz, & Yñiguez, 2016; Chien, Chang, & Chang, 2016; Hunsu et al., 2016). Each of the meta-analyses included only those traditional clicker studies that compared non-clicker classes (i.e., traditional lectures) to clicker-based classes and examined both non-cognitive and cognitive outcomes.

Examination of non-cognitive outcomes found only a small effect on attendance, engagement, interest, and perceptions of instructional quality, but a large effect on self-efficacy, indicating that the use of clickers only increased students' attendance, engagement, interest, and perceptions of quality by a small degree, while the use of clickers increased substantially students' confidence in their ability to successfully complete a relevant quiz.

Examination of cognitive outcomes found only a small-to-medium effect of clicker use on learning performance (i.e., knowledge retention, knowledge transfer, course performance). Relative to instructional impact, clickers are often used in conjunction with a series of review questions to stimulate student thought and obtain a sense of what students are learning. In examining the effect of using this type of questioning strategy, the meta-analyses were equivocal, with some studies finding a small positive impact of using clickers, but some not, and some studies finding a small positive impact of using questions, but some not. In addition to the questioning strategy, Chien et al. (2016) also examined the impact of clicker use when the use was and was not followed up by peer discussion and found a large effect for clicker use followed by peer discussion. Finally, when examining one-session and multi-session use of the clickers, Chien et al. (2016) found a small effect for one-session use and a large effect for multi-session use.

As demonstrated by these three meta-analyses, the impact of clicker use on student cognition is still not clear. Chien et al. (2016) found that clicker use resulted in mostly medium and large effects on student learning, while Hunsu el al. (2016) and Castillo-Manzano et al. (2016) found mostly no and small effects. In addition, the results of the question-based and peer-discussion-based pedagogy results indicate that instructional approach may interact with clicker use, possibly enhancing its impact.

Smartphone-based Clickers for Instructional Purposes

Traditional clicker use has fairly recently evolved into the use of smartphones as input devices. The use of smartphones in classrooms has several advantages over clickers: students already own smartphones and typically bring them to class without prompting, thus do not need to purchase, rent, or carry additional devices; smartphones do not rely on separate infrared or radio-frequency technologies; smartphones allow for a greater number of input question types compared to clickers; and students generally prefer using smartphones to clickers.

While smartphone-based clickers are fairly new, students bringing smartphones to class is not, necessitating a differentiated examination of smartphone use in classes for non-instructional versus instructional purposes. From a non-instructional perspective, Tindell and Bohlander (2012) found that 95% of students bring their smartphones to class, 92% use their smartphones to text message during class, and 10% have even texted during an exam. In addition, a consistent finding is that the more students use smartphones in classes for non-instructional uses, the poorer their class performance (Felisoni & Godoi, 2018). Specifically, several studies have shown a negative correlation between student in-class smartphone activity and grade point average (Bjornsen & Archer, 2015; Duncan, Hoekstra, & Wilcox, 2012; Froese et al., 2012; Harman & Sato, 2011; Junco, 2012b; Lepp, Barkley, & Karpinski, 2015), while Gingerich and Lineweaver (2014) found that students performed significantly worse on content assessments when they texted during a lecture. It should be noted that the conclusion that smartphone use in the classroom for non-instructional purposes leads to lower academic performance is not unique as there is a corpus of research clearly indicating that using laptops during class for non-instructional purposes also leads to lower academic performance, distracting laptop users as well as their peers (Junco, 2012a; Sana, Weston, & Cepeda, 2013).

While the use of smartphones for non-instructional purposes has a generally negative impact on student academic performance, the research on the impact of smartphones for instructional purposes has yet to reach a consensus. Smartphones in classes can serve as high-powered clickers, providing the ability to move beyond multiple-choice questions to higher order questions involving word or numeric responses, matching, sort and rank responses, or clicking on a region of an image responses. Thus, instructors are able to design questions and activities that more actively retain student attention (Beatty et al., 2006) and foster deeper cognition (Voelkel & Bennett, 2014; Wong, 2016). That said, there have been conflicting data regarding whether or not smartphone-based clickers are more effective than traditional clickers (Sun, 2014). Stowell (2015) found little difference between students who used traditional clickers versus smartphone-based clickers; specifically, Stowell found in one class that students who used traditional clickers versus smartphone clickers responded correctly more often to ungraded, in-class, multiple-choice questions (63.9% vs 55.3%, respectively), while in another class there were no such differences (54.7% vs 55.8%, respectively). Stowell also found no impact of smartphone-based clicker use on students' final grades.

