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RESEARCH ARTICLE

Anonymous versus public student feedback systems: metacognition and achievement with graduate learners

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Abstract
The aim of this repeated measures study was to examine an anonymous student feedback system (delivered using clickers) versus a public student feedback system (delivered using flashcards) on 52 graduate learners' metacognition and academic achievement scores. Three dimensions of metacognition were examined in a large lecture setting, including Metacognitive Learning Device Attribution, Metacognitive Knowledge in Lectures, and Metacognitive Self-Regulation. Results indicated that Metacognitive Learning Device Attribution and Metacognitive Knowledge in Lectures were significantly higher in the anonymous feedback condition as hypothesized while, contrary to our hypothesis, difference in Metacognitive Self-Regulation was not significant. Also, academic achievement differences were highly significant in favor of the anonymous feedback condition. Effect sizes for the three significant dependent variables ranged from moderate to very large with the largest effect size found for academic achievement. Findings are discussed in terms of the existing literature and the study's internal and external validity. Recommendations for future research are made.

Keywords Anonymous versus public feedback · Clickers · Metacognitive learning device attribution · Metacognitive knowledge in lectures · Metacognitive self-regulation

Academic institutions are developing programs that integrate technology use to a greater extent. Emerging technologies are being utilized in educational institutions, yet how these influence education, what problems need to be addressed, and how to employ technology strategically are questions that persist (Becker et al. 2016). Emerging trends indicate that educational institutions are not effectively implementing or using technology for research, learning or teaching (Becker et al. 2016; Johnson et al. 2016). Moreover, measuring learning as a result of technology has come into the forefront of higher education and is viewed as a solvable challenges (Becker et al. 2018). Often the need for technology is the unfortunate by-product of selection of technology to meet budget and other time-sensitive deadlines without enough data-driven research demonstrating effectiveness.

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Feedback systems are often used in both K-12 and college settings in conjunction with learning management systems and technology platforms. For this study, real-time student feedback is garnered by using multiple choice test questions to gauge learner preparedness and understanding. Questions are delivered using "clickers". The use clickers to provide real-time student feedback in lecture settings is a relatively new phenomenon beginning with Mazur's (1991) analysis of clickers and peer instruction in higher education. In this study, we examine the use of anonymous student feedback (delivered using clickers) in a large lecture setting. Clickers are a type of anonymous feedback because the responses provided to a question are not revealed to classroom peers, rather they are revealed in the form of a histogram showing the distribution of responses to the students.

This article presents findings from a comparative examination between clickers (an anonymous feedback system) and a flashcard-like system (a public feedback system). In this repeated-measures study, the dependent variables are learner metacognition and academic performance. Three types of metacognition were measured as dependent variables: Metacognitive Learning Device Attribution, Monitoring Knowledge in Lectures, and Metacognitive Self-Regulation.

Introduction

Real-time student feedback has been used for more than 100 years (e.g., Thorndike 1913–1914). Devices like flash cards also were used to provide feedback in the previous century as discussed by Mazur (1991). Research on using clickers to provide feedback has been published since Mazur's (1991) (Beatty et al. 2006; Caldwell 2007; Duncan 2006; Mayer et al. 2009; Meltzer and Manivannan 2002; Van Diik et al. 2001). Aspects of their efficacy, particularly on metacognition, still warrant research (Mayer et al. 2009). The main contribution of this study is to provide insight into the process whereby feedback shapes three dimensions of learner metacognition.

In this study, we suggest, but do not measure whether the use of anonymous feedback systems discourages conformity, better engages learners and provides a greater level of control over learning. Rather, we test whether an anonymous feedback system is related to metacognition and achievement compared to public feedback. A model of this process is shown in Fig. 1. The relationship between metacognition and achievement was not measured in this study, but a recent meta-analysis of 50 studies examining metacognition and achievement found that there are long term positive effects of metacognition on learning outcomes (*de Boer et al. 2018).

The main goal of this study is to look at whether public (delivered using flashcards) versus anonymous feedback (delivered using clickers) systems are related to three measures of metacognition, and the secondary goal is to look at how the two feedback systems relate to achievement. Though flashcards are not widely used, in the present study it was assumed that flashcards are analogous to the real world when instructors ask a class a question. The flashcard methodology in this study parallels the methodology used in Mayer et al. (2009). The three instruments that measure metacognition have been piloted and utilized in a previous study (Brady et al. 2013a) and are the focal outcomes of the current article.

Of the three metacognition components, two new components of metacognition related to feedback devices are introduced in this study. The name of the first construct is Metacognitive Learning Device Attribution. The learner device attributions in a lecture context occur in real-time and are dynamic as the instructional strategy is used.

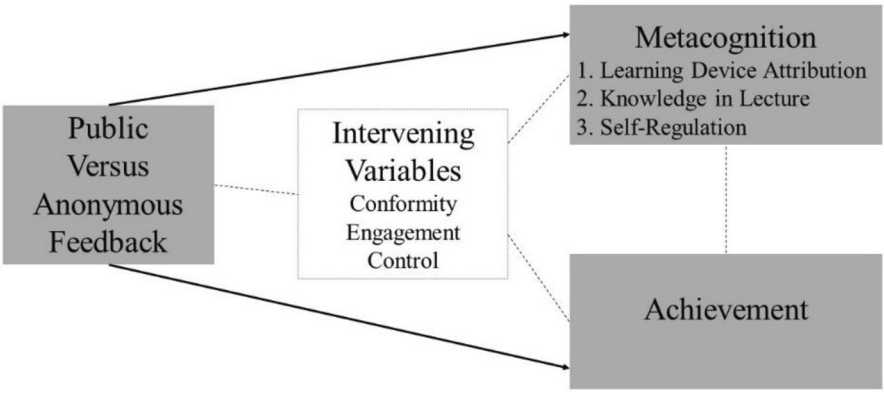

Fig. 1 Metacognition and public versus anonymous feedback. *Note* in figure, solid lines were empirically tested in this study and dotted lines were not empirically tested

These attributions are the learner connections made through use of the learner device (clickers, flash cards) and the questions asked. This dimension of metacognition is defined as a learner's ability to gauge correctness of response, improve judgments about knowledge, and increase ability to self-monitor learning *as being attributed to a learning device in the lectures*.

