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On Blending Active Student Responding With Synchronous Instruction to Evaluate Response Accuracy

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ON BLENDING ACTIVE STUDENT RESPONDING WITH SYNCHRONOUS INSTRUCTION TO EVALUATE RESPONSE ACCURACY

by

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As of 2016, approximately 28% of college students in the United States were taking at least one online course (U.S. Department of Education, 2016), and it was projected that the percentage of students enrolled in online courses would continue to increase 33% each year (Pethokoukis, 2002). The COVID-19 pandemic hastened further shifts from in-person to virtual learning for many institutions of higher education. Given this rapid shift to online instruction, it is critical to evaluate the effectiveness of online instructional procedures. Providing multiple opportunities for students to respond to instruction has proven to be an effective procedure across most educational settings (Archer & Hughes et al., 2011; Moore Partin et al., 2010) using various active student response systems including response boards and personal response systems (i.e., clickers). While there is a robust body of literature to support the effectiveness of embedding opportunities to respond during in-person instruction; to date, there is limited data on the effects of embedding opportunities to respond through synchronous online formats in post-secondary settings. Using an alternating treatments design, this study evaluated the effects of two active student response modalities (i.e., response cards and written responses in the chat forum) on response accuracy during a synchronous online graduate course. The results suggest that students performed more accurately on post-lecture queries following conditions that required written responses in the chat forum. Moreover, the accuracy of correct responding maintained across the exams and the cumulative final exam. Limitations and future implications are discussed.

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INTRODUCTION

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 in the United States were taking at least one online course (U.S. Department of 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 year, 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. Given that some have described the move from campus-based education to online education as not simply a fad, rather a trend shift (Maeroff, 2003), it is important to identify and remove barriers within higher education online formats 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).

Online education has many advantages that have resulted in its popularity. For example, numerous researchers report that online education offers more convenience and flexibility to learners than in-person classes (Sherrill & Truong, 2010), improves graduation rates by allowing students to work according to their learning style (Benton, 2005), curates friendlier environments (Sullivan, 2001), and reduces the time and costs for travel (Finch & Jacobs, 2012). Online education extends the reach of public and private intuitions (Roach, 2002), decreases labor costs (Bowen et al., 2012; Deming et al., 2015), provides instruction to a diverse body of students (i.e., age or academic disciplines) (Dumford & Miller, 2018; Richardson et al., 1999), and expands the capacity for education in new subject areas (Moore & Kearsley, 2011). Given the recent advances and demands for online education, close to 70% of higher education institutions in the United States report that online education is crucial to their long-term strategies (Allen & Seaman, 2013).

Many institutions of higher education offer online education in some combination of three primary 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 of hybrid instruction 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 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 didactic instruction (Gayman et al., 2018; Tallent-Runnels et al., 2006). More and more undergraduate and graduate students are taking a mixture of online (i.e., hybrid, asynchronous, or synchronous) and traditional courses (Moore & Kearsley et al., 2011). Instructors are often 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 et al., 2016).

There is relatively little research evaluating the necessary component variables for effective online instruction (Tallent-Runnels et al., 2006). Tallent-Runnels et al. (2006) conducted a systematic review of 76 research articles evaluating online teaching and learning. Their primary findings indicated that the majority of research evaluating the effects of online education were descriptive in nature. The second notable finding was that more research is needed to determine which format provides the highest level of interactions and the most effective learning experience. Most importantly, Tallent-Runnels et al. (2006) highlighted the need for research to experimentally isolate and analyze the variables related to instructional quality; that is, what instructional variables yield successful student outcomes during online education?

High levels of student engagement in the online environment is likely one variable closely related to student success. The relationship between student engagement and academic achievement “has the same scientific status as reinforcement in psychology and gravity in physics" (p. 3; Berliner, 1990). That is, it is a generally accepted rule that increased student participation 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. Maintaining student engagement may present more challenges in online environments due to competing contingencies and lack of stimulus control outside of the traditional educational setting (Meyer, 2014). Therefore, it is important to evaluate teaching strategies that can be used in online environments to effectively keep students actively engaged in instruction.

Behavioral researchers have evaluated numerous ways to improve student engagement during face-to-face instruction. Some of the most effective strategies for increasing student engagement and, therefore, learning includes antecedent strategies, such as providing high rates of opportunities for students to respond, as well as consequence strategies, such as following student responses with effective feedback (Sutherland & Wehby, 2001). There is robust empirical support regarding the effectiveness of providing students with frequent and varied opportunities to respond, as well as providing students with effective feedback (Haydon et al., 2013; Lewis, 2008; MacSuga-Gage & Simonsen, 2015; Sutherland & Wehby, 2001). These two strategies often go hand-in-hand because in order to provide students with effective feedback, students must make an active and observable responses to instruction. To make an active and observable responses to instruction, the teacher must provide multiple response opportunities.

These observable responses to instruction are often referred to as “active student responding” or ASRs (Barbetta et al., 1993; Heward, 1994; Vargas, 2009). Different questions teachers ask students during a given period are typically referred to as “opportunities to respond” or OTRs (Archer & Hughes et al., 2011; Ferkis et al., 1997; Haydon et al., 2012; MacSuga-Gage & Simonsen et al., 2015). OTRs take many forms and can be teacher directed (i.e., choral responding), peer directed (e.g., peer tutoring), or technology-mediated (e.g., gaming) (Common et al., 2020; Haydon et al., 2013). There are more than two decades of research supporting and validating the effectiveness of providing increased OTRs and ASRs across elementary, secondary, and post-secondary settings (Common et al., 2020; MacSuga-Gage & Simonson et al., 2015). 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).

Twyman and Heward (2016) noted that OTRs and ASRs can be delivered through low-technological (low-tech) or high-technological (high-tech) modalities. Low-tech modalities use materials that are relatively inexpensive, simple tools (Monem et al., 2018), such as response-cards (see review Randolph, 2007). Occasionally, low-tech modalities involve no extra tools and simply require unison vocal responses, referred to as choral responding (see review Haydon et al., 2013). There are more than two decades of research supporting and validating the effectiveness of low-tech ASR modalities across elementary settings (Berrong et al., 2007; Christine & Schuster, 2003; Gardner, 1990, 1994; Godfrey et al., 2003; Inwood, 1995; Lambert, 2001; Munro & Stephenson, 2009; Narayan et al., 1990; Wood et al., 2009) and secondary settings (Al-Attrash,1999; Armendariz & Umbreit, 1999; Cavanaugh et al., 1996; Common et al., 2020; Jerome & Barbetta, 2005; King, 1996; Lambert, 2001, 2006; MacSuga-Gage & Simonson, 2015; Monem et al., 2018; Reynolds, 2003). Very little research on the utility of low-tech OTR or ASR modalities 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 (Kreiner, 1997; Kellum et al., 2001; Malanga & Sweeney, 2008; Marmolejo et al., 2004; Zayac et al., 2015).

For example, Kellum et al. (2001) used an alternating treatments design to investigate the effects of increasing ASR using response cards on quiz scores for 40 students enrolled in a community college course. The instructor alternated between presenting review questions either with or without response cards while measuring the mean number of ASRs and the percentage of students receiving an A on class exams. The results of this study indicated that when response cards were used, student participation increased during the review portion of the class period and students scored higher on their end-of-class quizzes. However, the response cards did not seem to increase or decrease participation outside of the review questions for any of the class periods. Malanga and Sweeney (2008) compared the effects of daily assessments and response cards on average weekly quizzes for 40 college students. The researchers systematically rotated between daily assessments versus response cards from week to week. Students earned higher quiz scores on the end-of-week quizzes in the daily assessment condition, and the response cards produced mixed results. As such, the effects for response cards within the post-secondary settings on response accuracy and engagement warrants further analysis.

ASR can also be increased using high-tech tools, such as personal response systems (i.e., clickers). This type of ASR has more frequently been evaluated in post-secondary settings. These high-tech methods of ASR have been compared to low-tech methods during post-secondary lectures (see reviews by Kay & LeSage, 2009 and Liu et al., 2017). For example, researchers have compared the effects of clickers versus hand-raising (Anthis, 2011; Dill, 2008), response cards versus clickers (Brady et al., 2013; Fallon & Forrest, 2011; Stowell & Nelson, 2007), and response cards versus hand-raising (Kellum et al., 2001; Morling et al., 2008; Shaffer & Collura, 2009). Some researchers have even evaluated three different ASR modalities to determine their effects on student performance (Elicker & McConnell, 2011; Stowell & Nelson, 2007; 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 split into four different groups while the response modalities rotated in a blocked fashion every 4-weeks and corresponded with course exams. A fixed number of ASR questions were asked 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 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 participants indicated they believed their grades benefited from having response cards and clicker ASR modalities incorporated into the lecture. Furthermore, the participants indicated they would like to see ASR integrated into their other courses. The results of Zayac suggested that increasing ASR in the post-secondary settings was just as effective as doing so in elementary classrooms.

The use of clickers, response cards, and hand-raising can present interesting challenges in online instructional environments, where an instructor may not be able to simultaneously see all students. Additionally, clickers may not be feasible to use in an online environment because they need to be near a receiver. While there are other alternative high-tech software systems that might be useful for student engagement (e.g., Mentimeter at www.menti.com), many of these high-tech methods have simply not been empirically evaluated in online educational environments.

In summary, the literature on online education 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 is limited empirical data on the effects of such strategies for student engagement and learning. Despite the increase in utilizing 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 in the classroom, most of this research has been in elementary settings. Much less research has been conducted in the post-secondary settings, and that research has typically been conducted during in-person instruction. Research is needed on how similar methods of instruction can be used in post-secondary settings, and specifically in online formats. There is a tendency for instructors to utilize passive modes of instruction in post-secondary education, such as lectures and slides, which may not promote student attending and overt responding (Zayac et al., 2015). Research on ASR during online lectures may be important for identifying ways to increase mastery of course content in such contexts. Moreover, objective data measuring student engagement and academic achievement in the online lectures would be a useful addition to the literature. Importantly, given the decrease in stimulus control (such as proximity of the instructor or the physical classroom environment) for students to remain engaged and actively participate in class within an online format, it may be especially important for instructors to consider ways to measure and promote active student engagement across various modalities for online instruction. 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. Specifically, the research questions were:

- Given synchronous online class sessions in which the instructor provides multiple response opportunities, what are the effects of:
    - A response card versus
    - A written (chat function) active student response modality

  On the number of correctly answered questions during class and during timed knowledge assessments:
    - Conducted immediately before and after each class session,
    - On monthly exams, and
    - On a cumulative final exam at the end of the course?
- Given a synchronous online class session, what are the effects of various response modalities (i.e., response card and written responses in the chat) for active student responding on graduate student engagement during class?