Smartphone-based Clickers and Multitasking Distraction

The reasoning for the negative impact of smartphone use for non-instructional purposes on class performance is often multitasking-based distraction, the cognitive distraction that occurs when students attempt to engage in two tasks simultaneously, such as texting while listening to a lecture or searching the web while watching an in-class video (Chen & Yan, 2016). The negative impact of multitasking may be the result of attempting to focus on more than one task at a time or attempting to access long-term memory for more than one response or solution at a time (Watson et al., 2012). That said, the research addressing in-class, non-instructional multitasking is clear, it degrades students' academic performances, specifically, instant messaging in class (Junco, 2012b; Junco & Cotten, 2011), Facebooking in class (Judd, 2014; Wood et al., 2012), texting in class (Ellis, Daniels, & Jauregui, 2010), emailing in class (Wood et al., 2012), and general laptop use in class (Sana et al., 2013) have all led to decreases in students' academic performance. The potential for smartphone-based multitasking, and its concomitant degradation of performance, is clear when one recognizes that all of these tasks—instant messaging, Facebooking, texting, and emailing—may be engaged in from one's smartphone.

Yet, while the research is clear that technology-based multitasking in class impedes learning, the use of smartphone-based clickers as a form of additional classroom technology, which may or may not create a multitasking distraction environment, has not yet been clearly examined. When a smartphone is used to answer course content questions in class, no multitasking distraction occurs as the smartphone is being used for instructional purposes;

however, when a smartphone is used to scan Facebook or Twitter while course content instruction is co-occurring, the smartphone use creates a multitasking distraction situation. This situation results in a basic question: What do students do with their smartphones once an instructional application that involves the use of their smartphones ends? Do students put away their smartphones and concentrate on the course content, or do students engage in instant messaging, Facebooking, texting, or emailing, thus creating a multitasking distraction situation? To date, there are no *in-situ* observations of students' smartphone use following an instructional use of smartphones as clickers. In our study, we investigate the potential for multitasking distraction and persistence of multitasking distraction following an instructional use of smartphones as clickers.

Research Questions

The use of smartphone-based clickers has the potential to create detrimental in-class multitasking distraction events if students continue to use their smartphones for non-instructional uses beyond their original instructional purpose as clickers. The current research is designed to examine three questions: (1) Do students who use smartphone-based clickers for instructional purposes in class continue to use their smartphones for non-instructional purposes after the instructional episode ends? The hypothesis is that students who use smartphone-based clickers for instructional purposes will continue to use their smartphones for non-instructional purposes after the instructional episode ends; (2) To what extent, if any, does this non-instructional use of smartphones persist? The hypothesis is that the non-instructional use of smartphones will persist over the observed period; (3) Do students perceive the use of smartphone-based clickers in class for instructional purposes as a distraction? The hypothesis is that students will not perceive the use of smartphone-based clickers for instructional purposes as a distraction.

Methods

The impact of using smartphone-based clickers in a lecture-based class was examined through two methods: smartphone use in-class observations and a smartphone use survey.

Participants

All participants were enrolled in an upper-level undergraduate food science course at a large university in the southeastern United States, and they received no course credit for participation in this study. Smartphone use in-class observations included 154 observations of students enrolled in the same course with genders, ages, and ethnicities indeterminate due to the nature of the covert observations. In addition, no effort was made not to observe the same individual on different days. For the smartphone use survey data collection, all students in the course (N = 51) were emailed a request to participate and 28 students completed the non-incentivized, anonymous, and voluntary survey (54.9% response rate). Survey participants included 22 females and 6 males, with a mean age of 21.7 years (SD = 0.96) and reported ethnicities of 27 White/Caucasian and 1 Hispanic.

Procedure

Our study design was preliminarily reviewed by the Virginia Tech Institutional

Review Board (IRB) and deemed exempt from requiring official IRB review and approval.