Metacognitive Knowledge in Lectures is another new dimension of metacognition that is measured in this study. Metacognition Knowledge in Lectures is based on the work of Mokhtari and Reichard (2002) on metacognition in reading. This dimension of metacognition is defined as learner metacognition experienced in lectures by tapping into cognitive actions the learner takes *in lectures* in response to the learning experience.

The third dimension of metacognition, metacognitive self-regulation is defined by Pintrich et al. (1993) as being comprised of three general processes: planning, monitoring and regulation. It is important to distinguish metacognitive self-regulation from self-regulated learning or self-regulation because metacognitive self-regulation only includes a cognitive dimension. Metacognitive self-regulation has been widely researched.

The complexity of the metacognitive thought process in the learning environment is likely mediated by intervening variables. Conformity, engagement, and control are possible variables that mediate the effect of public versus anonymous feedback (see Fig. 1). These mediating variables are not measured in this study but are an explanation for the study's hypotheses. Conformity is a phenomenon that occurs in group contexts, influences perceptions of credibility and information processing, and, hence decision making (Aronson 2008). Engagement of learners is an experience known to enhance learning and a widely agreed upon factor that helps students learn (Schell et al. 2013). Learner control improves the learning process and promotes metacognitive awareness (Mayer 2011; Schraw and Gutierrez 2015), a process that may be enhanced through prompting and activating learner knowledge.

Conformity, engagement, and control are factors that contribute to the different experiences had by learners. The effects of the three mediating variables are depicted using dotted lines in Fig. 1. Research is reviewed in the literature section that suggests these are key factors that distinguish public versus anonymous feedback.

Research hypotheses

Four hypotheses were proposed. The first three hypotheses are in regard to metacognition. The first three hypotheses were that an anonymous feedback system (delivered using clickers) will be positively related to the three dimensions of metacognition compared to a public feedback system (delivered using flashcards). We also sought to determine whether an anonymous student feedback system and a public student feedback system would be related to differences in academic performance. Therefore, our fourth hypothesis was that an anonymous feedback system will be related to better academic performance in comparison to a public feedback system. The primary rationale for the hypotheses is discussed in "Public versus anonymous feedback" section below. Tentative explanations as to the "why" behind the hypotheses (i.e., unmeasured intervening variables) are discussed in the "Conformity and feedback" to "Learner control and feedback" sections below.

Literature review

To illuminate the need for this investigation, literature that attempts to ferret out the differences in use of public versus anonymous feedback and learning conditions is emphasized. First, research on public versus anonymous feedback is discussed. Next, the dimensions of metacognition are explained. The final three sections cover tentative explanations as to why anonymous feedback might positively influence metacognition and achievement. Collectively, the following five subsections are structured to explain how anonymous and public feedback might differentially provide for differences in metacognition and achievement.

Public versus anonymous feedback

Anonymous student feedback is a process by which feedback may be garnered in real-time during instruction without peer awareness (Heritage 2010; Mazur 1991). Opportunities to provide feedback anonymously in real-time lecture settings have been recently suggested as strategies that can shape in-depth learning and metacognition (Brady et al. 2013a; Mayer et al. 2009). The anonymity afforded by anonymous feedback systems (e.g., clickers) is important to learners (Heaslip et al. 2014), to their willingness to participate (Heaslip et al. 2014), and to provide opportunities for shyer learners to participate (Stowell and Nelson 2007; Stowell et al. 2010).

Metacognition is a recent idea in research on response systems, but it is not well understood. Recent research suggests that the individual nature of anonymous student feedback system may provide the closest in-class, real-time strategy to target individual learning other than tutoring (Brady et al. 2013a); thus, supporting the metacognitive knowledge needed to control learning and thinking (Mayer 2011).

Conversely, public feedback systems have a less anonymous aspect. Answers are in some fashion displayed for each individual and there is some ability of the group members to see responses of peers. Public feedback can be raising hands, use of flashcards, or hand signals. Our flashcard system is based on the work of Mayer et al. (2009). The handheld response system in the case of this study most resembles flashcards and was developed to

Fig. 2 Public and anonymous feedback systems. *Note* Photo presented in a lecture presentation for innovations in medical education presentation (Brady et al. 2015)

mimic clickers to as closely as possible. Figure 2 shows the flashcard system and clickers used in the current study.

Mayer et al. (2009) suggested future researchers should study metacognition and clicker use. Other research that has involved the measure of metacognition and clicker use prior to Brady et al. (2013a, b) has not been found. These two studies were apparently the first attempt to examine whether and how anonymous feedback systems influence metacognition with undergraduate educational psychology students. The current study replicates Brady et al. (2013a) but with graduate level learners in a different field of study. The first author developed instrumentation to measure three dimensions of metacognition in the original studies. The results of these prior studies of undergraduate education psychology students provided support for the hypothesis that higher metacognition and achievement are associated with clicker use in comparison to a public feedback system.