- Given experience with various response modalities for active student responding (i.e., response card and written responses in the chat), what are the stated perceptions of the various modalities by participants enrolled in the synchronous online course?

METHOD

Participants

Participants were students enrolled in a graduate course at a midwestern university in the fall semester of 2020, during the COVID-19 pandemic. The topic of the course was behavioral assessment and was a part of the university's course sequence for Behavior Analyst Certification Board® (BACB) certification. All students were enrolled in a program through the university that was designed to prepare both special education teachers and psychology students to work with children with developmental disabilities in school settings. The students were first-year master's students in the program. Approximately half of the class was comprised of special education teachers seeking master's degrees, autism certificates, and/or BACB certification. The other half of the class was comprised of master's level psychology students, also seeking BACB certification. The course was typically taught in an in-person format, but due to COVID-19, the course was taught in a synchronous online format. The course was co-taught by a tenured professor of behavior analysis who was a Board Certified Behavior Analyst (BCBA) at the doctoral level with over 20 years of experience teaching graduate students in-person and a BCBA doctoral candidate in behavior analysis. There were 17 students (16 females and 1 male) who served as participants in the study. 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). 15 out of 17 participants enrolled in the study completed the sociodemographic questionnaire (see Table 1).

Table 1

Sociodemographic Characteristics of Participants

	n	%
Ethnicity		
White/Caucasian	14	93.33
Bi-Racial	1	6.67
Age		
20-30	10	6.67
30-40	3	20
40-50	1	6.67
50+	1	6.67
Gender		
Male	1	6.67
Female	14	93.33
Current Occupation		
Full-time graduate student with job/assistantship related to field of ABA	8	53.33
Full-time graduate student with job/assistantship not related to the field of ABA	1	6.67
Full-time graduate student and full-time classroom teacher	2	13.33
Part-time graduate student and full-time classroom teacher	2	13.33
Other	2	13.33
Parental Status		
Children	5	33.33
No Children	10	66.67
Highest Degree		
Bachelors	10	66.67
Masters	5	33.33
Degree		
Special Education	6	40
Behavior Analysis	9	60
Certification		
Teaching Certification	9	60
BACB Certification	4	26.67
None	2	13.33
Teaching Experience		
1-3 years	3	20
4-8 years	2	13.33
9-13 years	0	0
14-18 years	3	20
None	7	46.67

Table 1- Continued

	n	%
ABA Agency Experience		
Beginner (0-5 hrs per week)	2	13.33
Adequate (6-11 hrs per week)	2	13.33
Advanced (12-17 hrs per week)	7	46.67
None	4	26.67
Total Supervised BACB Hours		
0-300	11	73.33
301-600	4	26.67

Note. N=15. 15 out of 17 participants enrolled in the study completed the sociodemographic questionnaire. ABA=Applied Behavior Analysis. BACB=Behavior Analyst Certification Board.

Following approval from the Human Subjects Institutional Review Board (see Appendix A), the researcher uploaded an approved informed consent document (see Appendix B) to the online learning management system used by the university (Desire To Learn; D2L). During the first session, the instructor and the co-instructor read the informed consent document to the students while simultaneously displaying the form on all students' computer screen using the share screen option on the university's videoconferencing platform (Webex; see below). After the informed consent document was reviewed in its entirety, students were allowed to ask clarifying questions. Students were informed that they were required to participate in all the class activities, which were graded for purposes of the course, regardless of whether they chose to participate in the study. If they consented to participate in the study, they were opting to have their performance data for these activities included in the study for research purposes. There was no penalty for opting out of the study. Students were then asked to review the informed consent document again after class and either provide or deny consent for their class performance data to be used for research purposes. Students electronically signed the document and uploaded it to an electronic folder on D2L. All 17 students enrolled in the course agreed to participate in the study and provided consent for their performance data to be used for research purposes. To maintain confidentiality, all students were assigned a participant number, and this number was associated with all their performance data for research purposes. This number was not linked to any identifiable information and was not shared with any of the students enrolled in the course.

Setting and Materials

Online Formats and Software

The class met synchronously online one evening per week, for a total of 11 sessions, from 5:30 pm to 8:00 pm using a private and secure online format called Cisco Webex. Cisco Webex is a streaming online format that allowed students from geographically diverse locations to virtually attend meetings and webinars. Cisco Webex also allowed the instructors to share their screens (i.e., screenshare), respond to students through instant messaging (i.e., chat), and record lecture presentations. In order to host each virtual meeting, the instructor created a meeting link (specifying the date and time) and invited enrolled students to attend using their university e-mail address. After students were invited to attend the meeting, the instructors then uploaded the meeting link to the online educational format (D2L).

The instructor uploaded the syllabus, assigned readings, lecture content, and supplementary resources to D2L for students to access. Moreover, students were able to upload completed assignments and view their current grades in the course at any time via D2L. Through D2L, students were also able to download a secure browser for taking exams. This browser was called Respondus Lockdown. Respondus Lockdown is a custom browser that restricts students from printing, copying, going to another website, or accessing other applications while exam material is displayed. Respondus Lockdown browser was used during all pre-and-post lecture queries (excluding one session), exams, and the cumulative exam.

Pre-and-Post Lecture Queries

Pre-and-post lecture queries were uploaded to D2L with Respondus Lockdown prior to each session beginning. These queries were similar to quizzes. There were 15 fill-in-the-blank questions per query, and students had a maximum of 15 minutes to complete the query. All questions were derived from assigned peer-reviewed research articles, handouts that students were assigned to read for class, and lecture content. We referred to these quizzes as queries to make it clear to the students that points were awarded only for participation in them, not contingent on accuracy. 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 and peanut butter", the student did not receive points for the query. The first time a student responded with irrelevant content, 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 students that if an any further irrelevant responses 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 points for incomplete or irrelevant responses on pre-and-post lecture queries.

Exams

There was a total of three exams throughout the study. All exams were uploaded to D2L with Respondus Lockdown. One exam (Exam 1) was proctored in person, although students completed it online using their computers. The students and instructors came to the classroom in accordance with the Center for Disease Control (CDC) Guidelines (CDC, 2021) and university policies (i.e., wearing face coverings and sitting at least 1.83 m apart), logged into Respondus Lockdown with their computers, and took the exam in front of the instructors to ensure no books or other extraneous materials were used. It was initially planned for all three exams to be delivered in this proctored format. However, due to increasing COVID-19 cases in the state over time, the remaining exams were made available to students at a pre-determined date and time, but the students logged in using Respondus Lockdown Browser to take the exams from a remote location, such as their own homes.

Each exam consisted of 11 to 12 short answer or fill-in-the-blank questions (totaling to 20 points). For each exam, there was a minimum of five fill-in-the-blank questions that were similar to the questions in the pre-and-post lecture queries or the OTRs presented during the synchronous online lecture. Exam 1 consisted of content that was taught during baseline conditions one through three. The remaining exams and the cumulative final included fill-in-the-blank questions from both the RC and the Chat conditions. Exam 2 consisted of content that was taught during conditions four through seven. Exam 3 consisted of content that was taught during conditions eight and nine. The Cumulative Final Exam consisted of content from all conditions including baseline, Chat, and RC. The Cumulative Final Exam consisted of 27 questions (totaling to 50 points). There were 15 fill-in-the-blank questions and the remainder of the questions were short answer. For the exams and the cumulative final exam, the fill-in-the-blank questions were similar to the OTRs presented in the online lecture. The students were required to write a response in the blank to complete different portions of the sentence. As such, the content was similar to questions presented during the online lectures, but the response required was slightly different from the original OTR presented. Additionally, unlike for the queries, points were contingent on accuracy of responding for the exams and the cumulative final exam.

Supplementary Materials

Additional resources that were used in this study included lecture PowerPoint slides, a computer or a tablet, an active university e-mail address, an active account on the Cisco Webex streaming format, Microsoft Excel and Word, Qualtrics™, pre-recorded lecture videos, 3 x 5 colored index cards, and storage capacity to download Respondus Lockdown browser.

Dependent Variables and Measurement

The primary dependent variables were ASR in RC and Chat conditions, accuracy of responding within the synchronous sessions, incorrect responses (error correction) within synchronous sessions, accuracy of responses in pre-and-post lecture queries, correct or incorrect engagement submissions, and prompted or independent vocal responses (see Table 2 for operational definitions of each).

Table 2

Operational Definitions

Variable	Operational Definition
ASR	
Response Card	Any instance where a student holds up the colored index card within 5 seconds of the instructor presenting the cue.
Written in Chat	Any instance where a student submits a written response in the public chat forum within 5 seconds of the instructor presenting the cue.
Accuracy of Responses Within Session	Any instance where a student responds in the correct modality to a planned OTR within 5 seconds of the OTR being presented and the answer has point-to-point correspondence or in the same response class with the instructor's vocal response, response cards, or a textual response.

Table 2 – Continued

Variable	Operational Definition
Incorrect Responses (Error Correction) Within Session	If two or more students respond incorrectly, the instructor will re-present the question, immediately provide the correct answer, re-ask the question, and provide behavior specific praise.
Pre-and-Post Lecture Queries	
Accuracy of Responses in Query	Any instance where the student's response has point-to-point correspondence or in the same response class with the pre-determined answers in D2L.
Incorrect Response in Query	Any instance where a student's responds does not have point-to-point correspondence and was not in the same response class with the pre-determined answers in D2L.
Engagement	
Correct Engagement Submission	Any instance where a student submits an e-mail to the instructor within a 1 hr period after class elapses.
Incorrect Engagement Submission	Any instance where the instructor does not receive an e-mail from students 1 hr after class concludes or when a student submits a word list that is inaccurate.
Prompted Vocal Responses	Any instance where a student responds to a question presented by the instructor.
Independent Vocal Responses	Any instance where a student interjects or makes a response to instruction (e.g., makes a vocal statement in class) independent of a question being presented.

Note. Total of 10 operational definitions. ASR = Active Student Response. OTR = Opportunity to Respond. D2L = Desire2Learn.

Pre-and-post lecture queries were used to measure any changes in performance on questions related to the lecture content from before and after the class lecture and discussion. Each pre-and-post-lecture query had a corresponding answer key. Accuracy on pre-and-post lecture queries was measured by comparing students' written responses to the corresponding answer key. An accurate response was defined as any instance where a student's response had point-to-point correspondence or in the same response class with the answer key. An incorrect response was defined as any instance where a student's response did not have point-to-point correspondence and was not in the same response class with the answer key. The researcher or one of the research assistants scored the queries and recorded the number of correct and incorrect responses in Microsoft Excel and Word. The percentage of correct responses were recorded per individual student by dividing the number of correct responses by the total of incorrect and correct responses and multiplying the result by 100. In addition, the average percentage correct across students was calculated by adding the scores for each individual query and dividing by the total number of students that completed the query and multiplying the results by 100.

