Blending Active Student Responding with Online Instruction to Evaluate Response Accuracy and Student Engagement

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Abstract
High rates of active student responding and opportunities to respond are considered best-practice instructional strategies for learning. Many educators in higher education have shifted from teaching primarily in-person to either a hybrid or an online format over the past decade. The global pandemic hastened further shifts from in-person to online learning for many institutions of higher education. Given this rapid shift to online instruction, it is critical to evaluate evidence-based teaching practices in online formats. Although there is a robust body of literature that supports the effectiveness of embedding opportunities to respond and active student responding during in-person instruction, to date, there is limited research that evaluates the effects of increased opportunities to respond during synchronous online courses in post-secondary settings. Using an alternating treatments design, this study evaluated the effects of two active student response modalities on response accuracy for seventeen students enrolled in a synchronous online graduate course. The results suggest that students performed more accurately on post-lecture queries following conditions that required written active student responses compared to responds cards. Moreover, the accuracy of correct responding maintained across the exams and the cumulative final exam. Limitations and future implications are discussed.

Keywords Online teaching · Active student responding · Opportunities to respond · Post-secondary · College teaching

Enrollment rates for online education have recently exceeded campus-based enrollment in the United States (Rieken et al., 2018). As of 2016, approximately 28% of college students were taking at least one online course (U.S. Department of Education).
Education, 2016), and it was projected that the percentage of students enrolled in online courses will continue to increase 33% each year (Pethokoukis, 2002). In the last two years, the coronavirus global pandemic forced the rapid closure of in-person learning for many school districts and universities across the world, which shifted even more institutions to online instructional modalities. It is critical to identify and remove barriers within online learning in higher education to improve the student experience (Dumford & Miller, 2018). As stakeholders in higher education continue to demand greater accountability and evidence of teaching effectiveness, the quality of teaching in online formats is important to evaluate (Wilbur, 1998).

Many higher education institutions offer online education in some combination of three formats: blended or hybrid instruction, asynchronous instruction, or synchronous instruction. Blended learning is instruction that combines face-to-face with online elements (Dumford & Miller, 2018; Tallent-Runnels et al., 2006). Instructors may select the online elements to occur in either an asynchronous or a synchronous format. Asynchronous instruction does not require students to be online simultaneously at an appointed time. Instead, students complete online work on their own time, at any point, before a deadline (Gayman et al., 2018; Tallent-Runnels et al., 2006). Synchronous instruction requires students to be online at an appointed time to complete activities, work on assignments, or participate in didactic instruction (Gayman et al., 2018; Tallent-Runnels et al., 2006). As undergraduate and graduate students are increasingly taking a mixture of hybrid, asynchronous, or synchronous online and traditional courses (Moore & Kearsley, 2011), many instructors are moving their courses to online formats without much training in effective online teaching practices. Furthermore, there is limited research to guide effective online instructional practices (Sun & Chen, 2016).

Behavioral researchers have evaluated numerous ways to improve student engagement during in-person instruction. For example, there is robust empirical support for the effectiveness of providing students with frequent and varied opportunities to respond as well as providing students with effective feedback (Archer & Hughes, 2011; Haydon et al., 2013; Kestner et al., 2018; Lewis, 2008; MacSuga-Gage & Simonsen, 2015; Sutherland & Wehby, 2001). To provide students with effective feedback, students must make active and observable responses to instruction. These observable responses to instruction are often referred to as active student responding (ASRs; Barbetta et al., 1993; Heward, 1994; Vargas, 2009). To make an active and observable response to instruction, the instructor must provide multiple response opportunities during a specified period of time, referred to as opportunities to respond (OTRs). Incorporating ASRs and OTRs within instruction reliably has positive effects on student performance (Munro & Stephenson, 2009; White, 1998), promotes fluency and automaticity in basic skills of any content (Common et al., 2020), and increases the probability of higher academic student achievements (Clement, 2009; Monem et al., 2018; Schumacher et al., 2015).

There are more than two decades of research supporting and validating the effectiveness of ASR modalities across elementary settings (Berrong et al., 2007; Christine & Schuster, 2003; Lambert, 2001; Munro & Stephenson, 2009; Wood et al., 2009) and secondary settings (Cavanaugh et al., 1996; Common et al., 2020; MacSuga-Gage & Simonson, 2015; Monem et al., 2018). Very little research on the
utility of OTRs or ASRs can be found for post-secondary settings, where lectures are still the predominant method of instructional delivery (Dowling & Alemayehu, 2004; Lewis, 2008). However, there are a few exceptions (see Kay & LeSage, 2009 for review of clickers; Kreiner, 1997; Kellum et al., 2001; Malanga & Sweeney, 2008; Marmolejo et al., 2004; Zayac et al., 2015).

Most recently, Zayac et al. (2015) directly compared three different ASR modalities (i.e., response cards, clickers, and hand-raising) in an alternating treatment design with 132 undergraduate psychology students. Students were divided into four different groups while the response modalities rotated in a blocked fashion every 4 weeks, corresponding with course exams. A fixed number of OTRs were provided across each modality. To evaluate the effects of the ASR modalities on mean quiz scores, data were analyzed using a one-way repeated measure of variance (ANOVA). While the mean exam score was higher in all ASR conditions when compared to the control group (no ASRs), there was no significant difference between either the response cards, clickers, or hand-raising. However, 78% of students indicated they believed their grades benefited from having response cards and clicker ASR modalities incorporated into the lecture. Furthermore, the students indicated they would like to see ASR integrated into their other courses. The results of Zayac et al. (2015) are consistent with other research (Anthis, 2011; Elicker & McConnell, 2011; Fallon & Forrest, 2011; Kellum et al., 2001; Stowell & Nelson, 2007) suggesting that the inclusion of ASR in post-secondary settings may impact academic performance.