Metacognition: a multidimensional construct

Metacognition is a multidimensional construct (Pintrich et al. 2000). Metacognition is highly influenced by individual variability and the interacting elements unique to learning environments (Brady and Forest 2018; Pintrich et al. 2000). Metacognition has been suggested as an important aspect to investigate with the use of anonymous student feedback systems (Mayer et al. 2009), and research since indicates metacognition is involved with use of these anonymous systems (Brady et al. 2013a, b). Metacognition has a central role the individual's interpretation of the learning experience and in how a learner proceeds with future learning efforts.

Pintrich et al. (2000) presented metacognition as having three components: (a) metacognitive knowledge, (b) metacognitive judgments/monitoring, and (c) self- regulation/cognition. Along the same lines, in his tribute to the career of Paul R. Pintrich, Shunk (2005, p. 91) states, "Metacognitive activities [assessment includes] planning, monitoring, and self-regulation." The third construct, self-regulation/cognition, is more general in focus and includes aspects of metacognition we believed to be more distinct from our first two dimensions. Subsequently, in the Bloom's Taxonomy revision, self-regulation and cognition are separate factors that are at

work within each aspect of metacognitive knowledge (Anderson et al. 2001; Krathwohl 2002). Krathwohl (2002) lists metacognitive knowledge, a general self-awareness *as pertaining to academic cognitive needs,* as (a) strategic knowledge, (b) knowledge about cognitive tasks which is knowledge that is both contextual and conditional, and (c) self-knowledge.

In this study, a new component of metacognition is further analyzed by the authors (Brady et al. 2013a, b). The name of this construct is "Metacognitive Learning Device Attribution", and this dimension is defined as a learner's ability to gauge correctness of response, improve judgments about knowledge, and increase one's ability to self-monitor learning in lectures *as being attributed to a learning device*. The learner device attributions in a lecture context occur in real-time and are dynamic.

A second and lesser known metacognition construct also is further analyzed, Metacognitive Knowledge in Lectures (Brady et al. 2013a, b). This dimension measures the degree of metacognition in lectures as experienced by the learner. The measure is based on a measure of metacognition in reading that has demonstrated reliability and validity (Mokhtari and Reichard 2002). Mayer (2008) also discusses the metacognition in reading construct and its relationship to other metacognition constructs.

Monitoring Knowledge in Lectures is similar in nature to metacognitive device attribution in that both are viewed in terms of the lecture process. However, Monitoring Knowledge in Lectures taps into actions the learner takes in lectures in response to the learning experience. Monitoring Knowledge in Lectures is a real-time process assessing learner ability to gauge the level of metacognitive thinking about one's own current degree of knowledge of test items in lectures contexts. For items pertaining to monitoring knowledge, participants were requested to think in general about their own metacognitive thoughts during the lectures. In contrast, Metacognitive Learning Device Attribution probes the degree to which learner metacognitive knowledge is attributed to a learning device, either public or anonymous feedback in the case.

Our third component, Metacognitive Self-Regulation is defined as monitoring one's cognition in planning activities, self-reflection, strategy choice, and regulation of one's own self-monitoring and knowledge. The evidence of metacognitive self-regulation can be seen in learning that reflects changes in one's cognition. Items were selected from the self-regulation and critical thinking subscales of the *Motivated Strategies for Learning Questionnaire* (MSLQ; Pintrich et al. 1993). The MSLQ instructs learners to consider the experience *in a course* and their own responses to engage with the learning process. During engagement with learning tasks, self-regulation occurs to ascertain the level of self-knowledge and degree of accuracy of task completion. Based on this improved understanding of the learning self (the active metacognitive participant) makes choices about how to proceed during learning activities. For questionnaire items pertaining to metacognitive self-regulation, participants were requested to consider note-taking and questioning strategies.

Does public and anonymous feedback differ in ways that might influence the metacognitive dimensions and achievement? Three possible intervening variables are posited and discussed in the following sections: conformity, engagement, and control (Fig. 1). It is important to emphasize that these sections are speculative and designed to provide a rationale for the hypotheses and to suggest further research.

Conformity and feedback

Asch's (1956) landmark study revealed the power of peer influence to the degree that a conscious decision by learners to conform with the group occurs when they knowingly provide the wrong answer to simple questions. As shown in Fig. 1, conformity is the first

proposed intervening variable effect. Asch's research has held up over time and in more modern renditions of his research using technology (Berns et al. 2005). Berns and colleagues added a neuroeducation feature to replicating Asch's procedures by using *f*MRI technology (images produced from *f*MRIs represent increased blood flow to activated areas of the brain). A significant difference was found when comparing the *f*MRI images between the participants who changed answers in response to social pressure and those who resisted conformity. This study replicated Asch's procedures and found a significant difference in the areas of the brain associated with discomfort, which in educational psychology may be more appropriately deemed dissonance. The participants that elected to change answers in response to social pressure experienced less discomfort than those that resisted the social pressure to change or conform. Further, subjects who resisted conformity showed lots of activity in the area of the brain associated with pain and emotional discomfort, the amygdala. This increased activity is relevant to the present study, because it shows a physical manifestation of the tension that individuals encounter when faced with the pressures of group conformity.