Accuracy of responses to the OTRs during class was recorded live during each synchronous lecture. An accurate response to an OTR was defined as any instance where a student answered a question in the prompted response modality (i.e., holding up a colored response card or typing words in the public chat forum) within 5 seconds of the cue (e.g., "Cards up" or "Press Enter") and their answer matched that on a prepared answer key. An incorrect response was defined as an instance where a student responds in the wrong modality within 5 seconds of the cue being presented. Immediately after an OTR was presented, students provided their answers in the correct modality. The researcher scored the responses by identifying if all students responded correctly or if two or more students responded incorrectly. If all students responded correctly, a plus sign was marked on the electronic datasheet. If two or more students responded incorrectly, a minus sign was marked on the data sheet. At the end of the session, the researcher divided the correct and incorrect responses by the total number of OTRs presented during the synchronous lecture and then multiplied the results number by 100.

Student engagement during the class lecture and discussion was difficult to measure during online instruction. If the class had been in-person, student engagement would have been defined as the students having their eyes on the teacher, on PowerPoint slides displayed in the classroom, on their papers as they wrote notes, etc. In an online environment, such definitions were difficult to accommodate. While we could have counted engagement when the students were looking at their screens, as evidenced by their faces being oriented toward their computer's camera, it was difficult for us to know what the student had displayed on their screen. Furthermore, when the instructors presented slides, only a few student's faces were simultaneously visible in their screen. In addition, sometimes student video feeds would intermittently freeze. Thus, directly measuring student engagement was difficult, if not impossible. Therefore, we developed a proxy for engagement. This included the instructors displaying on the bottom of randomly-selected PowerPoint slides in Times New Roman 14-point font words unrelated to the lecture. Along with the words were digits 0-5 and 6-9 and a written instruction for students to write down the words if the last digit in their University Identification Number (UIN) matched the number on the screen. At the end of the lecture, there was an instruction on the final slide, telling students to submit the words they wrote down to the course instructors via email after class. Data on engagement were, thus, recorded from the permanent products submitted via email by the students in the course. This proxy for engagement required students to be oriented to the Powerpoint slides, reading the content on the slides, and following the instructions written on the slides. A *correct engagement submission* was defined as any instance where a student submitted an e-mail to the instructor within 1 hr after the lecture concluded. An *incorrect engagement submission* was defined as any instance where the instructor did not receive an e-mail with a list of words from a student within 1 hr of the lecture concluding or when a student submitted a word list that did not match the words associated with that student's UIN. For example, if a student with a UIN 0 through 5 was assigned the words *taco* and *pen* and the student submitted the words *bananas* and *coffee*, an incorrect engagement submission was recorded.

In order to collect additional, direct measures of engagement, data were also recorded on the frequency of prompted and independent student vocal responses during all synchronous online lectures. If a student vocally responded to a question presented by the instructor, a prompted response was recorded. If a student made a comment or asked a question about the lecture content independent of any question from the instructor, an independent response was recorded.

In addition to the primary dependent variables described above, data were also collected on a number of secondary variables of interest including planned opportunities to respond, unplanned opportunities to respond, response modality, number of lecture slides, and duration of the lecture. The operational definitions for the secondary variables can be found in Appendix C but are not otherwise included in this analysis.

Data Collection, Interobserver Agreement (IOA), and Procedural Fidelity

Data Collection

The researcher served as the primary data collector throughout the study. In addition, there were three research assistants who recorded interobserver agreement data (IOA). Two of the research assistants were undergraduate students majoring in psychology and behavioral science. The other research assistant was a first-year master's student enrolled in a behavior analysis training program in the Psychology Department. The researcher collected data from live and recorded videos from the synchronous sessions. The research assistants recorded IOA on all primary and secondary variables from the recorded synchronous sessions. Prior to collecting data, the researcher trained the research assistants on all data collection procedures. The training method employed was behavioral skills training (BST; Parsons et al., 2012), which included instructions, modeling, rehearsal, and feedback. After receiving BST on the data collection system, each research assistant then coded data from a sample video and provided a rationale for each response in-vivo. For example, the researcher shared their screen and played specific clips of recorded synchronous lectures. The clips ranged in duration from 5 to 15 minutes. The researcher intermittently paused the video and asked the research assistants what variable to code. If a research assistant indicated a dependent variable should be scored, they were required to state the operational definition of the variable. If the research assistant responded correctly, behavior specific praise was provided, and the next clip was shown. If the research assistant responded incorrectly, they were instructed to read the appropriate operational definition out loud, and the researcher re-played the specific clip of the lecture. Prior to independently coding data for the recorded synchronous lectures, research assistants were required to answer the researcher correctly on 80% of opportunities when reviewing video clips. Across two training sessions, the research assistants responded accurately when reviewing video clips with the primary researcher on an average of 92% of opportunities (range 84.6% to 100%). The primary researcher facilitated one intermittent assessment throughout the duration of the study. During this intermittent assessment, the percentage of accuracy fell below 80%, and a brief training was conducted until mastery was reestablished.

Interobserver Agreement (IOA)

After training, the research assistants independently scored the recorded sessions for all primary dependent and secondary variables. Interobserver agreement was calculated using trial-by-trial interobserver agreement (Cooper et al., 2019). Each question on all knowledge assessments (i.e., the pre-and-post queries, exams, and the cumulative final) was conceptualized as a trial. As such, point-by-point agreement was used to assess the reliability of data collection by evaluating the number of trials with agreements divided by the total number of trials multiplied by 100 for the primary and secondary observers. Agreements were defined as any instance where an observer recorded occurrence of the correct response in correspondence with the answer key. A disagreement was defined as any instance where an observer recorded that an answer was correct, yet the primary researcher recorded that the answer was incorrect. Student data were aggregated and averaged for each session.

IOA for pre-and-post lecture queries was collected for 100% of baseline sessions ranging from 92% to 93% (M=92%). IOA was also collected for 100% of Response Card conditions (M=89%, range 82% to 92%) and 100% of Chat conditions (M=92%, range 88% to 95%). Additionally, IOA for the accuracy of within session responding was 100% (M=100%). At the end of each month, the primary researcher sent the research assistants engagement submissions from all students. The research assistants independently recorded if an engagement submission abided by the operational definitions and marked a 1 on the electronic datasheet to indicate which category (i.e., correct submission or incorrect submission). IOA for engagement submissions overall yielded high an agreement in baseline (M=100%) and in treatment conditions (M= 92.5%, range 85% to 100%). Additionally, IOA was also collected for 100% of sessions for vocal prompted responses (M= 74%, range 53% to 100%) and vocal independent responses (M= 66%, range 0% to 100%).

Procedural Fidelity

The two research assistants alternated taking procedural fidelity data on the recorded synchronous sessions during baseline and ASR conditions. The research assistants recorded if a treatment component occurred (1) or did not occur (-). Procedural components included: whether the pre-lecture query was available before lecture, whether the expectation slide was presented before each lecture, whether the instructor presented a response cue for each OTR, whether the instructor provided a 5- to 10-s delay between the OTR and the cue to respond, whether an error correction was implemented following any incorrect responses, and whether engagement prompts were presented as planned in the lecture. Procedural fidelity data were measured during 100% of baseline and ASR conditions and was 100% on all occasions (see Appendix D).

Experimental Design and Analysis

The effects of both ASR modalities on the primary 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. Data were analyzed through visual analysis and a functional relation was evident when the data paths of the two conditions separated, and replication of treatment effect for each independent variable was demonstrated when each successive data point reproduced the level of the prior data.

Procedures

Baseline

Lectures began at 5:30 pm. Students were instructed to complete the pre-lecture query between 5:30 and 5:45 pm. Students logged into D2L to complete and submit the pre-lecture query, after which they were to log into Cisco Webex for the lecture and discussion. Students earned two participation points for completing each query, regardless of the accuracy of their performance on the query. The instructor began each lecture by displaying a PowerPoint slide that listed the classroom expectations. These expectations were: camera on, be on-time, sit at desk or table, microphone muted, no eating, and needed materials (Figure 1).

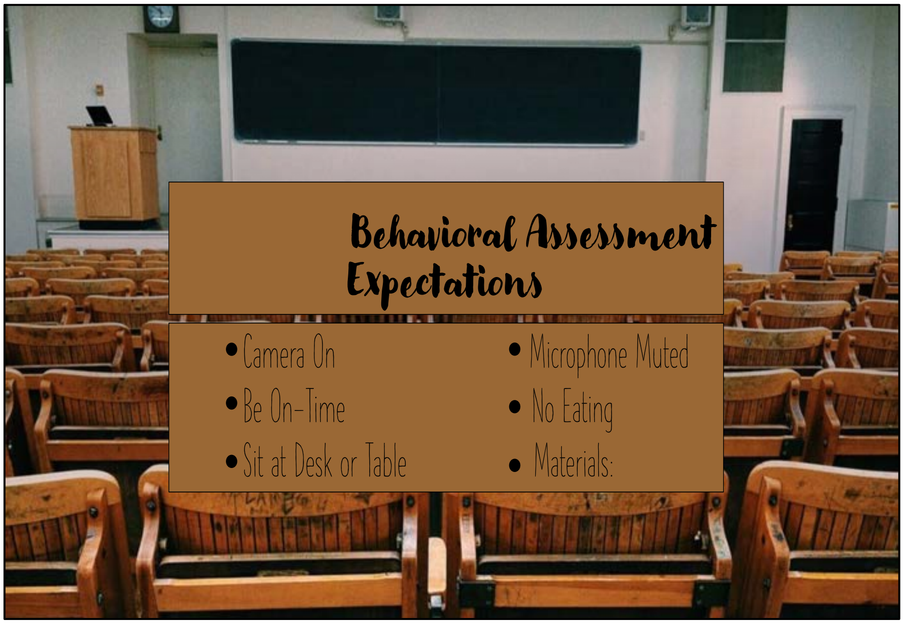

Figure 1. Classroom Expectations

While the expectation slide was displayed, the instructor reviewed the classroom expectations with the students. Next, the instructor proceeded to review the session content with the students. Powerpoint slides were presented using screensharing. The information on the Powerpoint slides was related to peer-reviewed articles the students had been assigned to read. There were no structured active student responding activities during baseline sessions. However, the instructors occasionally asked a question (e.g., "Can anyone think of an example of…?") or asked the students if they had any questions or comments regarding the lecture content. All sessions were recorded. Baseline lasted for three sessions.