Maintaining high levels of active student engagement in the online environment is likely one variable closely related to student success. The relations between student engagement and academic achievement “has the same scientific status as reinforcement in psychology and gravity in physics” (Berliner, 1990, p. 3). That is, it is a generally accepted rule that increased student engagement leads to improved academic performance (MacSuga-Gage & Simonsen, 2015; Zayac et al., 2015). Student engagement is a critical component to effective classroom practices (Hu & McCormick, 2012). It can be difficult to maintain student engagement during in-person learning, and it may be even more difficult to do so in online environments due to competing contingencies and lack of stimulus control outside of the traditional educational setting (Meyer, 2014). For example, in online learning environments, students have competing contingencies for engaging in texting, social media, e-mail, etc., which are all available on the screen simultaneously with their learning management system. During in-person learning, teachers can use proximity control (Weaver et al., 2020) to control off-task behavior, even when students are using their computers in class, to somewhat control off-task behavior. They can walk around the classroom as they teach, which can influence student behavior. This is impossible in online learning environments. Therefore, it is important to evaluate teaching strategies that can be used in online environments to effectively maintain student engagement during instruction.

The literature on online teaching practices at the post-secondary level is limited in at least two ways: (1) there is a lack of clear, concrete strategies for increasing student engagement in online education at the post-secondary level, and (2) there are limited empirical data on the effects of such strategies for student engagement and learning. Despite the increased use of online teaching practices, there appears to be a dearth of
empirical studies focused on specific strategies for maintaining student engagement and high levels of performance within the field of behavior analysis (Malkin et al., 2018). While there is robust evidence for the effectiveness of increasing OTRs and ASRs during in-person instruction, most of this research has been in elementary settings. Much less research utilizing OTRs and ASRs in the post-secondary settings has been conducted, and even fewer have been conducted during asynchronous or synchronous online formats. As such, research is needed on how similar methods of instruction may be used in post-secondary online settings. Thus, the purpose of this study was to evaluate the effects of two different ASR modalities during synchronous online instruction provided at the graduate level to determine their effects on accurate responding on knowledge assessments and engagement.

Method

Participants

Participants were graduate students at a midwestern university, with a verified course sequence, enrolled in an interdisciplinary program designed to train special education teachers and behavior analysts to sit for the Board Certified Behavior Analyst (BCBA) Exam. The course was co-taught by a tenured professor of behavior analysis who was a BCBA-D with over 20 years of experience teaching graduate students and a BCBA doctoral candidate in behavior analysis.

This study was approved by the university’s Human Subjects Institutional Review Board. All students in the course were required to participate in the class activities and provided informed consent for their data to be used in the current study. Consent was obtained following the first synchronous online session. During the first session, the consent form was displayed on the students’ computer screen using the share screen option on a videoconferencing platform while the instructor and co-instructor read through the form aloud. Students were informed that they were required to participate in all class activities regardless of whether they chose to participate in the study and there was no penalty for opting out of the study. After the first session, students were provided with an electronic copy of the consent form, asked to provide or deny consent for participation in the study, and upload a signed copy of the consent form to the online learning management system used by the university (Desire To Learn; D2L).

A total of 17 students (16 females and 1 male) enrolled in the behavioral assessment course and all students provided consent to participant in the current study. Many students (15 out of 17) identified as Caucasian and the two students identified as Asian American or Bi-Racial. Students ranged in age (20 to 50 years), teaching experience (0 to 18 years), clinical experience (0 to 17 hrs per week), and total accumulated supervised experience hours for the BACB exam (0 to 600 hrs).
Setting and Materials

All students and instructors were required to have an active university e-mail address to participate. The materials used in this study included a variety of hardware (e.g., computer or laptops), software (e.g., Microsoft PowerPoint, Microsoft Excel, Microsoft Word, D2L, Cisco Webex, Qualtrics, and LockDown Browser), and 3 × 5 colored index cards. Cisco Webex (or Webex) is a streaming online format that allows students from geographically diverse locations to virtually attend meetings. Webex software was used to stream all class sessions. Webex allowed participants to turn on their camera and microphone as well as respond in a chat room. At the time of the current study, Webex software did not allow for polling and other interactive features. LockDown Browser secures the online testing environment to prevent cheating. LockDown Browser was used during all unit exams and queries to prevent students from accessing online materials or other browsers while completing course unit exams and queries.