Smartphone-based clicker. Students were required to use the TopHat^{TM} personal response system, either on their smartphones or on their laptops, as part of class participation. Use of TopHat^{TM} was free for students in this class with the subscription cost covered by the university's Center for Teaching and Learning. TopHat^{TM} allows the course instructor to query students using different question formats, such as multiple-choice questions, word or numeric responses, matching, sort and rank responses, or clicking on a region of an image responses. Student responses could then be stored and shared (or not) with students.

Class design. The use of the smartphone-based clickers was built into the fabric of the T, Th 75-minutes per class food science course during weeks 7-13 of the 15-week academic semester. The course is taught using a mixed approach, with the first 40-45 minutes used for lecture and the last 30-35 minutes used for experiential learning through sensory evaluation of, and group discussion of, foods and beverages relevant to the day's lecture material. Within each of these classes, the smartphone-based clickers were used three times during the lecture portion of the class: once at the beginning of the class using two multiple-choice questions as a course review, once in the middle of the class using two non-multiple-choice questions to encourage deeper thinking, and once at the end of the class using two multiple-choice questions as a daily review. Students answered questions independently and received course credit for participating with the smartphone-based clicker questions: one point for simply answering a question and one point for answering a question correctly. The course instructor explained the correct response to each question once the student-response time period had ended.

Smartphone use in class: observation and distraction assessment. In order to observe students' use of their smartphones during class, up to four graduate student observers entered the 120-seat lecture hall classroom unannounced, along with the enrolled students, in order to remain covert during the eight separate observation days. The covert observations were used to provide primary data of students' use of their smartphones rather than relying on self-reported student data. Observers were graduate students (four authors of this study) who were similar in age and demographics to the students enrolled in the course, but not familiar to the students. The students were not aware that their smartphone use was being observed, although they had been notified that an educational technology study was being conducted in their classroom during that semester. The observers distributed themselves throughout the class (i.e., front, back, left, right) in positions that provided acceptable sight lines to students with visible smartphones. Each observer identified up to five students to observe during the class who were close enough to the observer for each student's smartphone screen to be visible.

Each student was observed for the first five minutes following the beginning-of-class and middle-of-class smartphone-based clicker questions. Once the instructor "closed" the second of the beginning-of-class questions, the observer would take note of whether or not each student used, or continued to use, their smartphone for non-instructional purposes (e.g., texting, social media) within the first, second, third, fourth, and fifth minutes on a datasheet. This observational pattern was then repeated for the middle-of-class questions, resulting in a total of ten separate observation occasions per student per class. All observers were trained to use the data collection techniques by enacting the observation protocol during two classes prior to the beginning of data collection.

Multitasking distraction was assessed using a binomial test comparing the proportion of students persisting in using their smartphones within the first, second, third, forth, and fifth minutes beyond the conclusion of the instructional episode to the baseline value. To obtain the baseline of student smartphone use in class, a parallel class – same course and same instructor – was used. Two observers gathered data from 20 students across two class periods by sitting in the class, observing students' smartphone use, and recording whether or not students were using their smartphones for non-instructional purposes (e.g., texting, making a call, surfing the web). Smartphone use was checked every five minutes to see if the students were on their phones at that instant of the class for the first 40 minutes, resulting in eight observations per class for baseline determination.

Measures

The researcher-constructed smartphone use survey was administered online during week 13 of the 15-week semester. The survey consisted of three 6-point Likert-scaled questions (1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, 6 = Strongly Agree) focused on perceptions of the smartphone-based clicker use and distraction (i.e., Using TopHat™ distracted me from class; Using TopHat™ decreased my focus on class; Using TopHat™ diverted my attention from class). Student demographics (i.e., age, gender identification, ethnicity, and major) were also collected. A reliability analysis within the current study yielded a Cronbach's alpha of .88.

Results

Pertaining to RQ1, "Do students who use smartphone-based clickers for instructional purposes in class continue to use their smartphones for non-instructional purposes after the instructional episode ends, resulting in multitasking distraction?," we assessed the proportion of students using smartphones beyond the instructional episode. The student baseline of non-instructional use of smartphones was 1.8%; that is, students were observed engaging with their smartphones for non-instructional purposes 1.8% of the time during baseline conditions. A series of five binomial tests indicated that the proportion of students using their smartphones 1, 2, 3, 4, and 5 minutes beyond the conclusion of the instructional episode was higher than the baseline criterion ($p < .001$ for all five tests; see Table 1). These results indicate that a statistically significant proportion of students continued use of their smartphones for non-instructional purposes beyond the instructional episode, thus putting them into a multitasking distraction situation.