According to Aronson (2008), conformity is reduced if the individual has a strong commitment to the initial judgment/answer choice. The public display of student responses may be a distraction to learners that inhibits focus on one's own thoughts and understanding and instead, is shaped by the external social context. A tension problem exists in the learner's conflict between values related to conformity and to the individual. This tension theme was found through a qualitative analysis comparing public feedback and anonymous feedback systems (Brady et al. 2013b). Respondents indicated feeling conflicted between the pressure to stay with their initial response or to change answers to match peer responses when using the public feedback systems. Furthermore, this was expressed in terms of deciding between being correct or conforming to the group (Brady et al. 2013b). This perspective of participants aligns with Aronson's (2008) determination of the reasons for the variation in response; Aronson states this is linked to two goals—being right and staying in the good graces of the group.

In an anonymous feedback system, conformity is greatly reduced or possibly eliminated. This is because anonymous feedback systems provide a safe space to reflect on one's individual level of preparation, knowledge, and understanding in real-time without the interfering worries of peer perception or evaluation. Less conformity is one reason we hypothesize that metacognition will be higher in the anonymous condition.

Learner engagement and feedback

The premise of using feedback systems is that questions will be asked. It is important to note that questions better engage learners (Mayer et al. 2009). In a quasi-experimental study examining questioning (multiple choice questions used in lectures) with comparison (flashcards), treatment (clickers), and control groups (no questions), Mayer and colleagues found significant improvements in performance outcomes for the group using the anonymous feedback system. They attributed the higher performance to questioning and better learner engagement. This finding aligns with current understanding that questions are indeed important in learning.

Watkins and Mazur (2013) used a strategy to gauge conceptual understanding that involved peer instruction combined with clickers, flashcards, raising hands, or writing the answer on paper so that the learner commits to an answer. If too many students answered incorrectly, the students were directed to discuss their responses in small groups while staff

went from group to group to monitor and guide the discussions. The systems for garnering student feedback were not evaluated in Mazur and Watkins, however, the authors suggest promoting understanding by having learners commit to answers using various student feedback systems to increase engagement.

Several reasons have been suggested about why learners are reluctant to answer questions in lectures by raising hands; and thus, are less likely to be engaged. Resisting hand raising has been related to shyness (Stowell and Nelson 2007), and an inability or unwillingness to respond (Hooker et al. 2016). In a review of research literature about participation and engagement, Rocca (2010) found apprehension and feelings of inadequacy in front of the instructor and peers are related to participation, in particular, with large class sizes (Rocca 2010). Stowell and Nelson (2007) found anonymous feedback systems provide safety for the shyer and less social students. Hooker et al. (2016) suggest that except for a few learners, most are unable or unwilling to respond to public questions asked during lectures. Anonymous questions, on the other hand, provide a safe place to reflect, reducing the feelings of vulnerability, and thereby increasing engagement of all students.

Engagement is the second possible intervening variable effect that could play a role in the present study (Fig. 1). Research suggests that learner engagement is enhanced through use of the anonymous feedback systems because they ameliorate the passive participation tendency of learners in large lecture settings (Heaslip et al. 2014). The public display of response with public feedback systems may be a distraction to learners that inhibits learner engagement. In contrast, the anonymous feedback system is not fraught with such distractions; instead, the timely feedback provided by the anonymous feedback system is a noted benefit and should increase engagement (Chen et al. 2010). Furthermore, the vail of anonymity removes the perceived threat to feedback that is public in nature, and thus, further engages the learner in their own learning (Brady et al. 2013b; Heaslip et al. 2014).

Learner control and feedback

Learner control is the third possible intervening effect that explains the basis for the hypothesis that anonymous feedback systems positively affect metacognition (Fig. 1). The anonymity afforded by the anonymous feedback system may, in effect, provide learners with a measure of control over the learning context. Specifically, it becomes the individual learner's choice to think about the question and reveal the response selected. Such is not the case with public feedback systems. Answers are revealed publicly before the correct answers are known. Thus, the only choice left for students is that of choosing the answer perceived as most correct or conforming to fellow students' responses.

In considering pedagogy and learning, research indicates there is an inverse relationship between dependency on external agencies and control of learning (De Corte et al. 2004). When learners increase their ability to control learning, dependency upon external agencies for support decreases, allowing learners to engage in more productive metacognitive learning and to acquire skills that improve the learning process (Brady et al. 2013a; Mayer 2011).

In terms of anonymous student feedback system use, there are indications in recent research that clickers provide a sense of control over the learning process through the increased interaction between instructor, instructional content, and learners (Blasco-Arcas et al. 2013; Mollborn and Hoekstra 2010).

In summary, as shown in Fig. 1, we hypothesize that the effects of anonymous or public feedback on three dimensions of metacognition and achievement are mediated by three

constructs—learner engagement, conformity and control. Our hypotheses stem from the existing literature as reviewed above in "Conformity and feedback" to "Learner control and feedback" sections. These mediating variables are not measured in the present study, so we recognize that further research is needed to test whether our hypotheses are valid.

Method

Research design

For this study, a repeated measures design was used. The independent variable was the feedback method (i.e., anonymous student feedback versus public student feedback); the dependent variables examined were three dimensions of metacognition (Metacognitive Learning Device Attribution, Monitoring Knowledge in Lectures, and Metacognitive Self-Regulation), and a fourth dependent variable, academic performance.

Participants

Participants included graduate health science students (n = 52); 96% elected to participate. The study was undertaken in a semester-long class at a major research institution in the southwestern United States. The mean age of participants was 26.3 (age range = 22–41 years) with 29 or 53.7% females. Latino/Hispanic represented 17% of participants, 9.4% African American, 18.9% Asian, 47.2% White, and 7.5% were not identified.