Engagement

During the first lecture session only, the instructor asked the students to take out their university ID cards, which had a series of numbers on the back and 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."* There were 11 students whose UIN ended with 0 through 5 and there were 6 students whose UIN ended with 6 through 9. The co-instructors recorded this information for future reference so they would know which students should submit which words on the engagement submissions. This also ensured that each student was familiar with the last digit of their UIN. This exercise was never repeated throughout the course, and no vocal prompts or cues were provided to indicate there would be words at the bottom of any slides or that the students should attend to the words and submit an email with the words. Next, the instructors proceeded with the classroom lecture, accompanied by PowerPoint slides. The engagement prompts and UINs were embedded in randomly selected slides during the lecture (see example in Figure 2).

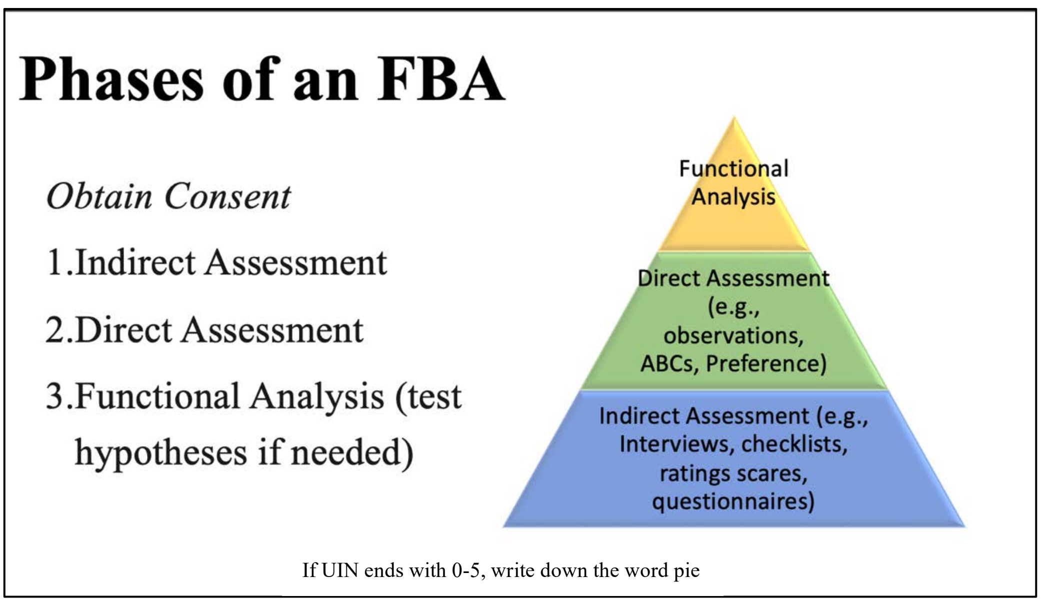

Figure 2. Engagement Prompts

For example, a slide might say "*If your UIN ends with 0-5, write down the word ball*." Another slide might say "*If your UIN ends with 6-9, write down the word basket*." There were two to three words presented for each set of UINs throughout the lecture. These prompts were active on the screen for an average duration of 2 minutes and 13 seconds across all conditions. The instructor did not orient the students to the engagement prompts when they appeared, rather the instructor continued discussing lecture content. At the end of the lecture, the final PowerPoint slide contained a prompt for students to immediately complete the post-lecture query following class, reminded students of any assignments that were due, and any other housekeeping information. Additionally, at the bottom of the last PowerPoint slide for each lecture, an instruction appeared on the slide "*As soon as the lecture ends, send the co-instructor an e-mail with the words you wrote down during lecture*" (see Figure 3). The instructor did not prompt students to attend to this instruction at the bottom of the screen. The co-instructor collected all emails sent with the engagement prompts after the lecture concluded, then compared the submitted engagement prompts to the words presented on the lecture slides.

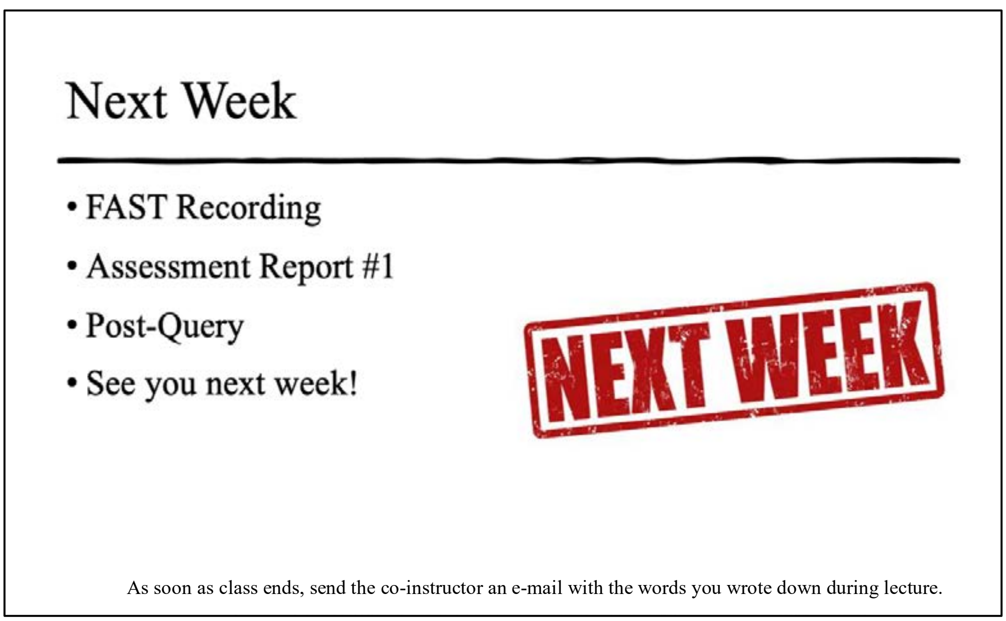

Figure 3. Instructions for Engagement Submissions

Response Cards

Generally speaking, the Response Card (RC) conditions were conducted the same as baseline, except for the addition of programmed active student responding opportunities that were embedded in the lecture. After students completed their pre-lecture query, the students logged into the Cisco Webex classroom, where the instructor presented the classroom expectation slide specific to the RC condition (Figure 4, top panel). This slide stated that the students needed to have three colored (red, blue, yellow) index cards or similarly colored substitute objects (i.e., red, yellow, blue coffee cup) available to use throughout the lecture to indicate their response. (These supplies were also listed on the course syllabus so that students had the necessary supplies when these class sessions occurred.) Similarly, colored substitute objects (e.g., three coffee cups--pink, yellow, and blue) were allowed due to many students losing their index cards during the semester.

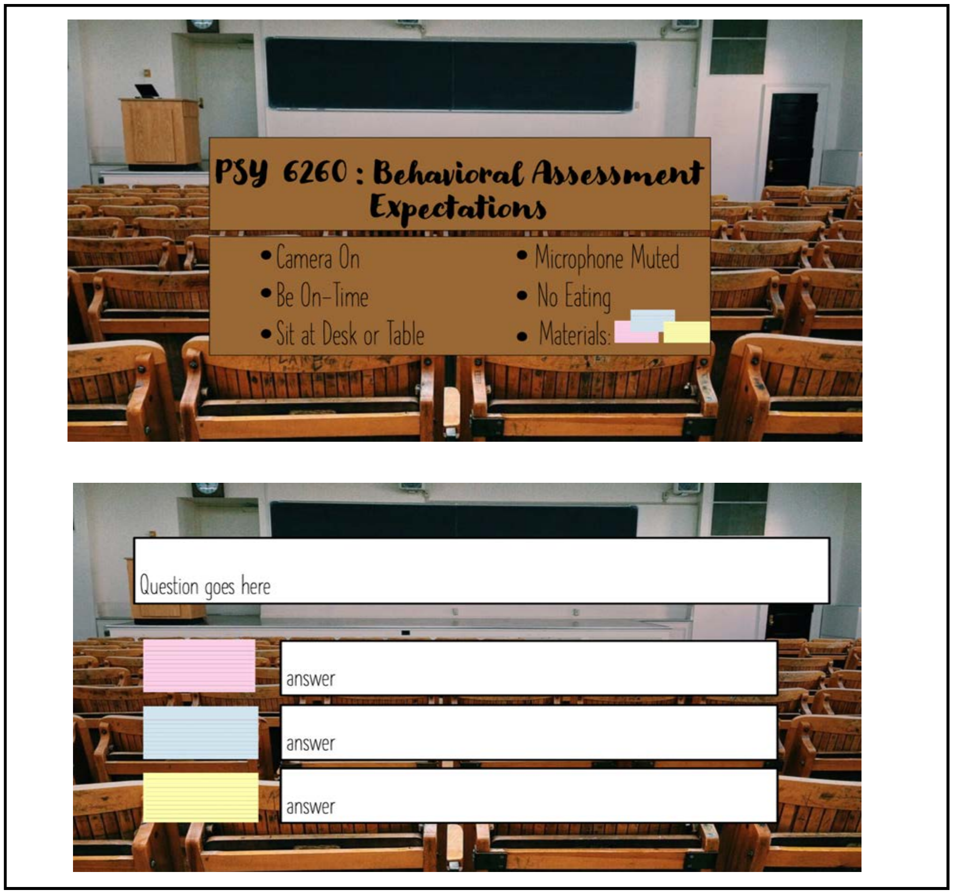

Figure 4. Response Card Conditions

After reviewing the expectations and the needed materials, the instructor proceeded with the lecture in the same manner as in baseline, with the addition of presenting eight to 10 planned OTRs intermittently throughout the lecture.

Each OTR slide (Figure 4, bottom panel) in the RC condition contained a question and three possible answers. When the slide was displayed, the instructor read the question aloud, read the response options and corresponding color, provided 5- to 10-s of "think time," and presented a cue for the students to hold up the colored card (or substitute object) corresponding to the students' selected answer. After all students actively responded, feedback was provided to the group regarding the correctness of their responses. 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 attention. Think about your response (pause for approximately 5s)…Get ready (pause for approximately 5s)…Cards up."* The co-instructor then scrolled through all of the video screens of the students to check which card was displayed by each student. The co-instructor then reported to the instructor whether the students held up the correct colored card (or object), if some students made errors, or a lot of students made errors.