To address RQ2, "To what extent, if any, did this non-instructional use of smartphones persist?," a Cochran's Q test was calculated in order to determine if there were any differences between means across time. There was a statistically significant difference in the proportion of students using their smartphones across minutes 1, 2, 3, 4, and 5, $X^2(4) = 28.408$, Cohen's $w = 0.64$, $p < .01$. Following this significant result, a series of McNemar tests, with a Bonferroni correction for four comparisons, were used post hoc to locate the significant differences between pairwise means. Only four comparisons were made in order to determine if there was a general decline in the proportion of students using their smartphone from minute 1 through minute 5 (i.e., comparisons between minutes 1 and 2, minutes 2 and 3, minutes 3 and 4, and minutes 4 and 5). The results of these comparisons indicated that smartphone use at minutes 1 and 2 were statistically similar, that smartphone use declined statistically significantly between minutes 2 and 3, and that smartphone use remained statistically unchanged from minutes 3 through 5 (see Table 2). In addition, using Cohen's w as a measure of effect size indicates that even the significant decrease (effect) in the proportion of students using their smartphones between minutes 2 and 3 was small. These results indicate that students' use of smartphones for non-instructional purposes persisted throughout the first five minutes following the conclusion of the instructional use of the smartphones.

Table 1
Comparison of Proportion of Students Engaging in Smartphone use Beyond the Instructional Episode to Baseline

Minute	N	Smartphone Use No	Smartphone Use Yes	'Yes' Proportion[1]	Baseline Proportion[1]	*p*
1	154	89	65	.42	.018	< .001
2	154	95	59	.38	.018	< .001
3	154	110	44	.29	.018	< .001
4	154	118	36	.23	.018	< .001
5	154	111	43	.28	.018	< .001

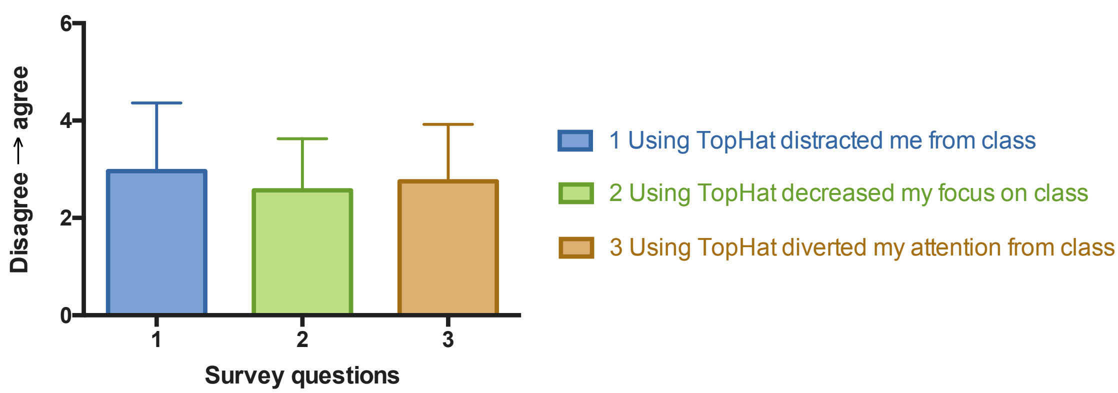
[1] The number of observations was $n = 20$ for baseline group, and $n = 154$ for the group who used TopHat

Table 2
McNemar Pairwise Comparison Tests of Proportions in Smartphone use Beyond the Instructional Episode (w/Bonferroni correction)

Minutes	Proportions[a]	Comparisons	Chi Square	Cohen's w[b]	*p*
1	.42[b]				
2	.38[b]	Minutes 1 and 2	.781	.10	.377
3	.29[c]	Minutes 2 and 3	6.754	.30	.009*
4	.23[c]	Minutes 3 and 4	1.225	.13	.268
5	.28[c]	Minutes 4 and 5	1.161	.12	.281

* = statistically signification at $\alpha \leq .0125$
[a] Means with similar superscripts are statistically similar, means with dissimilar superscripts are statistically different ($p < .0125$)
[b] Cohen's w effect size is defined as small = 0.2, medium = 0.5, and large = 0.8.