Data-gathering instruments

The metacognition outcomes pertaining to this study are: (a) Metacognitive Learning Device attribution, (b) Metacognitive Knowledge in Lectures, and (c) and Metacognitive Self-Regulation. The first of three self-report surveys measuring the three metacognition dependent variables is the first author's *Metacognitive Learning Device Attribution Scale* (Brady et al. 2013a). This metacognitive scale gauges the degree to which learners feel that metacognition is directly attributed to the instructional device, either clickers or flashcards. The second scale, *Metacognition in Lectures* was based on a subset of items from Mokhtari and Reichard (2002); the revised scale was designed to gauge metacognition in lectures settings as experienced by the learner. The third scale is a subset of 15 items from the *Motivated Strategies for Learning Questionnaire* (MSLQ) (Pintrich et al. 1993; Brady et al. 2013a). This scale was a subset of items that Pintrich et al. (1993) identified as metacognitive self-regulation/critical thinking. The MSLQ is a widely utilized, public domain survey and is well-validated (Artino 2005; Pintrich et al. 1993). The actual scales for each of the metacognition dimensions that were used in the present study are found in Brady et al. (2013a, b).

An example from the *Metacognitive Attribution to Device Scale* is, "When I responded to a clicker/flashcards question and then the answers were displayed indicated I was wrong, I gained understanding". An example of the *Metacognition in Lectures Scale* is, "Clickers/flashcards help me to know what questions to ask when the topic is difficult." An example from the *Metacognitive Self-Regulation Scale* is, "I ask myself questions to make sure I understand the material I have been studying in this class." Each of the three instruments

included a 7-point Likert scale. Cronbach alphas are reported in Table 1. The reliabilities were judged to be high enough for research purposes.

Participants completed the three metacognitive surveys online at two key points in the study. Qualtrics© links to the surveys were delivered to students via an email after the 5th and 12th weeks of the semester. The surveys took approximately 10 minutes. The first administration took place following the use of clickers and the second administration occurred at the end of the course following public feedback use. The two administrations included the same three metacognitive scales.

Procedure

Upon matriculation to the first year of the graduate health science program participants purchased clickers. Clickers send radio-frequency signals to record student responses to multiple choice questions; the software utilized was TurningPoint 2013 with Turning Technologies ResponseCard IR. A public student feedback system (flashcards) was employed as the comparison method because it was close in nature to the clickers (Mayer et al. 2009). When asked a question, learners indicated response choice by raising signs with the corresponding answer choice. As with the anonymous feedback system (delivered using clickers), a public feedback system (delivered using flashcards) allows for questions to be asked of the participants during lectures, and the participants then select their desired answer. For the public feedback system to be comparable to an anonymous feedback system, the system needed to be visible enough for the instructor to ascertain the answers quickly, reducing the delay of tallying the answers. For the public feedback system, colored paper with printed, large bold letters (e.g., 'A', 'B', 'C', or 'D') glued to handles that resembled tongue depressors were used. This methodology was drawn from the work of Mayer et al. (2009).

Short quizzes consisting of 12 multiple choice questions were administered at the start of each lecture. Lectures were three hours in length. These assessments indicated level of preparation for lectures, and level of understanding of the reading materials and lectures at the point of the assessment. The questions were used as a starting point for the lecture to engage learner cognition. To illustrate the type of questions, one multiple choice question used was, "The way we express our feelings of loss for the death of a loved one is defined as…" The response selections were "A Bereavement;" "B Grief;" "C Mourning;" and "D Release." The point of the questions was to gauge learning understanding before lecture to guide the learning experience. These introductory questions were *not* used to measure achievement in this study.

With the anonymous feedback system, learners "clicked" the response choice, and with the public student feedback system learners raised their selected answer choice using flashcards. Participants could see the general response of peers with the public

Table 1 Cronbach's alphas for metacognition scales

Instruments	Post-test (anonymous feedback system)	Post-test (public feedback system)
Metacognitive learning device attribution	.723	.704
Metacognitive knowledge in lectures	.910	.935
Metacognitive self-regulation	.729	.859

feedback system before the correct answers were revealed. Afterward, the correct slide answer was displayed in the same PowerPoint format for the anonymous student feedback system and the public student feedback system. Results with the anonymous feedback system included a histogram with the response distribution.

Photos were used to record the public feedback student system responses. This provided easy access to comparative data. Photos took approximate five seconds to take and interrupted learning less than pausing class to tally answers. Taking the photo may have caused minimal discomfort, however, photos did not seem to interfere with the learning process. As was the case with anonymous feedback, the student response distribution from the photos was then conveyed to the class as a form of feedback.

To measure student achievement, in-class periodic assessments were used as part of the instruction strategy for this course, and as such were a normal part of the course activities students would experience regardless of the study. For the anonymous student feedback system, the sum of the first five periodic assessments and the midterm constituted the achievement outcome measure. Similarly, for the public student feedback system, the first five periodic assessments and the final were added to obtain the achievement score. The midterm covered material from the start of the course to the point of the midterm administration; during this half of the course, the anonymous student feedback system was used. The final exam covered material following the midterm and through to the end of the course; during this period the public student feedback system was used. Both the first half of the semester half and the second half of the semester data were converted to "percentage correct" for comparison purposes.

Results

To analyze the differences between anonymous and public student feedback on the three metacognition dimensions and a single academic performance outcome, four dependent *t*-tests were conducted (see Table 2). To assess practical significance, effect size (ES) indices were used and calculated using the ratio of the difference between treatment to the standard deviation of the anonymous feedback group (see Table 3).