Pre-and Post-Lecture Queries

Each week, students were asked to complete a pre- and post-lecture query, which was very similar to a quiz except that no points were contingent upon accuracy of responding. The label “query” was used rather than “quiz” to denote that points were awarded only for relevant response and were not contingent on accuracy. Pre- and post-lecture queries were uploaded to D2L with LockDown Browser prior to each session beginning. There were 15 fill-in-the-blank questions per query, and students had a maximum of 15 min to complete the query. All questions were derived from assigned readings (e.g., peer-reviewed research articles and handouts) and lecture content. If students fully completed the query and wrote answers relevant to the content, they were awarded 2 participation points. If students completed the query but wrote answers that were not relevant to the content, no points were awarded. For example, if a question asked “____, ____, play, and alone are the traditional functional analysis conditions” and a student responded with “chocolate, peanut butter”, the student did not receive participation points for the query. The first time a student responded with irrelevant answers, participation points were awarded, but the student was given a warning statement. In the warning statement, the instructor reviewed the syllabus section that outlined participation expectations and reminded the student that if irrelevant answers were received in the future, no points would be awarded for the query. Throughout the study, only one student required a warning statement, and no students lost participation points for incomplete or irrelevant responses on pre- and post-lecture queries.

Unit and Final Exams

There was a total of three unit exams and one final exam throughout the study. All unit exams and the final exam were uploaded to D2L with LockDown Browser. One exam (Exam 1) was proctored in-person, in accordance with the Center for Disease Control Guidelines (CDC, 2021) and university policies (i.e., wearing
face coverings and sitting at least 1.83 m apart). Due to increasing COVID-19 cases in the state over the course of the semester, the remaining exams were made available to students asynchronously online at pre-determined dates and times. Whether proctored or asynchronous, students were instructed not to use books or extraneous materials, exercise academic integrity, and use the LockDown Browser when completing all unit exams.

The unit exams and the cumulative final exam consisted of fill-in-the-blank and short answer questions that were similar to the OTRs presented in the online lecture, but the response requirement was slightly different from the originally presented OTR. Each unit exam consisted of approximately five fill-in-the-blank questions and six or seven short answer questions (totaling to 20 points). Unit exam 1 consisted of content that was taught during baseline Sessions 1 through 3. Unit exam 2 consisted of content that was taught during Sessions 4 through 7 and unit exam 3 consisted of content that was taught during Sessions 8 through 11. All sessions involved the use of ASR strategies. The cumulative final exam consisted of content from all sessions. There were 27 questions on the cumulative final exam (totaling 50 points), and 15 of the 50 questions (30%) were fill-in-the-blank format. The remaining questions were short answer. Unlike for the queries, points were contingent on accuracy of responding for the unit exams and the cumulative final exam.

**Procedural Acceptability**

After all course assignments and exams were graded, a 15-question survey was e-mailed directly to students using the Qualtrics software. There were no points awarded for completing the procedural acceptability survey. Three questions were specific to the ASR conditions (e.g., which modality of ASR was most preferred; which modality helped you better understand the material; which modality kept you most engaged). Students were able to respond by selecting “Respond Cards”, “Chat”, or “Indifferent”. The remaining questions focused on the student experience using ASR technology during the synchronous online course, the likelihood of students recommending or using ASR in their teaching practices, and the methods used to assess for engagement. Using a Likert scale, students were able to respond by selecting “strongly disagree” to “strongly agree”.

**Round Table Discussion**

To evaluate open-ended feedback from students at the end of the study, the co-instructor sent an e-mail to all students enrolled in the class to ask for their participation in a round table discussion. There were no points awarded for attending the round table discussion. Prior to beginning the discussion, the co-instructor stated that the purpose of the discussion was to gather contextual information about their experience using the ASR technology and share the purpose of the research study (Note during the last session many graduate students manded for
information related to the study). A total of 7 questions were asked during the round table discussion. During the discussion, the co-instructor read aloud seven questions from the procedural acceptability survey, allowed the students to freely discuss their answers, and transcribed all student responded on Microsoft Word.

**Dependent Variables and Measurement**

**Dependent Variables**

The primary dependent variable was accuracy of responding on the pre-and post-lecture queries, unit exams, and the cumulative final. *Accurate responses* were defined as any instance where the student’s response had point-to-point correspondence or in the same response class as the responses on the answer key. For example, the answer key may note that the correct answer to a question is “antecedent, behavior, and consequence” and a student would receive participation points for writing “antecedent, behavior, and consequence”, “A-B-C”, or “three-term contingency.” *Incorrect responses* were defined as any instance where a student’s response did not have point-to-point correspondence or was not in the same response class as the response in the answer key. For example, the answer key may note that the correct answer to a question is “establishing operations” and a student would not receive points for writing “Abolishing operations” or “Motivating operations.” The secondary dependent variable was student engagement. Engagement data were recorded from permanent products submitted via e-mail after each condition by the students. *A correct engagement submission* was defined as any instance where a student submitted an e-mail with a complete and an accurate list of words to the instructor within a 1 hr period after the class elapsed.

**Data Collection and Interobserver Agreement**

The first author served as the primary data collector throughout the study. There were three research assistants who also helped collect data for the study. Two research assistants were undergraduate students majoring in psychology and behavioral science. One research assistant was a first-year master’s student enrolled in a behavior analysis training program. The primary data collector trained all research assistants on the data collection procedures. Using pre-recorded 5 to 15-min clips from the synchronous online class sessions, behavioral skills training was employed for data collection procedures (BST; Parsons et al., 2012). Prior to independently coding data, research assistants were required to correctly code the lecture clips with 80% accuracy. After two training sessions, the research assistants recorded data with 92% accuracy and completed their training.