Figure 1
Survey of students' perceptions of distraction due to the use of smartphone-based clickers in class for instructional purposes.



The survey consisted of three 6-point Likert-scaled questions (1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, 6 = Strongly Agree).

Overall, these results indicate that when students use smartphone-based clickers in class, the rate of smartphone use for non-instructional purposes (multitasking distraction) increases and persists beyond the instructional use for at least 5 minutes.

Finally, for RQ3, "Do students perceive the use of smartphone-based clickers in class for instructional purposes as a distraction?," a survey was conducted. Students disagreed (2) to somewhat disagreed (3) that the use of the smartphone-based clicker was distracting, decreased their focus, or divided their attention (Figure 1). As a check, the three questions were assessed to make sure they constituted a single "multitasking distraction" factor. All criteria validating the use of exploratory factor analysis were satisfied: adequate sample size for a one-variable test (N = 28; see MacCallum, Widaman, Zhang, & Hong; 1999; Preacher & MacCallum, 2002), Kaiser-Meyer-Olkin (KMO) sampling adequacy of .71, and Bartlett's test of sphericity was significant, χ^2 (3) = 47.43, p < .01; thus, an exploratory factor analysis was conducted using the Maximum Likelihood extraction method with the Promax with Kaiser Normalization rotation method (κ = 4). The number of factors was determined through a screen test, resulting in one factor explaining 82.5% of the variance. The standardized factor loadings for the three items were .884, .900, and .940, respectively.

As a single factor, the three questions were combined into a 6-point Likert-scaled composite score. The composite "multitasking distraction" score, as a mean across all three questions and 28 participants, was 2.76 (SD = 1.10), indicating that students disagree to somewhat disagree that engagement in the smartphone-based clicker was a distraction.

Discussion

Clickers have been used extensively in classrooms to foster student attendance, engagement, interaction, and learning. Recently, however, the use of handheld clickers has been joined by the use of smartphone-based clickers. This use of smartphones in the classroom raises issues regarding the potential for smartphones to foster multitasking distraction, which has been demonstrated to have a potentially negative impact on students' learning (see Sana et al., 2013) .The current research examined students' use of smartphones for non-instructional purposes following their use for instructional purposes and demonstrated that 42% of students begin to use their smartphones for non-instructional purposes immediately following the instructional episode and that 28% of students persisted in using their smartphones for non-instructional purposes five minutes after the instructional episode ended. This continued use of the smartphones for non-instructional purposes created a multitasking distraction situation as regular class instruction recommenced immediately following the smartphone-based clicker activity.

This persistence of smartphone usage may be partially the result of students not perceiving the use of their smartphones as problematic. When surveyed as part of this research, students *disagreed* to *somewhat disagreed* that the use of the smartphone-based clickers was distracting, decreased their focus, or divided their attention. This perception aligns with findings from Sanbonmatsu, Strayer, Medeiros-Ward, and Watson (2013), who determined that within a sample of 277 undergraduate students, 70% of the students overestimated their ability to multitask. Similarly, Stowell (2015) found that in a sample of 141 undergraduate students, 58.2% of students who used a smartphone-based clicker in class indicated that they "never" or "rarely" were "distracted by other things on the device" (p. 332). These findings address students' multitasking self-efficacy: their belief in their ability to successfully multitask, in this case, during the use of technology. Of importance is the finding that when students believe they can accomplish a specific task (e.g., technology-based multitasking), they are more likely to engage in that task (Bandura, 1997; Schunk, 1989). Thus, it is likely that students who believe they can successfully multitask with their smartphones during a lecture are going to engage in using their smartphones more often in class than students who do not. That said, Brooks (2015) and Wu (2017) found that while students may have high beliefs in their abilities to engage in technology-focused multitasking, the level of their beliefs does not positively impact their ability to actually multitask. Thus, there is evidence of a discord between students' perceptions of their abilities to multitask (self-efficacy) and their actual abilities to multitask (performance), which may lead students to engage in multitasking, even when inappropriate or detrimental.