If students responded correctly the instructor provided behavior specific praise (e.g., *"You all are correct. The demand, attention, play, and alone are the traditional functional analysis conditions. Great job!"*). 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, if two or more students incorrectly answered the question described above, 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 were 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 were in traditional functional analysis. Great job!")*, and the lecture continued until the next programmed opportunity to respond appeared. At the end of the lecture, the students were instructed to complete the post-lecture query, as in baseline.

Written Responding in the Chat

The Chat conditions were conducted exactly the same as the RC conditions, except the modality of ASR was different for students. After completing their pre-lecture query, the students logged into the Cisco Webex, where the instructor presented the classroom expectation slide specific to the Chat conditions (see Figure 5, top panel). While this slide was present, the instructor stated that students should use the public chat function in WebEx to respond to the question slides during the lecture. Again, eight to 10 programmed opportunities to respond were intermittently presented. Each slide contained a question and an image displaying the chat function (Figure 5, bottom panel).

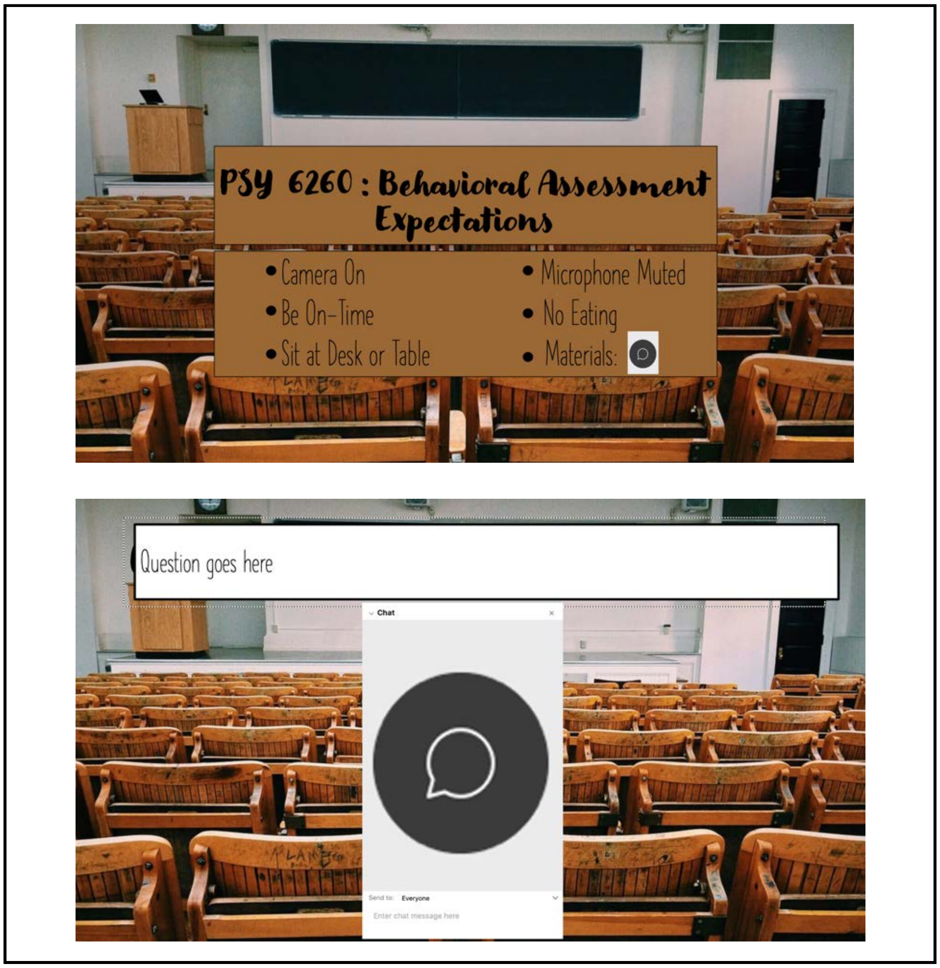

Figure 5. Chat Conditions

When the slide was displayed, the instructor read the question aloud, provided 5- to 10-s of "think time," and presented a cue for the students to respond to the entire group in the public 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 s) …Get* *ready (pause for approximately 5s)… Press enter."* The co-instructor scrolled through all of the chat responses to check for correct or incorrect responses. If students responded correctly, the instructor provided behavior specific praise. If two or more students responded incorrectly, the same error correction procedures described earlier was administered. Concluding the lecture, the students were instructed to complete the post-lecture query and the instructor stopped the lecture recording.

Procedural Acceptability

Procedural acceptability was measured in two ways. First, all students received a questionnaire to indicate whether they felt the programmed OTRs helped them learn the class material more effectively, whether they enjoyed one of the modalities more than the other, and whether they felt these procedures helped them be more engaged in the synchronous lectures. Student feedback was obtained from a 20-question Qualtrics™ survey that was e-mailed directly to all students enrolled in the course through at conclusion of the course (after all lectures, exams, and assignments had been completed). The questions consisted of multiple choice and short answer questions. Items on the questionnaire included the participants' demographic information, preferred ASR modality, perceived influence of both ASR modalities on engagement, and willingness to use ASR modalities with their own students or clients. Students were prompted through e-mail to complete the questionnaire a total of three times. While students did not receive points for completing the procedural acceptability questionnaire, 15 out of 17 (88%) students completed it.

In addition to the procedural acceptability questionnaire, the researcher conducted a 38-min roundtable discussion session through Cisco Webex after the study concluded. Students were invited to attend the session to learn what the study was about and to share additional information with the researcher. It is important to note, all students completed the procedural acceptability questionnaire prior to attending the roundtable discussion. During the roundtable discussion, the researcher notified the students that the discussion would be recorded and that the function of the discussion was to gather additional feedback from the students enrolled in the course. No points were awarded for students attending the roundtable discussion. A total of 4 out of 17 (23%) students attended the roundtable discussion. During this time, the researcher asked a series of open-ended questions (Table 3) and documented student responses to each question. Students were encouraged to provide vocal and open-ended feedback to all questions. At the conclusion of the discussion, the researcher shared with the students the purpose of the study and specific variables that were being measured.

Table 3

Round Table Discussion

What did you think was the purpose of the research study?
Which modality did you prefer and why? (Response Cards or Chat)
Which modality was most reflective of the queries?
Which modality helped you remember the answers for the queries?
Did you notice the “secret words” (i.e., engagement prompts) throughout the slides?
Did you notice the instruction on the last slide?
Have you used different ASR modalities in your previous classes?
Anything else you would like to share?

Note. 4 of the 17 students enrolled in the study attended the roundtable discussion. ASR = Active Student Responding.

RESULTS

Accuracy on Pre-and-Post-Lecture Queries

The results for the pre-and-post lecture queries across both ASR response modalities are depicted in Figure 6. During the first three baseline conditions, there were no preprogramed OTRs, and the average percentage correct on the pre-lecture queries was 45%, ranging from 40% to 54%. For post-lecture queries, the average percentage correct was 64%, ranging from 53% to 72%. As such, there was an average of 18% improvement between the pre-and-post lecture queries in the baseline conditions.

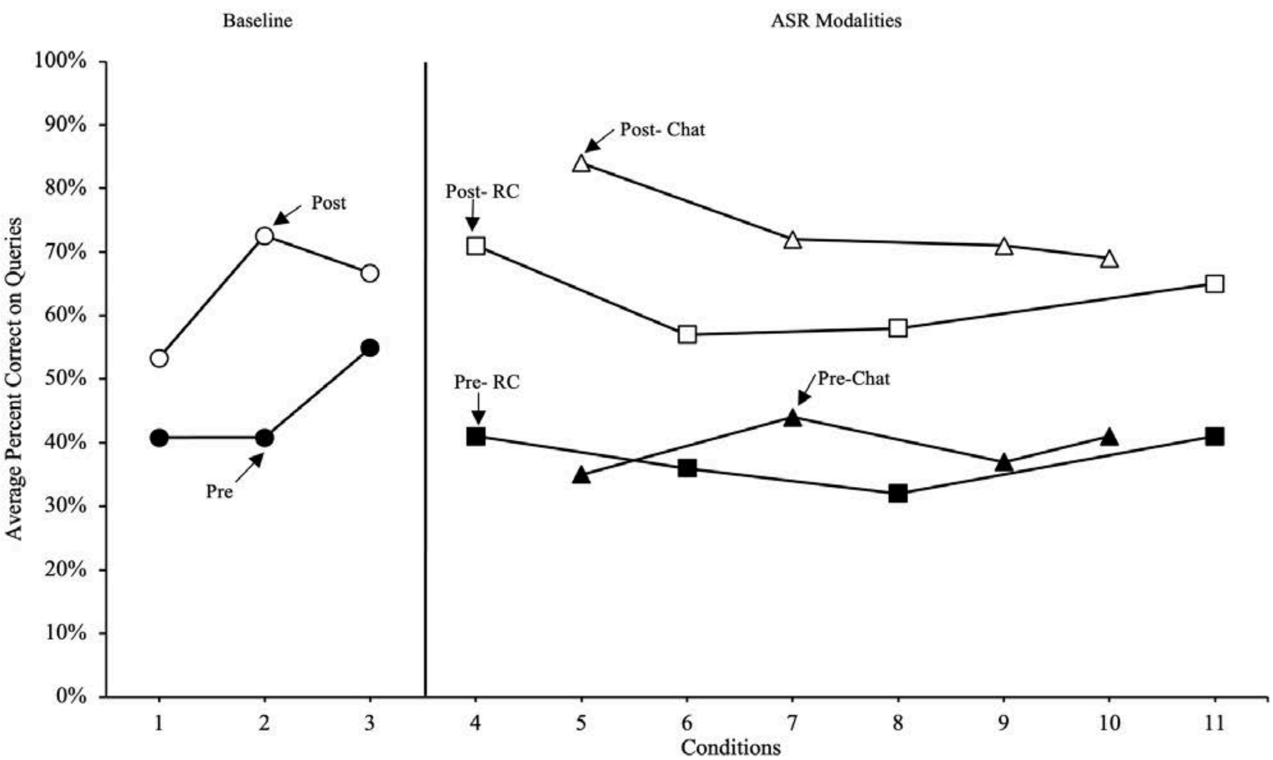

Figure 6. Average Percent Correct on Pre-and-Post Lecture Queries Across All Conditions

During the Response Card (RC) conditions, pre-lecture query scores averaged to 37% correct, ranging from 32% to 41%. Similarly, students averaged to 39% correct on pre-lecture queries during the Chat condition, ranging from 35% to 44% correct. This was approximately the same as baseline responding for pre-lecture queries. Thus, across all three conditions, pre- lecture query scores were relatively consistent.