Point-by-point agreement was used to assess the consistency of data collection by dividing the number of query and exam questions with agreements by the total number of query and exam questions and multiplying by 100. Agreements were defined as any instance where an observer recorded a correct response in correspondence
with the answer key. IOA for pre- and post-lecture queries was collected for 100% of all conditions. During baseline, agreement averaged 92% (range 92% to 93%). During Response Card conditions, agreement averaged 89% (range 82% to 93%), and during Chat conditions, agreement averaged 92% (range 88% to 95%). IOA for engagement submissions was 100% in baseline and averaged 95% (range 80% to 100%) during the Response Card and Chat conditions.

**Procedural Fidelity**

Research assistants collected procedural fidelity data by viewing the recordings of each class sessions and completing a checklist of the independent variables. Procedural fidelity was 100% across all baseline and ASR conditions.

**Experimental Design**

The effects of both ASR modalities on the dependent variables were evaluated using an alternating treatments design (Barlow & Hayes, 1979). This design, through rapidly alternating conditions, allows one to demonstrate a functional relation between the independent and dependent variables in a short period of time.

**Procedure**

**General Information and Procedures**

The course was originally designed to be taught in-person, but due to the COVID-19 pandemic, the course was taught in a synchronous online format instead during the fall 2020 semester. The first and second authors co-taught and co-presented each lecture apart from three sessions, during which there were guest speakers. When guest speakers taught class sessions, the instructors worked with them to ensure the independent variables were implemented as necessary for the study.

The course was 15 weeks in duration and the class met synchronously online one evening per week, for a total of 11 sessions. The remaining sessions were used for the unit and final exams. Across all sessions, students were instructed to log into D2L and complete a pre-lecture query between 5:30 and 5:45 pm. They submitted the pre-lecture query on D2L and then logged into Webex at 5:45 pm for the synchronous online lecture and discussion, which lasted until approximately 8:00 pm. Following the lecture and discussions, students logged out of Webex, logged in to D2L, and completed the post-lecture query. They had 15 min to complete the post-lecture query. Students earned 2 participation points for completing each query, regardless of the accuracy of their performance on the query.

During the first class period only, the instructor asked the students to take out their university ID cards, which had a series of numbers on the back referred to as their University Identification Number (UIN). The instructor said “You will have to use the last digit of your UIN at different times during the lectures. Please get out your university ID and share the last digit and your name.” The students typed the
last digit of their UIN into the chat feature in Webex. The purpose of this exercise was to ensure that each student was aware of the last digit in their UIN so they could participate in the engagement prompts (see below). This exercise was never repeated during the study. There were 11 students whose UIN ended with 0 through 5, and there were six students whose UIN ended with 6 through 9.

Engagement prompts were embedded on randomly selected slides during the lectures (see Fig. 1, top panel). An engagement prompt consisted of a single word, along with either UINs 0 through 5 or 6 through 9, at the bottom of randomly selected slides. There were two to three words presented for each UIN set (0–5 and 6–9) throughout the lecture. These prompts were active on the screen for an average duration of 2 min, 13 s across all conditions. The instructor did not orient the students to the engagement prompts when they appeared. The instructor continued discussing relevant lecture content without attending to the engagement prompts. An example of an engagement prompt was, “If your UIN ends with 0–5, write down the word ball” or “If your UIN ends with 6–9, write down the word dog.” At the end of each lecture, the final PowerPoint slide included reminders for the next lecture and an engagement prompt instruction. The instruction stated, “As soon as the lecture ends, send the co-instructor an e-mail with the words you wrote down during lecture” (see Fig. 1, bottom panel). The first author collected all e-mails sent with the engagement prompts after the lecture concluded.

**Baseline**

During the three baseline sessions, the instructor conducted the lecture in a “business-as-usual” format. Prior to beginning the session and while using the screen share function, the instructor presented the classroom expectations slide that included the following expectations: Camera On, Be On Time, Sit at Desk or Table, Microphone Muted, No Eating. The instructor shared PowerPoint slides,

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**Fig. 1** Synchronous Engagement. *Note.* The top panel displays the engagement prompts. The bottom panel displays the engagement prompt instructions.
reviewed information from the readings, added additional content vocal verbally, and asked occasional questions (e.g., “Can anyone give me an example of a norm-referenced test?”). There were no pre-programmed OTRs. If a student asked a question, the instructor answered it. Further, if a student interjected a comment, the instructor responded to the comment and encouraged further discussion.

**Response Card Condition**

The Response Card (RC) condition was conducted the same as baseline, in that students completed the pre-lecture query, logged on to the synchronous online lecture, and the instructor taught on lecture content. The primary difference between the RC conditions and the baseline conditions was the inclusion of programmed OTRs. Prior to beginning each RC session, the instructor presented the classroom expectations slide that was similar to the baseline slide except that it included the expected materials—the blue, pink, and yellow index cards (see Fig. 2, top panel). Each RC condition consisted of eight to 10 planned OTRs that were displayed on a PowerPoint slide (Fig. 2, bottom panel). While the OTR slide was displayed, the instructor read the question aloud, read the response options, and stated the corresponding index card color. The instructor then provided 5 to 10 s of think time and presented a cue for the students to hold up the colored index card corresponding to the selected answer. For example, when an OTR appeared the instructor said, “Okay class, now it is time to check for understanding. ____ ___, play, and alone are traditional functional analysis conditions. Hold up the pink card if you think the answers are attention and sensory; hold up the blue card if you think the answers are demand and attention; or hold up the yellow card if you think the answer is tangible and