Students' perceptions that smartphone use in class is not distracting may be impacted by their smartphone "checking habits" (Oulasvirta, Rattenbury, Ma, & Raita, 2012), the propensity to quickly scan the smartphone's home screen or a single application (e.g., texts, Facebook, email) for new dynamic content. This checking typically only lasts for a few seconds, although it may lead to engaging more fully in an application. While the persistent use of smartphones following their instructional use as clickers may be the result of checking habits, it may also be indicative of media multitasking, the simultaneous use of multiple forms of media (e.g., cell phone applications, PowerPoint slides, laptop applications). Continual use of multiple forms of media, or heavy media multitasking (HMM), as opposed to light media multitasking (LMM), is related to higher levels of distractibility, lower levels of attentional control, and lower levels of executive control (Loh, Tan, & Lim, 2016; Ophir, Nass, & Wagner, 2009). In addition, these findings have led to the conclusion that HMMs employ breadth-biased attentional control, where HMMs spread their attention across a series of information sources (e.g., laptop Facebook, cell phone Twitter, laptop of student in front row, teacher's PowerPoint slide), attending to each information source in only a shallow or superficial manner (Lin, 2009; Loh et al., 2016). It may be that HMM students continue to use their smartphones following their instructional use due to their attentional breadth bias and that they persist in using their smartphones due to an inability to block out the dynamic distractions from the smartphone (Loh et al., 2016; Ophir et al., 2009; Sanbonmatsu et al., 2013). The end result of this media multitasking is poorer classroom learning (Jacobsen & Forste, 2011; Loh et al., 2016; Wood et al., 2012; Wu, 2017).

Taken together, these results indicate that there is potential for multi-tasking distraction following the instructional use of smartphone-based clickers.

Although smartphone-based clickers can facilitate engaged and student-centered learning in lectures (Ma, Steger, Doolittle, & Stewart, 2018), instructors making use of this technology should be aware of the potential for multitasking distraction and take measures to limit this distraction, even if students self-report that the instructional use of smartphones is not distracting. These suggestions, however, should be balanced against the study's limitations, mainly the use of a single context – class, instructor, institution type, instructional approach – resulting in a small observation sample and relatively small sample sizes. In addition, while students' persistence in using their smartphones was observed, the negative impact of such multitasking on their learning is currently theoretical. Follow-up studies of smartphone use persistence are necessary to examine the direct impact of such multitasking on learning.

The ease of use and positive effect of smartphones as clickers is worthy, but it is in-class smartphone use, in general, which is negatively correlated with academic performance. However, the research on the positive impact of smartphones as clickers for learning is currently underdeveloped. The current research provides a first glimpse at students' use of smartphone-based clickers after their use for instructional purposes ends. The observations indicated that students engage in, and persist in, their use of the smartphones for non-instructional purposes, leading to the creation of multitasking distraction situations. These types of multitasking distractions have been demonstrated to reduce learning, a finding that will need to be confirmed in future research. These results indicate that it may be beneficial for instructors choosing to use smartphone-based clickers to design and implement instruction with the foreknowledge that use of the smartphones requires direct attention to avoid or reduce the likelihood of creating multitasking environments.

References

Anderson, L. S., Healy, A. F., Kole, J. A., & Bourne, L. E. (2013). The clicker technique: Cultivating efficient teaching and successful learning. *Applied Cognitive Psychology, 27*(2), 222-234. doi:doi:10.1002/acp.2899

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Macmillan.

Banks, D. A. (2006). *Audience response systems in higher education: Applications and cases*. Hershey, PA: IGI Global.

Beatty, I. D., Gerace, W. J., Leonard, W. J., & Dufresne, R. J. (2006). Designing effective questions for classroom response system teaching. *American Journal of Physics, 74*(1), 31-39. doi:10.1119/1.2121753

Bjornsen, C. A., & Archer, K. J. (2015). Relations between college students' cell phone use during class and grades. *Scholarship of Teaching and Learning in Psychology, 1*(4), 326.

Brooks, S. (2015). Does personal social media usage affect efficiency and well-being? *Computers in Human Behavior, 46*, 26-37.

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips. *CBE—Life Sciences Education, 6*(1), 9-20.