At least initially, there was clear differentiation between the RC and Chat conditions for the post-lecture queries. There was an average of 25% increase in accuracy of responding on post-lecture queries following the RC condition. There was slight variability across the RC conditions, but overall accuracy on post-lecture queries remained in the same general range as post-lecture baseline conditions. In contrast, there was on average a 34% increase in accuracy on post-lecture queries for the Chat conditions. There was a marked difference between the post-lecture query scores in the Chat conditions as compared to the post-lecture query scores in the RC conditions. However, it is important to note that as the study progressed, there was a gradual decrease in the average accuracy scores for the Chat post-lecture queries. Despite this gradual decrease, average scores on Chat post-lecture queries were always higher than the scores on RC post-lecture queries.

Individual query scores overlayed on the class averages for each pre-and-post lecture query are shown in Figure 7. On the top panel of Figure 7, the individual student data are displayed for the baseline and RC conditions. The bottom panel of Figure 7 repeats the baseline data again, for comparison, to the Chat conditions. In general, across all conditions, there was wide variability in responding in the pre-lecture queries. When evaluating the RC post-lecture queries, there was a wide range of student scores which may indicate that RC had variable effects on correct responses. The Chat conditions in general, however, had more constricted variability or a smaller range and yielded higher overall scores on the post-lecture queries compared to the RC conditions.

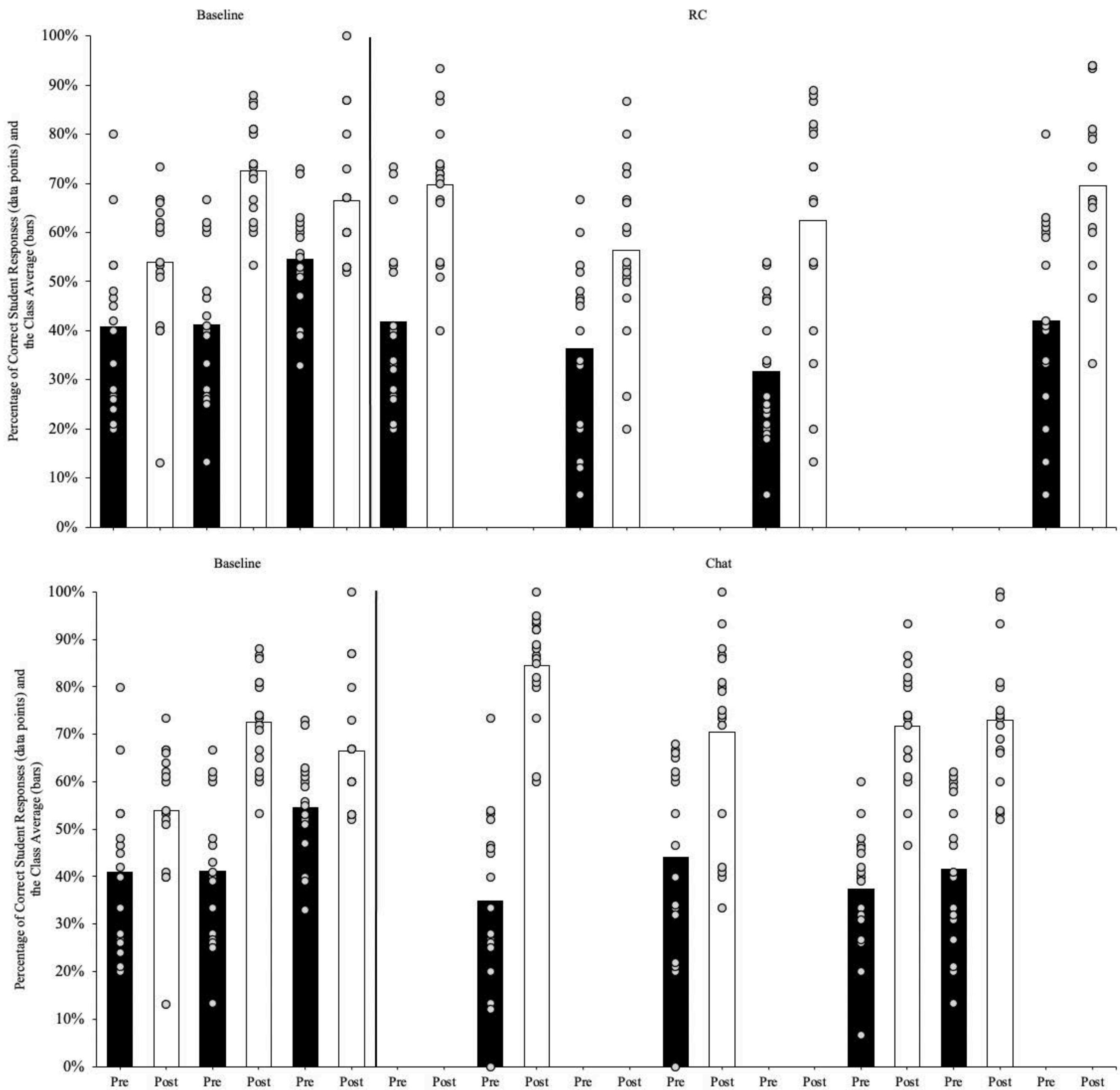

Figure 7. Individual Performance on Pre-and-Post Lecture Queries

The percentage of correct responding to OTRs presented in class are shown in Figure 8. During baseline, no pre-programed OTRs were presented. Thus, there are not data for baseline conditions. On average the group responded 75% correct during the RC conditions and 76% correct during the Chat conditions. Generally speaking, correct responding during the lecture and discussion was undifferentiated across the RC and Chat conditions. It is important to note that the first conditions across both modalities yielded lower scores (65% for RC and 50% for Chat) than all other conditions. Nonetheless, there was little-to-no differentiation between the percentage of group correct responding within the RC and Chat conditions.

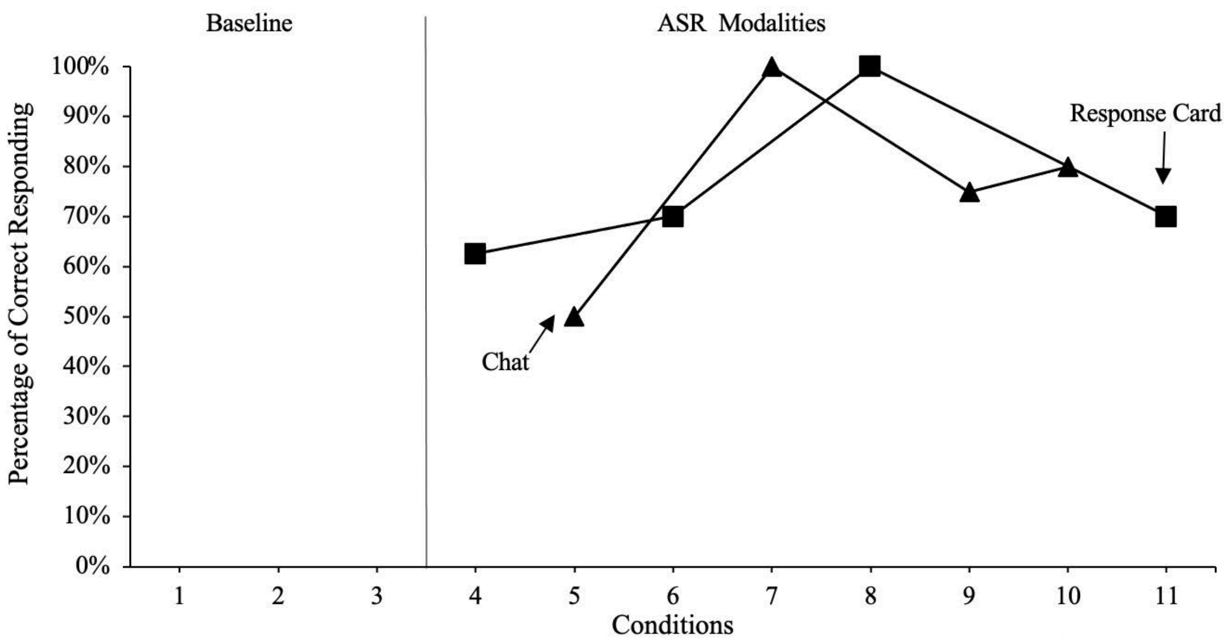

Figure 8. Group Responses Within Response Card and Chat Conditions

Exams and Final

The exam results are displayed in Figure 9. The top panel displays the mean exam scores. The middle panel displays the mean percentage correct on fill-in-the-blank questions. The bottom panel displays student exam scores throughout the study. Across all panels, Exam 1 contained questions from content that was taught in the absence of any preprogramed ASRs; while Exams 2, Exam 3, and the Cumulative Final contained questions related to both RC and Chat ASR conditions.