![Fig. 2](image)

*Fig. 2 Response Card Conditions. Note. The top panel displays the expectations and materials needed for the Response Card (RC) conditions. The bottom panel displays the format of the opportunities to respond during the RC conditions.*
attention. Think about your response (pause for approximately 5 to 10 s) ...Get ready (pause for approximately 5 s) ...Cards up.” Students then held up the colored card that corresponded to their answer, and they were instructed to keep holding up their cards until the instructor could scroll through all the videos to view their cards. (Note when the screen share option of Webex was implemented, only about four student video screens were visible. The instructor could click an arrow to scroll through all the video screens.)

If all students responded correctly or if only one student made an error, the instructor provided behavior specific praise to the group (e.g., “Yes! Demand, attention, play, and alone are the traditional functional analysis conditions. Well done!). If two or more students responded incorrectly, an error correction procedure was administered. This included the instructor providing a clarifying statement about the correct and incorrect responses, re-presenting the question, and providing feedback on the correctness of responding the second time. For example, the instructor said, “It looks like we need to re-visit this question. Remember that in the Iwata et al. (1982/1994) seminal article, the tangible condition was not included as part of the functional analysis. Let’s try this question again. ___, ___, play, and alone are the traditional functional analysis conditions. Please think about your response...Get ready...Cards up.” Following this second opportunity to respond, behavior specific feedback was again provided (e.g., “Yes! Now you’ve got it. The demand, attention, play, and alone are traditional functional analysis conditions. Great job!”), and the lecture continued until the next programmed OTR appeared. At the end of the lecture, the students were instructed to complete the post-lecture query.

![Fig. 3 Chat Conditions. Note. The top panel displays the expectations and materials needed for the Chat conditions. The bottom panel displays the format of the opportunities to respond during the Chat conditions.](image-url)
Chat Condition

The instant messaging conditions (herein referred to as the Chat conditions) were identical to the RC condition, except that all students made their ASRs in the chat function of Webex rather than using their RCs. After the students completed the pre-lecture query and logged on to Webex, the instructor presented the classroom expectation slide specific to the Chat condition (see Fig. 3, top panel) and stated that students should type out their responses in the public chat forum when responding to the OTRs. Again, eight to 10 programmed opportunities to respond were intermittently presented throughout the lecture. Each slide contained a question and an image displaying the chat icon (Fig. 3, bottom panel).

When the OTR slide was displayed, the instructor read the question aloud, provided 5 to 10 s of think time, and presented a cue for all students to respond publicly in the chat forum. The instructor and co-instructor both monitored the chat as the students’ answers appeared. After all students actively responded, feedback was provided to the group regarding the correctness of their responses. For example, “Okay class, now it is time to check for understanding. ____ , ____ , play, and alone are traditional functional analysis conditions. Please think about your response... Type your answer in the chat (pause for approximately 5 to 10 s) ...Get ready (pause for approximately 5 s) ... Press enter.” The co-instructor scrolled through all chat responses to check for correct or incorrect responses. The instructor provided behavior specific praise if all students or if all but one student responded correctly. If two or more students responded incorrectly, the instructor administered the same error
correction procedure as described in the RC conditions. Concluding the lecture, the students were instructed to complete the post-lecture query.

**Results**

**Pre- and Post-Lecture Queries**

The results for the pre- and post-lecture queries are depicted in Fig. 4. The average percent correct on the pre-lecture queries during the baseline conditions was 45% (range, 40–54%). During the RC condition, pre-lecture query scores averaged to 37% (range, 32–41%). Similarly, students averaged 39% (range, 35–44%) correct on pre-lecture queries during the Chat condition. Thus, across all three conditions, pre-lecture query scores were relatively consistent.

The average percent correct on the post-lecture queries was 64% (range, 53–72%) during baseline. There was an average of 18% improvement between the pre- and post-lecture queries in the baseline conditions. The average percent correct on the post-lecture queries was 62% (range 58–71%) for the RC condition and 74% (range, 69–84%) for the Chat condition, with an average of 25% improvement and 34% improvement in the RC and Chat conditions, respectively. At least initially, there was clear differentiation between the RC and Chat conditions for the post-lecture queries, with the Chat condition producing higher post-lecture query scores. There was slight variability across the RC sessions, but the overall, accuracy on post-lecture queries for the RC condition remained in the same general range as post-lecture query scores during baseline. Even though there was a gradual decrease in the average scores as the study progressed, the percentage of accurate responses on the Chat post-lecture queries remained higher than the scores on the RC post-lecture queries.

**Unit Exams and Final**

The exam results are displayed in Fig. 5. Recall that, Exam 1 consisted of content that was taught in the absence of any pre-programed OTRs, while Exams 2 and 3 contained questions to both RC and Chat conditions. The Cumulative Final Exam contained questions from all three phases of the study. For the baseline exam (i.e., Exam 1), 64% of the class did not receive a passing grade (i.e., above 84%) and the class average was 76% overall. As the semester progressed and as students were exposed to both ASR modalities, there was an 14% average increase on the exam scores from Exam 1 to Exam 2 (92%; see Fig. 5, top panel). For Exams 2 and 3, 97% of the class earned a passing score. For the Cumulative Final Exam, only three students received a grade in the 70% to 84% range and all other students received a score of 88% or above. The class average for the Cumulative Final Exam was 90%.