Table 2 Metacognition and achievement means

Means					
Scales	N	Anonymous Feedback	Public Feedback	*t*-value	*P*
Metacognitive learning device attribution	52	4.96	4.31	5.29	.001
Metacognitive knowledge in lectures	48	3.97	3.23	2.88	.01
Metacognitive self-regulation	48	4.51	4.33	1.15	.118
Achievement	48	87.38	74.88	5.70	.001

In the cases of N = 48, four surveys were discarded due to missing responses

Table 3 Effect sizes

Measures	Difference scores anonymous-public	*SD*	*Effect size*
Metacognitive learning device attribution	.65	.89	.73
Metacognitive knowledge in lectures	.74	1.16	.64
Metacognitive self-regulation	.21	.67	.31
Achievement	12.50	5.86	2.13

Metacognitive learning device attribution

Metacognition Learning Device Attribution is a learner's ability to gauge correctness of response, improve judgments about knowledge, and increase ability to self-monitor learning in lectures *as being attributed to a learning device*. The measure of metacognitive learning device attribution assessed the degree to which participants thought the feedback method was responsible for eliciting metacognitive knowledge. As shown in Table 2, and as hypothesized, differences in metacognitive learning device attribution were highly significant ($p = .001$) in favor of the anonymous student feedback system. As shown in Table 3 the effect size between anonymous and public feedback is .73 for this dimension, meaning that compared to other interventions in the behavioral sciences, the difference between clicker and flashcard use was near large using Cohen's (1988) criteria (small = .20, medium = .50, and large = .80).

Metacognitive knowledge in lectures

Metacognitive Knowledge in Lectures measures learner experience in lectures by tapping into actions the learner takes in the lectures in response to the learning experience. The measure of metacognitive knowledge in lectures assessed the degree to which students were able to gauge knowledge, self-monitor, understand what questions to ask, regulate note-taking, and form study plans due to the lecture experience. As hypothesized, differences in metacognitive knowledge in lectures were statistically significant ($p = .01$) in favor of the anonymous student response system (Table 2). As shown in Table 3, a moderate to large effect size was found (ES = .64).

Metacognitive self-regulation

Metacognitive Self-Regulation is defined by Pintrich et al. (1993) as awareness of learning, knowledge and cognitive control. Later Pintrich expounds on metacognitive knowledge by describing this dimension as knowledge of strategies that may be related to the transfer of learning, thus, connecting transfer to self-regulation (Pintrich 2002). Metacognitive self-regulation provides a picture of the motivation for metacognitive strategies by learners. It was hypothesized that metacognitive self-regulation results would be higher in the anonymous condition, but this was not the case. The difference between anonymous and public feedback was not significant ($p > .05$) and the effect size (ES = .30) was small.

Achievement

Significance was found between the two groups on the record of assessment performances, in favor of anonymous student feedback system use ($p = .001$) with a very large effect size (ES = 2.13). This finding was in line with hypothesis #4 and a large body of prior research that was reviewed in our literature review.

Discussion

The first question we asked was whether learner metacognition differed between an anonymous student feedback system (delivered using clickers) and a public student feedback system (delivered using flashcards). We hypothesized that the anonymous student feedback system would positively impact three dimensions of metacognition compared to the public student feedback system. The second question we asked was whether an anonymous student feedback system and a public student feedback system would result in differences in academic performance. We hypothesized that the anonymous student feedback system would relate to better academic performance.

Student feedback systems and metacognition

Results from the comparison of means suggest that two dimensions of metacognition were significantly and positively associated with the anonymous student feedback system. Higher scores were found for metacognitive device attribution (ES = .73) and metacognitive knowledge in lectures (ES = .64). The results for metacognitive self-regulation was in the predicted direction but not statistically significant. The results for self-regulation were not significant, however, a potential explanation is that the index of metacognitive self-regulation had as its reference "the course" rather than a specific mention of "lectures" or the study intervention (clickers vs. flashcards).

The fact that the anonymous feedback was positively associated with *metacognitive device attribution and metacognitive knowledge in lectures* supports Mayer et al. (2009) who predicted that clicker use would impact metacognition. This finding also closely parallels a segment of Brady et al. (2013a). A portion of the 2013a study involved a repeated measures design in a sample of 33 undergraduate educational psychology students in the summer session of an undergraduate educational psychology course. Higher scores were found for both *metacognitive device attribution and metacognitive knowledge in lectures* using measures that were identical to this study (see Table 2 in Brady et al. 2013b, p. 60). Brady et al. (2013b) also included a quasi-experimental independent group study using fall and spring sections of the same course. Both a quantitative analysis and a qualitive analysis (Brady et al. 2013b) provided only mixed support for the hypothesized relationship between clickers and metacognition, suggesting a repeated measures design that allows the same student to experience and compare an anonymous and public feedback system is a more powerful way to test the hypothesized effect of feedback on metacognition.

Student feedback system, formative assessment and academic performance

Beginning with Edward Thorndike's early work on feedback and target practice in World War I over 100 years ago, the necessity of student feedback to enhance learning has been

widely recognized in the field of educational psychology. In his landmark synthesis of over 50,000 studies and over 500 meta-analyses, *Hattie (2009) ranks feedback as the 9th most important of 138 achievement influencing factors that he considered. The effect size for 23 meta-analyses of feedback was .73.

Clickers and flashcards are also ways to provide formative assessment (Brady and Forest 2018). "Formative assessment is a process used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes" (Formative Assessment for Students and Teachers 2008, as cited by Heritage 2010, p. 9). In terms of effect size, formative assessment ranks 3rd among the 138 factors that *Hattie (2009) considered (ES = .90).