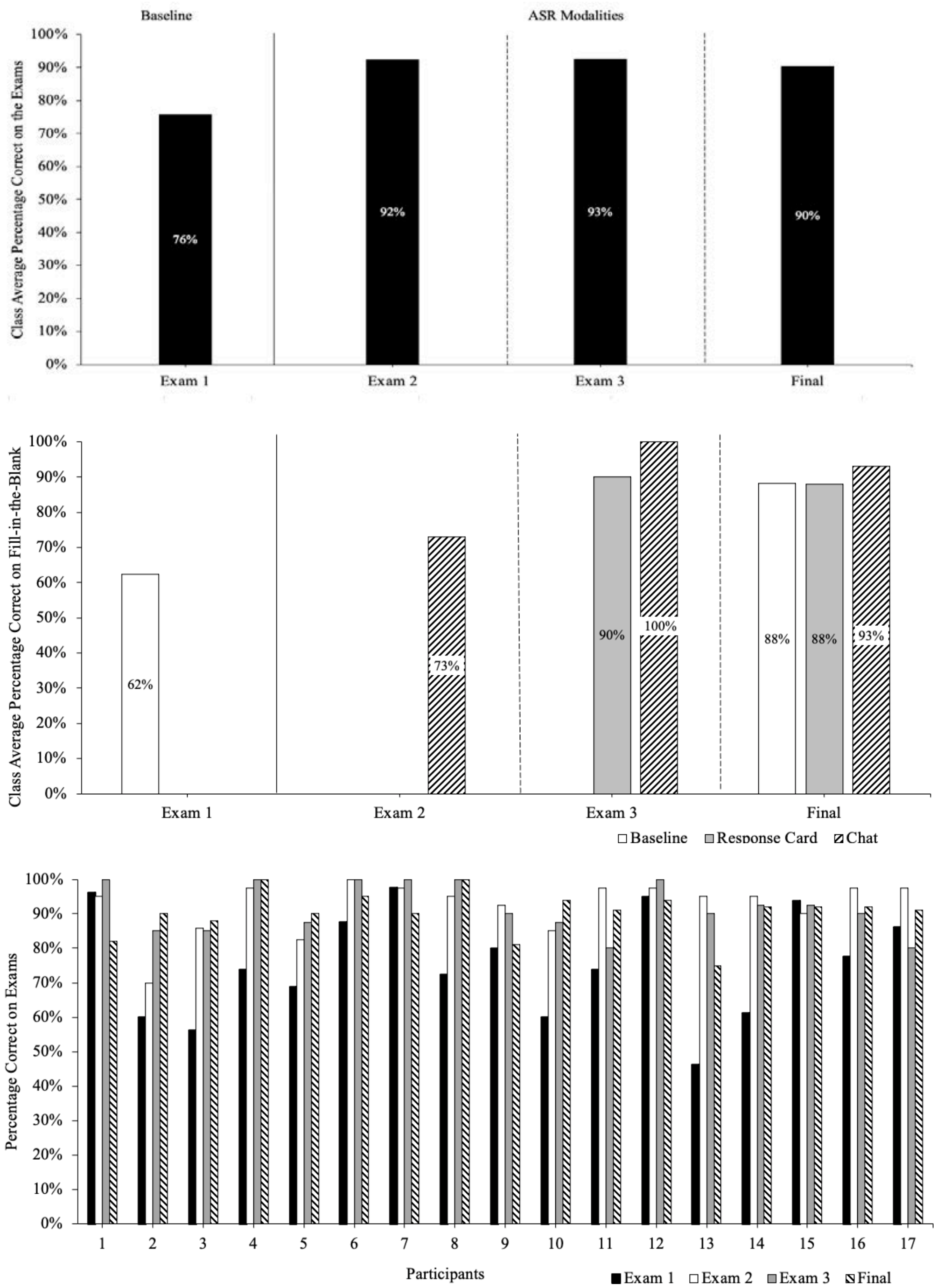

Figure 9. Exam Scores

The top panel of Figure 9 displays the total mean exam scores throughout the study. Exam 1 was administered following the baseline conditions, in which no preprogrammed consequences were embedded in the lecture. The class mean on Exam 1 was 76%. Six students received below 70% correct and five students received between 70% and 84% on Exam 1. As this was a graduate level course, according to university policies, the requirement for a passing grade in the class was 84%. According to this standard, 11 students or 64% of the class did not pass Exam 1 and only students five (29%) received a passing grade. As the semester progressed and as students were exposed to both ASR modalities, there was an average increase of 14% from Exam 1 to Exam 2 (M=92%; see Figure 9, top panel). On Exams 2 and 3, no students received a failing grade and only one student received a grade in the 70% to 84% range. As such, 97% of the class passed Exams 2 and 3. Most importantly 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. Furthermore, when analyzing all exam scores compared to Exam 1 (M=76%), the class on average steadily performed higher in Exam 2 (M=92%), Exam 3 (M=93%), and the Cumulative Final Exam (M=90%).

It was not possible to examine the effects of specific ASR response modalities on exam scores, because each exam contained questions related to class sessions that used RCs as well as questions related to class sessions that used the Chat. Therefore, we disaggregated fill-in-the blank questions that were specific to the lectures in which the information was presented. The middle panel in Figure 9 displays the mean percent correct on fill-in-the-blank questions related to lectures that used RC and lectures that used the Chat by exam. During Exam 1, the class on average responded correctly to 62% of the fill-in-the-blank questions that were identical or closely related to questions in the pre-and-post lecture queries. There was a total of five fill-in-the-blank questions on Exam 2 and the class on average responded correctly to 73% of the fill-in-the-blank questions. There was a total of four fill-in-the-blank questions on Exam 3 and the class on average responded more accurately on questions from the Chat conditions (M=100%) than the RC questions (M=90%). Similarly, for the Cumulative Final, students more accurately responded to the fill-in-the-blank questions that were presented in the Chat conditions (6 questions; M=95%) than baseline (3 questions; M=88%) or RC (6 questions; M=88%) conditions.

The bottom panel of Figure 9 displays the individual exam scores across the 17 students who participated in the study. All students gradually improved their exam scores as the study progressed.

Engagement

Figure 10 shows the total number of correct engagement submissions. There were relatively few submissions (i.e., 2 to 3 submissions) in the absence of either ASR modality (baseline). Once each ASR modality was presented, engagement submissions increased. However, submissions were variable across both conditions. Although the Chat condition initially resulted in a higher number of engagement submissions, eventually the RC condition resulted in a higher number of submissions. In general, however, engagement submissions were disappointingly low across all sessions.

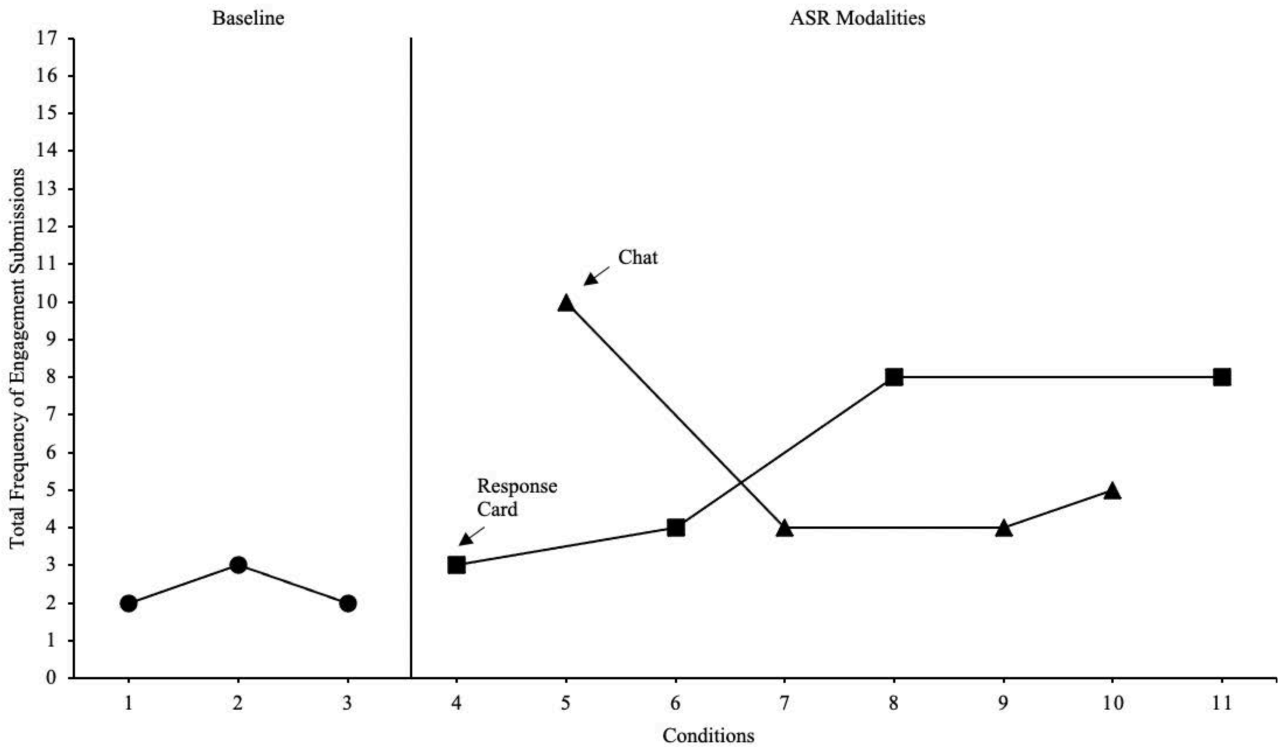

Figure 10. Engagement Submissions Following Active Student Responding Conditions

Another measure of engagement was prompted and independent vocal responses. In the top panel of Figure 11, vocal responses for baseline and the RC conditions are depicted. During baseline sessions, there was an average of 7.3 prompted and 12 independent vocal responses across all conditions. In the RC conditions, students engaged in more prompted vocal responses (M=11.5, range 6 to 13) than independent responses (M= 4, range 3 to 5). During the Chat condition (shown in the bottom panel of Figure 11), students also engaged in more prompted vocal responses (M=13.76, range 4 to 22) than independent vocal responses (M=7, range 0 to 14; see Figure 11, bottom panel). Thus, when comparing vocal engagement across both ASR modalities, the data indicate that students engaged in slightly more prompted and independent responses in the Chat conditions. However, the data are highly variable and undifferentiated from the baseline condition.