To provide a measure of content maintenance across the duration of the study, the middle panel of Fig. 5 displays this disaggregated exam questions for the fill-in-the-blank questions only. During Exam 1, the class averaged 62% correct on the
Fig. 5 Exam and Final Scores. *Note.* The top panel displays the class mean exam scores for all questions. The middle panel displays the class mean percentage correct on fill-in-the-blank questions only. The bottom panel displays individual student exam scores throughout the study. Exam 1 occurred in the absence of ASR (active student responding). Exams 2, 3, and the Final were all administered after ASR modalities were introduced.
fill-in-the-blank questions. The class averaged 73% correct on the fill-in-the-blank questions on Exam 2. This exam only contained fill-in-the-blank questions from the Chat condition due to an error on the researchers’ part. Exam 3 consisted of fill-in-the-blank questions from both the Chat and RC conditions. During Exam 3, the class averaged 100% on the questions from the Chat condition and 90% on the questions from the RC condition. Similarly, for the Cumulative Final Exam, students responded more accurately on the fill-in-the-blank questions from the Chat condition (93%) as compared to the baseline (88%) or RC (88%) conditions.

The bottom panel of Fig. 5 displays the individual exam scores across the 17 students who participated in the study. There are notable individual differences across student performance when comparing the scores from Exam 1 to Exams 2, 3, and the Cumulative Final. As students were exposed to both ASR conditions, a scaffolding increasing trend appeared and students progressively performed more accurate across Exams and the Cumulative Final throughout the study. Generally speaking, accuracy on exams improved over the duration of the course. This was true for Students 2, 3, 4, 5, 6, 8, 10, 11, 13, 14, and 16. Students 1, 7, 12, 15, and 17 had very high baselines, leaving little room for improvement. Student 9 performed better on Exams 2 and 3 than on Exam 1. However, this student’s final exam score was similar to baseline.

![Fig. 6 Correct Engagement Prompt Submissions. Note. The square data path denotes correct engagement prompt submissions following the Response Card (RC) conditions. The triangle data denote correct engagement prompt submissions following the Chat conditions. Guest lectures were present on sessions 3, 9, and 10](image-url)
Engagement

Relatively few students (2–3) submitted correct engagement prompts during the baseline conditions (see Fig. 6). When ASR activities were presented, engagement prompt submission increased. However, there was variability across conditions. Initially, a large increase in engagement prompt submissions occurred with the Chat condition. However, this did not maintain over time. As the study progressed engagement prompt submissions increased during the RC condition. Over time, the RC condition produced more engagement prompt submissions than the Chat condition. In general, however, engagement prompt submissions were disappointingly low across all sessions given that 17 students were enrolled in the current study.

Procedural Acceptability

Fifteen of 17 (88%) students in the class completed the procedural acceptability survey. Most students indicated that the RC condition was most preferred (66%) and most engaging (46%; see Table 1). Overall, most students reported that the ASR modalities affected their online class participation, and they wished all their online classes used ASR systems like what was used in the current study (see Table 2). When evaluating student perceptions of the “secret words” (i.e., engagement prompt submissions), students indicated that they did not notice the “secret words” and that the “secret words” did not enhance their online class experience. Most noted that they would have written down the “secret words” if points had been contingent on them. Moreover, students reported they did not think the “secret words” were a good measure of their online engagement. Nonetheless, 93% of students agreed or strongly agreed that the inclusion of the RC and the Chat ASR modalities enhanced their overall online class experience.

Table 1  Procedural acceptability questionnaire

| Question                                      | n  | %     |
|-----------------------------------------------|----|-------|
| Which modality of ASR was most preferred?     |    |       |
| Response cards                                | 10 | 66.67 |
| Chat                                          | 3  | 20    |
| Indifferent                                   | 2  | 13.33 |
| Which modality helped you better understand the material? |    |       |
| Response cards                                | 2  | 13.33 |
| Chat                                          | 4  | 26.67 |
| Indifferent                                   | 9  | 60    |
| Which modality kept you most engaged?         |    |       |
| Response cards                                | 7  | 46.67 |
| Chat                                          | 5  | 33.33 |
| Indifferent                                   | 3  | 20    |

Note. Active student responding (ASR) refers to the two modalities used for student engagement (i.e., Response Cards and Chat). 15 students completed the procedural acceptability questionnaire.
Table 2  Procedural acceptability questionnaire—continued