Castillo-Manzano, J. I., Castro-Nuño, M., López-Valpuesta, L., Sanz-Díaz, M. T., & Yñiguez, R. (2016). Measuring the effect of ARS on academic performance: A global meta-analysis. *Computers & Education, 96*, 109-121. doi:10.1016/j.compedu.2016.02.007

Chen, Q., & Yan, Z. (2016). Does multitasking with mobile phones affect learning? A review. *Computers in Human Behavior, 54*, 34-42.

Chien, Y. T., Chang, Y. H., & Chang, C. Y. (2016). Do we click in the right way? A meta-analytic review of clicker-integrated instruction. *Educational Research Review, 17*, 1-18. doi:10.1016/j.edurev.2015.10.003

Duncan, D. K., Hoekstra, A. R., & Wilcox, B. R. (2012). Digital devices, distraction, and student performance: Does in-class cell phone use reduce learning? *Astronomy Education Review, 11*(1).

Felisoni, D. D., & Godoi, A. S. (2018). Cell phone usage and academic performance: An experiment. *Computers & Education, 117*, 175-187.

Filer, D. (2010). Everyone's answering: Using technology to increase classroom participation. *Nursing education perspectives, 31*(4), 247-250.

Froese, A. D., Carpenter, C. N., Inman, D. A., Schooley, J. R., Barnes, R. B., Brecht, P. W., & Chacon, J. D. (2012). Effects of classroom cell phone use on expected and actual learning. *College Student Journal, 46*(2), 323-332.

Gingerich, A. C., & Lineweaver, T. T. (2014). OMG! Texting in class = U Fail :(Empirical evidence that text messaging during class disrupts comprehension. *Teaching of Psychology, 41*(1), 44-51. doi:10.1177/0098628313514177

Harman, B. A., & Sato, T. (2011). Cell phone use and gradepoint average amoung undergraduate university students. *College Student Journal, 45*(3), 544-549.

Hunsu, N. J., Adesope, O., & Bayly, D. J. (2016). A meta-analysis of the effects of audience response systems (clicker-based technologies) on cognition and affect. *Computers & Education, 94*, 102-119.

Jacobsen, W. C., & Forste, R. (2011). The wired generation: Academic and social outcomes of electronic media use among university students.

Cyberpsychology, Behavior, and Social Networking, 14(5), 275-280.

Judd, T. (2014). Making sense of multitasking: The role of Facebook. *Computers & Education, 70*, 194-202.

Junco, R. (2012a). In-class multitasking and academic performance. *Computers in Human Behavior, 28*(6), 2236-2243. doi:10.1016/j.chb.2012.06.031

Junco, R. (2012b). The relationship between frequency of Facebook use, participation in Facebook activities, and student engagement. *Computers & Education, 58*(1), 162-171.

Junco, R., & Cotten, S. R. (2011). Perceived academic effects of instant messaging use. *Computers & Education, 56*(2), 370-378.

Lepp, A., Barkley, J. E., & Karpinski, A. C. (2015). The relationship between cell phone use and academic performance in a sample of U.S. college students. *SAGE Open, 5*(1). doi:10.1177/2158244015573169

Lin, L. (2009). Breadth-biased versus focused cognitive control in media multitasking behaviors. *Proceedings of the National Academy of Sciences, 106*(37), 15521-15522.

Loh, K. K., Tan, B. Z. H., & Lim, S. W. H. (2016). Media multitasking predicts video-recorded lecture learning performance through mind wandering tendencies. *Computers in Human Behavior, 63*, 943-947.

Ma, S., Steger, D. G., Doolittle P. E., & Stewart, A. C. (2018) Improved academic performance and student perceptions of learning through use of a cell phone-based personal response system. *Journal of Food Science Education, 17*(1), 27-32.

MacCallum, R. C., Widaman, K. F., Zhang, S., & Hong, S. (1999). Sample size in factor analysis. *Psychological Methods, 4*(1), 84-99.

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93*(2), 390.

Mostyn, A., Meade, O., & Lymn, J. S. (2012). Using Audience Response Technology to provide formative feedback on pharmacology performance for non-medical prescribing students-a preliminary evaluation. *BMC Medical Education, 12*(1), 113.

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences, 106*(37), 15583-15587.