Because clicker and flashcard use both involve feedback and formative assessment, it is not surprising that the literature on clickers largely supports the use of clickers to improve student achievement (Castillo-Manzano et al. 2016; Chien et al. 2016; Han 2014; Hunsu et al. 2016; Kay and LeSage 2009). Nevertheless, there is still a need for a better understanding of how and when clicker use works best, and what is it about clickers that make them work.

In this study, we examined anonymous versus public student feedback systems. As predicted, anonymous student feedback had a greater effect on academic performance than public feedback (ES = 2.13). The degree to which differences occurred suggested that there was a difference in student ability to gauge their own learning and self-monitor their thought with the anonymous student feedback system, and to reflect on their individual level of preparation. The public feedback system resulted in overall poorer metacognition and achievement that is presumably due to the ability of learners to see peer answers and experience the conformity effect (Brady et al. 2013b). This finding supports research indicating that the public student feedback systems are less effective than anonymous student feedback systems when achievement is the outcome studied (Brady et al. 2013a, b, Brady and Forest 2018). Furthermore, given the previously described effects of clickers on metacognition, the achievement results may indicate that the enhancement of learner metacognition in lectures is related to the difference in achievement between the anonymous and public feedback groups.

During the public student feedback system use achievement results were lower which could be due to less authentic representation of level of understanding, decreased ability to gauge the correctness of answers, and distracting peer influence. Moreover, the results with the public student feedback system may have been distorted due to apparent answer changes by learners. At the very least the results present a strong argument for use of anonymous feedback systems in lectures or other assessment situations that require individual knowledge construction. Results oppose the notion that hand-raising, hand-signals, or other visible means of garnering feedback are better alternatives.

Instructional method and contextual characteristics

What is it about anonymous feedback that makes the method effective? As shown in Fig. 1, we hypothesize that compared to public feedback, anonymous feedback is associated with less conformity, greater student engagement, and more student control. These three factors in turn lead to higher metacognition. A shortcoming of this study is that conformity, engagement and control were not experimentally manipulated nor measured. Further research on these factors is needed in the context of both feedback and other interventions that have been proposed as affecting metacognition and achievement.

This article adds to the large body of research that indicates the choice of student feedback strategy influences the learning context (Anthis 2011; Castillo-Manzano et al. 2016; Chien et al. 2016; Han 2014; Hoekstra 2008; Hunsu et al. 2016; Kay and LeSage 2009; Lantz 2010; Mayer et al. 2009; Stowell 2015; Stowell and Nelson 2007; Stowell et al. 2010). The learning context refers to an academic setting in which knowledge is impacted, constructed, or otherwise transmitted using pedagogical practices to create long term change in behavior (Mayer 2008). Furthermore, this article supports the conclusion that public feedback systems (e.g., hand-raising, hand-signals, flashcards, and other public feedback systems) are more clearly discernable to learners before the correct results are recorded and thus can contribute to a false memory effect (Cleary 2008). The false memory effect is a phenomenon where the learner recalls information accurately yet believes contrary information to be accurate when peers come to a consensus.

In addition, we speculate that students in the public feedback condition in our study did not get the benefit of learning from their mistakes. We did not measure "learning from mistakes" so only further research will confirm our speculation. Not learning from mistakes is a barrier to engaging learner metacognition. This is consistent with body of literature that demonstrates increased knowledge accuracy and increased ability to process knowledge resulted from clicker use (see meta-analyses by *de Boer et al. (2018) and Hunsu et al. (2016)).

Internal and external validity

The design for this study is a repeated measures design with the first set of measures administered after the implementation of the anonymous student feedback system (deliver using clickers) and the second set administered after the public feedback system (delivered using flashcards). Internal validity refers to the strength of a causal inference in a study and external validity refers to the generalizability of a causal inference. The internal/external validity distinction was introduced by Campbell (1957) and has been continually revised by multiple scholars over the last 60 years (Shadish et al. 2002). The publication of *Experimental and Quasi-Experimental Design for Causal Inferences by* Shadish et al. (2002) is generally considered the authoritative source for judging the quality of a quasi-experimental design. We used a repeated measures design rather than a nonequivalent control group design because pre-testing on 2 of 3 metacognitive measures was impossible and repeated measures establishes a frame of reference for comparing clickers to flashcards. Furthermore, because randomization was impossible, a control group study would have included a selection bias that makes causal inferences untenable (Shadish et al. 2002). In contrast, in a repeated measures design, each student serves as their own control. This facet of the design eliminates any selection bias and is more powerful statistically (Shadish et al. 2002).

The primary threat to internal validity in the present study is the order effect. A different set of results might have been obtained if the order of the interventions had been reversed. Our study was conducted in a single classroom context over a whole semester and thus, a true experiment was impossible. Differences in instructor approach, course content, quiz difficulty etc. between the first and second half of the course could explain the results reported. For example, the instructor may have changed his expectations when changing from an anonymous to public feedback system. Another example is that the content from the first half to the second may have been more challenging. Neither of the preceding examples are thought to have occurred and numerous possibilities explaining the difference between the first and second halves of the semester are possible.

External validity pertains to the generalizability of the results to other students and settings, implementations of the intervention, and to other measurements. Threats to generalizability are common to all educational research studies and evidence that furthers generalizability of a study's conclusions can best be accomplished by further research using different students, settings, interventions and measurements. On a positive note, the fact that the semester long study was conducted in a real-world setting does enhance the overall generalizability of the results. The present study is a replication of a previous study on college undergraduates (Brady et al. 2013a) that further attests to the external validity of our findings.