|                                                                 | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|------------------------------------------------------------------|-------------------|----------|---------|-------|----------------|
|                                                                 | n  | %    | n  | %    | n  | %    | n  | %    | n  | %    |
| Participation in class was affected using ASR                    | 0  | 0    | 1  | 6.67 | 5  | 33.33 | 6  | 40   | 3  | 20   |
| I wish all online classes used ASR                               | 0  | 0    | 1  | 6.67 | 5  | 33.33 | 6  | 40   | 3  | 20   |
| I am likely to use ASR system with my own students as a result of this experience | 0  | 0    | 2  | 13.33| 2  | 13.33 | 9  | 60   | 2  | 13.33|
| I am likely to recommend my co-workers or peers use ASR in their teaching | 0  | 0    | 0  | 0    | 2  | 13.33 | 11 | 73.33| 2  | 13.33|
| I watched recorded lectures to prepare for exams                 | 6  | 40   | 3  | 20   | 1  | 6.67  | 2  | 13.33| 3  | 20   |
| I noticed the “secret words” throughout lectures at the bottom of the slides | 2  | 13.33| 2  | 13.33| 1  | 6.67  | 5  | 33.33| 5  | 33.33|
| I began to anticipate the “secret words” appearing on lecture slides | 4  | 26.67| 5  | 33.33| 3  | 20    | 2  | 13.33| 1  | 6.67 |
| I participated more in lecture due to the “secret words”         | 5  | 33.33| 5  | 33.33| 1  | 6.67  | 2  | 13.33| 2  | 13.33|
| I would have written down the “secret words” if they were worth points | 0  | 0    | 0  | 0    | 1  | 6.67  | 6  | 40   | 8  | 53.33|
| I think the inclusion of “secret words” is a good way to measure engagement | 5  | 33.33| 6  | 40   | 2  | 13.33 | 1  | 6.67 | 1  | 6.67 |
| Inclusion of ASR enhanced my online class experience              | 0  | 0    | 1  | 6.67 | 0  | 0     | 9  | 60   | 5  | 33.33|
| Inclusion of ASR and “secret words” enhanced my online experience | 0  | 0    | 9  | 60   | 2  | 13.33 | 3  | 20   | 1  | 6.67 |

Note. 15 out of 17 students completed the procedure acceptability questionnaire
ASR active student responding
“Secret words” refer to the engagement prompt submissions
Round Table Discussion

A total of 4 out of 17 (23%) students attended the roundtable discussion. Students stated that the RC condition was most preferred because it was “less stressful than the Chat condition,” “quicker” and “less pressure if I responded incorrectly.” The students also noted that the “secret words” (i.e., engagement prompt submissions) were “difficult to read,” “distracting from lecture content,” and “not a priority because of the lack of contingencies.” One student stated that “overall, it is hard to remain engaged with online classes, but the ASRs helped me stay engaged because I knew a question would be coming soon.”

Discussion

The rippling impacts of the COVID-19 global pandemic effected every part of our educational system, causing an unexpected disruption of traditional teaching and learning methods (Adedoyin & Soykan, 2020). As online instruction has become the primary teaching format across every level of education during this time (Vlachopoulos, 2020), it is crucial to evaluate the effects of various instructional methodologies on student performance in online learning environments. Behavior analytic studies have shown that increasing OTRs improves ASR in students and, therefore, learning. The effects of OTRs and ASRs have been demonstrated in elementary and secondary education settings, but rarely in post-secondary education and even more scarcely in online learning environments. As such, the purpose of the current study was to evaluate the effects of two ASR modalities, Response Cards and Chat, on student performance across pre-and post-lecture queries, unit exams, and the cumulative final exam in a synchronous online graduate course. The secondary purpose was to analyze the effects of both ASR modalities on student engagement during online lectures.

The results of this study indicated that, on average, students performed higher and there was less variability on post-lecture queries following the Chat session, although there was a gradually decreasing trend in query scores in the Chat conditions over time. The class average was higher on Exams 2 and 3, where students were required to actively respond to instruction during the online lectures, as compared to Exam 1 when no active student responding was required. Even though the number of engagement prompt submissions varied per ASR condition, students progressively submitted more engagement prompts throughout the study following the RC conditions than following Chat or baseline conditions. Interestingly, even though students performed higher on the post-lecture queries following the Chat conditions, the majority of students indicated that the RC conditions were most preferred and more engaging. Even though the number of engagement prompt submissions varied per ASR condition, students progressively submitted more engagement prompts throughout the study following the RC conditions than following Chat or baseline conditions, suggesting that the RC conditions maintained student engagement in the lecture discussion better.
While the RC and the Chat conditions were methodologically similar, the topography of the active responses varied across both conditions; thus, there are several considerations that may have contributed to student performance throughout the study. Students engaged in a selection-based response (i.e., multiple choice format) in the RC conditions or a production-based response (i.e., fill-in-the-blank format) in the Chat conditions. In the RC or selection-based conditions, students were required to read the instruction and select one out of three answers that were displayed on the screen. While multiple choice questions are an efficient and popular form of assessment across many disciplines (Kuechler & Simkin, 2010; McKenna, 2019), these responses required less effort than the Chat responses. Moreover, some have criticized the validity of multiple choice questions and doubt that they adequately capture student knowledge (Davies, 2002; Medawela et al., 2018).

In the Chat or production-based conditions, students were required to read the instruction, type, and submit the answer in the public chat forum. Unlike the RC conditions where the answers were displayed, the students were required to supply their own answers to a question in a fill-in-the-blank format. Some researchers agree that fill-in-the-blank questions provide a more robust learning experience and promote critical thinking (Jonick et al., 2017). The act of producing a textual response may produce better learning and retention. In addition, when students actively responded in the public chat forum, they were able to observe 17 examples of the correct answer (assuming everyone answered correctly). This may have increased the probability that students responded correctly to a similar question when it appeared on a post-lecture query or on an exam. The permanent product in the public chat forum may have provided more salient feedback than the visual feedback of a colored card during the RC conditions.