Oulasvirta, A., Rattenbury, T., Ma, L., & Raita, E. (2012). Habits make smartphone use more pervasive. *Personal and Ubiquitous Computing, 16*(1), 105-114. doi:10.1007/s00779-011-0412-2

Preacher, K. J., & MacCallum, R. C. (2002). Exploratory factor analysis in behavior genetics research: Factor recovery with small sample sizes. *Behavior Genetics*,*32*(2):153-61.

Sana, F., Weston, T., & Cepeda, N. J. (2013). Laptop multitasking hinders classroom learning for both users and nearby peers. *Computers & Education, 62*, 24-31.

Sanbonmatsu, D. M., Strayer, D. L., Medeiros-Ward, N., & Watson, J. M. (2013). Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PLoS One, 8*(1), 1-8. doi:10.1371/journal.pone.0054402

Schunk, D. H. (1989). Self-efficacy and achievement behaviors. *Educational Psychology Review, 1*(3), 173-208.

Shapiro, A. M., & Gordon, L. T. (2012). A controlled study of clicker-assisted memory enhancement in college classrooms. *Applied Cognitive Psychology, 26*(4), 635-643.

Stowell, J. R. (2015). Use of clickers vs. mobile devices for classroom polling. *Computers & Education, 82*, 329-334.

Sun, J. C. Y. (2014). Influence of polling technologies on student engagement: An analysis of student motivation, academic performance, and brainwave data. *Computers & Education, 72*, 80-89. doi:10.1016/j.compedu.2013.10.010

Tindell, D. R., & Bohlander, R. W. (2012). The use and abuse of cell phones and text messaging in the classroom: A survey of college students. *College Teaching, 60*(1), 1-9. doi:10.1080/87567555.2011.604802

Voelkel, S., & Bennett, D. (2014). New uses for a familiar technology: introducing mobile phone polling in large classes. *Innovations in Education & Teaching International, 51*(1), 46-58. doi:10.1080/14703297.2013.770267

Watson, C. E., Terry, K. P., & Doolittle, P. E. (2012). Please read while texting and driving. In J. E. Groccia & L. Cruz (Eds.), *To improve the academy, volume 31* (pp. 295-309). New York: John Wiley and Sons.

Wong, A. (2016). Student perception on a student response system formed by combining mobile phone and a polling website. *International Journal of Education & Development using Information & Communication Technology, 12*(1), 144-153.

Wood, E., Zivcakova, L., Gentile, P., Archer, K., De Pasquale, D., & Nosko, A. (2012). Examining the impact of off-task multi-tasking with technology on real-time classroom learning. *Computers & Education, 58*(1), 365-374.

Wu, J. Y. (2017). The indirect relationship of media multitasking self-efficacy on learning performance within the personal learning environment: Implications from the mechanism of perceived attention problems and self-regulation strategies. *Computers & Education, 106*, 56-72.

Ellis, Y., Daniels, B. W., & Jauregui, A. (2010). The effect of multitasking on the grade performance of business students. *Research in Higher Education Journal, 8*.

SIHUI MA is a Ph.D. student in the Department of Food Science and Technology and Graduate Teaching Scholar in the College of Agriculture and Life Sciences at Virginia Tech. Her research interests include cider production strategies, analytical method development for bioactive compounds, and food science education.

DANIEL G. STEGER is a graduate student in the Department of Agriculture, Leadership, and Community Education at Virginia Tech, Blacksburg, Virginia, United States. His interests include Science, Technology Engineering and Mathematics (STEM) education methodologies, inclusive teaching practices, and the practical application of lecture technologies.

DR. PETER E. DOOLITTLE is the Director of the School of Education at Virginia Tech and conducts research on the role of working memory in multimedia learning environments.

DR. ANDREW H. LEE is a recent Ph.D. graduate from the Virginia Tech Department of Food Science & Technology.

DR. LAURA E. GRIFFIN is a recent Ph.D. graduates also from the Virginia Tech Department of Food Science & Technology.

DR. AMANDA STEWART is an Assistant Professor in the Department of Food Science & Technology at Virginia Tech. Her interests focus on higher education in agriculture and the science of wine and cider production.

Acknowledgements

The authors would like to thank Dr. Melissa Chase, Virginia Tech Department of Food Science & Technology, for her guidance on building effective research teams