Future research

One concept that is less discussed in the research literature is teacher anonymity. Often clickers are used to track student responses for grading purposes. In order for this to occur, each personal student feedback system needs to be registered to the student, and the instructor imports the information to the feedback system software. Students essentially lose the anonymity aspect as far as the instructor is concerned. Anonymity provides learners with a safe space to learn, free of performance issues, but at the same time, there are situations where teacher anonymity is not warranted. Much further research is needed on the topic of teacher anonymity.

Because of the repeated measures research design in this study, there is a high probability other influences on metacognition and achievement were not controlled. To address this problem more fully, a first recommendation is that large-scale (N = 200 schools) randomized experiments be used to provide stronger causal inferences about the independent and dependent variables. The indications in the present study are strong enough to suggest that anonymous feedback could be beneficial in other settings but only a true experiment can prove causality (Shadish et al. 2002).

We used a unique sample, medical students, in this study. Given that our results are only the second to relate clicker use to metacognitive outcomes, the study needs to be replicated in other groups and settings (e.g., a more diverse sample of primary, secondary or college students) to ascertain whether our results are generalizable to other populations. To make matters even more complex, it is possible that the positive effect of clickers on metacognition is moderated by learner characteristics. Regarding metacognition, *de Boer and colleagues (2018) meta-analysis support this idea in finding that interventions designed to foster better metacognition had more positive outcomes on students who were from a lower SES background.

Metacognition components are difficult to examine in terms of identifying the relevant dimensions of metacognition to measure. One recommendation is to examine constructs from the vantage point of more than one discipline (e.g., Berns et al. 2005), in order to incorporate understanding of constructs used in education. This additional vantage point may provide insights that void or validate aspects of traditionally accepted theories of educational psychology, guiding and increasing the accuracy of measurements (Immordino-Yang and Christodoulou 2014).

There is support in this study for further research on the dimensions of metacognition. Two new aspects of metacognition were introduced in the study: Metacognitive Learning Device Attribution, and Monitoring Knowledge in Lectures. There is a high probability other relevant dimensions of metacognition were not measured. Another recommendation is for further development of scales that can better identify these components. Pintrich

et al. (2000) recommend taking measures of metacognition to the next step and conducting large scale factor analytic studies. Both large sample (N > 200) exploratory factor analysis and confirmatory factor analysis are necessary to determine the validity of this study's instrumentation as well as other components of metacognition. Moreover, factor analytic studies would increase the ability to accurately measure this complex construct reliability and validity that has found its way into a notable level of importance in twenty-first century research on student learning.

With additional instructional strategy use, anonymous feedback systems engage learners in deeper cognition. Deeper cognition influences the learner to focus on strategies utilized in preparation for lecture and on the instructional goals of the class in real-time. The literature review suggests that these new interventions should decrease learner conformity and increase learner control and engagement. The present study did not include measures of these three constructs, thus further research is warranted.

Anonymous feedback systems increase individual learner accuracy in gauging self-knowledge level in lectures and are more likely to foster positive attributions about the feedback, while the public student feedback system results in a distraction that hinders the learning process (Brady et al. 2013a). However, public feedback may play an important role in other contexts such as discussion, peer instruction or group projects. Public feedback may provide opportunities for discussion that address conformity and bias. This may provide for vigorous discussion under guidance and is arguably a need for twenty-first century learners. The ability to engage in rigorous academic debate, however, might combat student shyness and concern about correctness or peer opinion that inhibits the learning process. The instructional tool selected by the instructor should support the learning activity and goals of the lesson and the desired learning outcome.

Beside feedback, formative assessment is another commonly cited benefit of anonymous clicker use (see Kay and LeSage (2009) for review). This is ironic because the main source of information of formative assessment is typically thought to be interviews and observations, rather than multiple choice questions. Further, under formative assessment, outcomes are measures using open-ended rather than closed-ended questions. Nearly 10 years ago in an article on next generation formative assessment, Heritage (2010) wonders if we are losing an opportunity because of the use of multiple-choice tests. Heritage states "the core problem lies in the false, but nonetheless widespread, assumption that formative is a particular kind of measurement instrument, rather than a *process* that is fundamental and indigenous to the practice of teaching and learning (p. 1)". With the advent of increased reliance of clickers, Heritage's concerns are even more relevant a decade later. It is difficult to imagine that a teacher-student process can be accomplished solely only with multiple choice questions. Moreover, clickers are not the only way to accomplish anonymous feedback. Anonymous response systems are a step in the right direction, but continual teacher-student conversation and observation are going to be needed to accomplish effective formative evaluation.

Conclusion

We found highly significant results for two of three dimensions of metacognition. As hypothesized, private verses public feedback differences on metacognitive device attribution (p = .001) and metacognitive knowledge in lectures (p = .01) were significantly different with near large (ES = .73) and moderate (ES = .64) effect sizes respectively. More

specifically, students had higher scores after the anonymous student feedback intervention. In contrast, metacognitive self-regulation was not influenced significantly ($p > .05$), indicating that the choice of feedback system may not impact metacognitive self-regulation in terms of individuals navigating the course. Finally, the achievement outcome was highly statistically significant ($p = .001$) with a very large effect size (ES = 2.13) in favor of the anonymous feedback system. This finding replicates many prior studies showing increased achievement when peer influences are reduced or eliminated.

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*Meta-analysis

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