It is interesting that students preferred the RC condition to the Chat condition. Students reported they found the Chat condition more stressful, because their textual response was associated with their name in the public chat. In the RC condition, they held up a colored index card and their face was visible with the card. However, due to the screensharing, only a few videos could be seen at one time. Perhaps the students felt they could “hide” any incorrect answers more easily from their peers in the RC condition. A compromise that might be useful would be to use polling features in videoconferencing software, where individuals can answer anonymously in a poll. With the chat feature, students could have responded privately just to the instructor. This might have the benefit of requiring a production response and be less stressful to students because the response is private. However, this strategy would not provide students with the opportunity of viewing multiple correct response in the chat forum. Future research evaluating these differential effects would be interesting and informative.

To measure the maintenance of concepts throughout the lectures, identical or similar questions from the lectures appeared on the unit exams and the cumulative final exam. An increasing trend in exam performance was observed for most students. We hypothesize that this improved performance could have been due to the use of ASR activities. However, it is possible that improved scores were due to other factors, such as repeated exposure to the questions, habituation to the testing style of the instructor, learning strategies to perform better on the exams, and the like.
There is no way to rule out these variables as an explanation for the improvements in exam scores over time in the present study. Further, the first exam was proctored and in-person, meaning that the students were required to show up to a designated location and both instructors physically monitored the students while they took the exam. Due to increasing cases of the novel COVID-19 virus, the remaining unit exams (Exams 2, Exam 3, and the Cumulative Final Exam) were administered asynchronously online. While all exams, whether proctored or asynchronous, used the Lockdown Browser feature, were timed, and clear consequences were outlined for graduate students cheating, it is possible that the absence of physical proctoring was an important independent variable affecting the improved exam scores. When taking the exams at home, it is possible the students had books, notes, or other materials present that influenced their test scores, even though they were instructed to not have these materials out during the exams.

In the procedural acceptability survey and roundtable discussion, the students noted that they may have performed better on queries and may have attended to the engagement prompts more if points had been tied to them. We did not assign points to these activities, because we wanted to isolate the effects of the ASR activities. Points that explicitly rewarded accuracy on the queries may have confounded the effects of the ASR activities. Further, points were not made contingent on submitting the word lists for engagement prompt submissions because we wanted to determine whether the ASR activities alone would increase engagement. It seems clear that the ASR activities were not powerful enough alone to affect engagement, at least not as measured by the presence of the “secret words.” The students even questioned whether the “secret words” were a good proxy for engagement. We agreed and also questioned whether the “secret words” were a good proxy for engagement. Interestingly, we have observed that it is a common practice during professional presentations and continuing education activities for presenters to provide a “secret word” that audience members observing the talk asynchronously or synchronously online must write down and submit following the presentation to confirm their attention to the talk they attended. As such, it appears this is a generally accepted method of assessing attending in the field of behavior analysis. Thus, given the results from this study, it is recommended that presenters change from presenting “secret words” (i.e., displaying a word irrelevant to the content) to a fill-in-the-blank format that is content specific. By doing so, presenters may be able to more accurately assess if the audience retained the main content points and further refine their teaching practices.

Evaluating engagement during synchronous online lectures is challenging. During in-person instruction, engagement would be measured by observing whether students are oriented toward the teacher, have their eyes on the teacher, are writing notes, etc. This is very difficult to measure in an online environment. Even in a synchronous online learning environment, it can be difficult to measure engagement because students may be oriented toward the computer, but they may have another application open (e.g., e-mail) and may appear to be attending to the teacher because they are oriented toward their computer screen. Yet, they may actually be reading e-mails. Another complication potentially may be that a student may have their camera off or their image may be frozen on the screen. In these cases, observing engagement (according to how it is typically measured during in-person instruction)
is almost impossible. There is little to no research that has evaluated a method for effectively measuring student engagement during synchronous online class sessions. There may be a less effortful, yet discrete methods to measure engagement during a synchronous graduate level course. Future research should evaluate effective measures of engagement in online environments. For example, perhaps one could display simple instructions on a PowerPoint slide (e.g., if you can see this, pat your head) as a proxy for student engagement during online lectures.

Despite the limitations of this study, these findings contribute to our current literature in several ways. This study represents an initial attempt to evaluate specific instructional strategies designed to increase active student responding (i.e., engagement) in a graduate-level course taught online. As the use of online instructional formats continues to increase, it is important to evaluate how we can effectively provide instruction and maintain student engagement. Behavior analysts have several strategies that are effective in improving learning outcomes during in-person instruction, such as ensuring high rates of OTRs and ASRs. This study represents an initial attempt to translate these strategies from in-person to online, synchronous instruction and from elementary and secondary environments to post-secondary or graduate school environments. Given that there is such limited research evaluating these specific variables in the literature, this study is an initial attempt to begin addressing these issues. Additional research is warranted, given the limitations and difficulties we encountered. Dewey (1916) noted that students learn by doing and that learning is an active process. As such, we believe that there is value evaluating methods to maintain academic achievement and engagement through online teaching formats. It is our hope that this study encourages future research in this area.

Declarations

Conflict of interest The authors have no conflict of interest to disclose.

Informed Consent All participants provided consent to participate in the current study.

Research Involving Human Participants and/or Animals This study was approved by the universities Human Subjects Institutional Review Board.

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