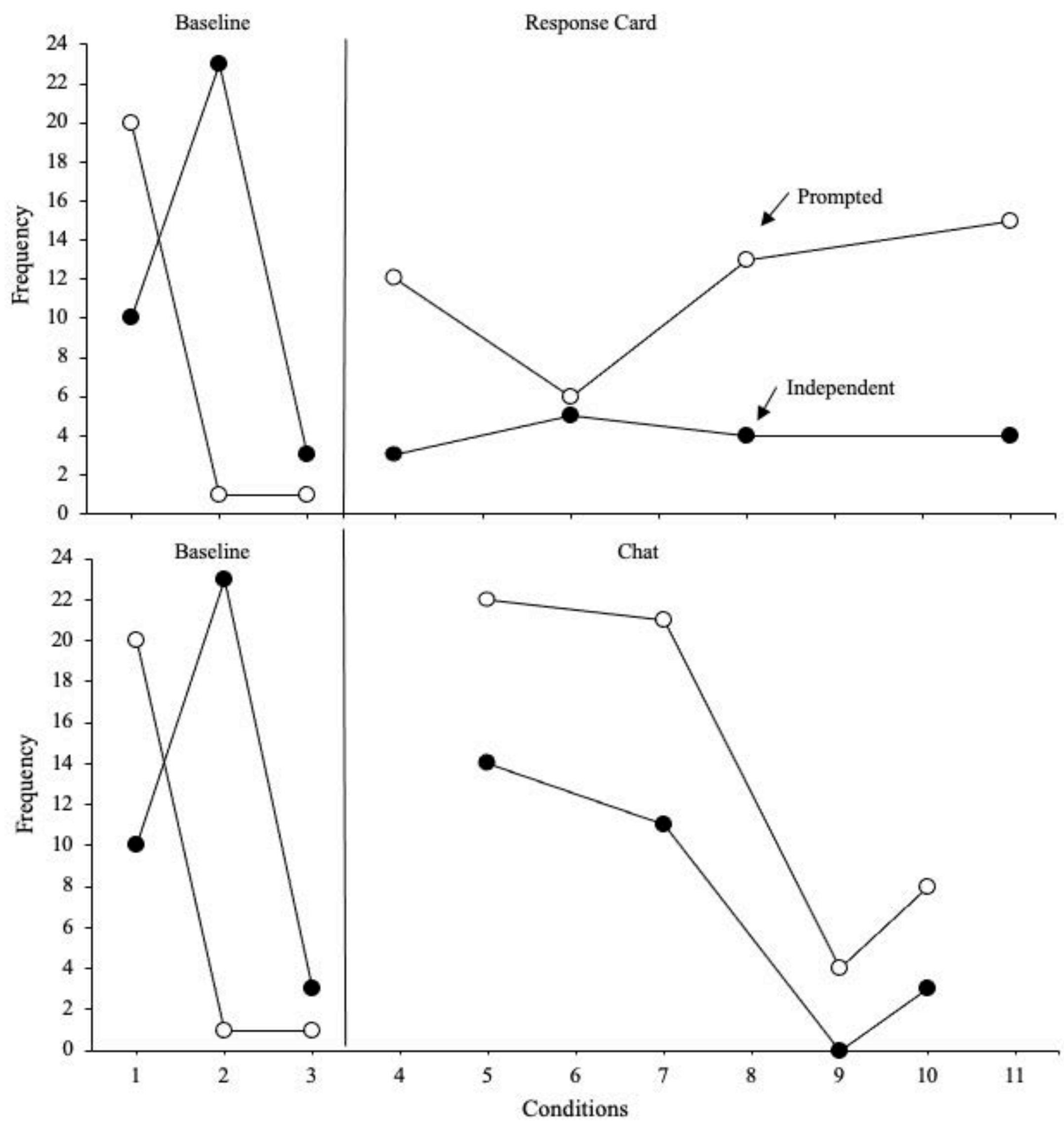

Figure 11. Student Vocal Engagement During ASR Conditions

Procedural Acceptability

The results of the procedure acceptability questionnaire are shown in Tables 4a and 4b. Fifteen of the 17 students (88%) enrolled in the study completed the procedural acceptability questionnaire. Table 4a summarizes student responses to questions that had discrete answers. The majority of students indicated that the RC condition was most preferred (66%) and most engaging (46%) (see Table 4a). The majority of students (60%) believed that neither ASR modality helped them understand the lecture material better.

Table 4a

Procedural Acceptability Questionnaire

	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).

Table 4b summarizes student responses to questions that had a Likert scale for responses. Overall, most students reported that the ASR modalities affected their online class participation and wished all of their online classes used ASR systems like what was used in the current study. When evaluating student perceptions on the “secret words” (i.e., engagement prompts), 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. However, students reported they didn't think the "secret words" were a good measure of their 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.

Four (23%) of students attended the roundtable discussion. Students indicated 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 prompts), 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."

Table 4b

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	13.22	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.

DISCUSSION

The rippling impacts of the COVID-19 global pandemic has affected 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 (Vlachopoulous, 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. This has been frequently demonstrated in elementary and secondary education settings, but rarely in post-secondary education and even more rarely 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, exams, and the cumulative final 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 final purpose was to document graduate student perceptions towards both ASR modalities during online lectures. Analyses of the specific research questions for this study follow.

Given a synchronous online class session in which the instructor provides multiple response opportunities, what are the effects of response cards and a written (chat function) active student response modality on the number of correctly answered questions during class, on pre-and-post knowledge assessments, on exams, and on the cumulative final?

The results of this study indicated that, on average, students performed higher on post-lecture queries during the Chat condition as compared to the RC or baseline conditions.

Moreover, when evaluating the post-lecture query scores across the RC and Chat conditions, there was a less variability for correct responding across post-lecture queries following the Chat conditions. The class performed lower on Exam 1 compared to Exams 2 and Exam 3, where students were required to actively respond to instruction during the online lectures. When analyzing the effects of the RC and Chat conditions on correct responding, students on average performed better on the exams that required active engagement to instruction during lectures compared to lectures that did not require any ASR. Students responded more accurately on Chat fill-in-the-blank questions on Exam 3 (Chat M = 100% and RC M = 90%) and on the Cumulative Final Exam (Chat M = 93%, RC M = 88% RC, and Baseline M = 88%). Importantly, 82% of students passed the Cumulative Final Exam which consisted of twice as many points than all exams.

These findings contribute to our current literature in several ways. The present study represents an initial attempt to analyze a specific instructional strategy designed to increase active student responding (i.e., engagement) in a graduate-level course taught online. As online instructional formats have presented many challenges that may affect student performance (Babatunde et al., 2020), one method to directly address one of the primary concerns is to create a framework that target skills, concepts, acquisition, and engagement (Vlachopoulos, 2020). This framework must include embedding frequent opportunities to respond and active student responding during online lectures. By doing so, instructors would be able to frequently assess for understanding and address students misunderstanding more easily due to real-time feedback (Herreid, 2006). Moreover, as active student responding helps students engage in the lecture materials in a non-aversive fashion (Beeks, 2006; Graham et al., 2007; Gutherie & Charlin, 2004), it is hypothesized the same would be true in an online format.

While the RC and the Chat conditions were methodologically similar, the active student response and the response effort for each ASR modality varied across both conditions. There are several factors that may have contributed to student performance within each condition. That is, students were required to engage in a selection-based response (i.e., multiple choice questions) or a production-based response (i.e., fill-in-the-blank) (Medawela et al., 2018).

In the RC or selection-based conditions, students were required to read the instruction and select one correct response out of three responses displayed on the screen. For multiple choice questions, students are asked to select the best possible answer from the choices listed (McKenna, 2019). While multiple choice questions are an efficient and popular form of assessment across many disciplines (Kuechler & Simkin, 2010; Stovall, 2013), 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 which may be a better indicator of student understanding or knowledge. For fill-in-the-blank questions, a list of choices is not provided, and students are required to supply their own answers to a question or a prompt (Jonick et al., 2017). Some may argue that fill-in-the-blank questions may provide a more robust learning experience and promote critical thinking (Jonick et al., 2017). When evaluating the ASR modality and the response effort (i.e., multiple choice or fill-in-the-blank), one must acknowledge how these factors may have contributed to student performance which align with the behavior analytic literature towards alternating between both formats to determine the effects on student engagement and academic performance.

Another factor that may have contributed to higher performance in the Chat conditions compared to the RC conditions was the repetitive feedback displayed by peers in the public Chat forum. For example, when students actively responded in the Chat condition, this may have served as a permanent product and thus produced 17 examples of the correct active student response to the instruction. This in turn, may have increased the probability of students responding correctly to the instruction the next time it was presented on the post-lecture query or exam. While students were able to see approximately four of their peers screen when actively responding in the RC conditions, it hypothesized that the permanent product in the public chat form was more salient feedback than the visual feedback from a select number of peers.

When evaluating the extent to which active student responding maintained over time, the pre-and-post lecture queries and exams were administered. Given the short temporal contiguity between synchronous online lecture and post-lecture queries, students were required to recall the information presented during the lecture in a relatively short timeframe which may have contributed to higher scores in the post-lecture queries for some students. In an attempt to measure the maintenance of the content presented during the lecture, identical or similar questions from the lectures appeared on the Exams and the Cumulative Final Exam. While there were other factors that may have contributed to scores on the more formal knowledge assessments (i.e., previous exposure to lecture content, sequencing effects, and time allocated to studying), it is hypothesized that exposure to both active student response modalities positively increased the maintenance over time given the high percentage of accurate responding across the Cumulative Final Exam and Exams 2 and 3 for the fill-in-the-blank questions.

As it relates to evaluating response accuracy from pre-and-post lecture queries and exams, future researchers should extend the current study by assigning points to pre-and-post lecture queries. By doing so, researchers may be able to evaluate if the scores are reflective of a skill deficit or a motivation factor. To systematically assess the generalization of concepts and skills throughout the study, future researchers may also program in generalization questions on the exams to evaluate if content taught during the synchronous online lectures generalized to other skills and concepts through short answer or think-a-loud formats.

While the effects of both response modalities increased student performance throughout the duration of the study, some limitations should be noted. The instructor and co-instructor developed all pre-and-post query questions as well as the questions on the Exams and Cumulative Final Exam. As such, it is possible that the quality of the presented questions may have varied across each condition. While the both the instructor and co-instructor thoroughly reviewed all exam questions, there was overall a lack of systemic question development. As such, future researchers should develop an internal review process for questions that will be presented throughout the lecture, exams, and finals.

It is possible that a testing effect was present during the exams which may serve as a limitation to the current study (Roediger & Karpicke, 2006). The first exam was proctored, meaning that the students were required to show up to a designated location and both the instructors and co-instructor monitored the students take the exam. Due to increasing cases of the novel COVID-19 virus, the remaining Exams 2, Exam 3, and the Cumulative Final Exam were administered asynchronously. While all exams, rather proctored or asynchronous, used Respondus lockdown feature, were timed, and clear consequences were outlined for graduate students breaching academic integrity, it is possible that this may have impacted exam scores. Moreover, it is also possible that the baseline exam score was lower due to the novelty effect of the first Exam. As such, future researchers should evaluate the effects of proctored vs non-proctored exams using Respondus Lockdown on student exam scores.

Given that there is limited research evaluating these specific variables in our literature, this study may serve as foundational research in this area. By evaluating methods to increase student response accuracy, instructors will then be able to further refine their teaching practices in an individualized manner through online environments.

Given a synchronous online class session, what are the effects of various response modalities (i.e., Response Cards and Chat) for active student responding on graduate student engagement?

Engagement was measured across two topographies including permeant product to engagement (i.e., engagement submissions) and vocal-verbal engagement (i.e., students vocally engaging with lecture content). While the number of engagement submissions varied per ASR modality, students progressively submitted more engagement prompts throughout the study following the RC conditions than following Chat or baseline conditions. However, this progressive pattern of responding was not similar for vocal engagement. During the first baseline condition, there were higher prompted responses compared to all other conditions. It is hypothesized that the high frequency of responding was due to this condition being the first synchronous class condition and the instructor presented frequent prompted questions. During the second baseline condition, it is hypothesized the high frequency of responding was due to the instructor covering a topic (i.e., preference and reinforcer assessments) that was very applicable to the graduate students current practicum training. Nonetheless, vocal-verbal engagement was variable in the baseline conditions as well as the ASR modalities. One factor that may have contributed to lower vocal-verbal engagement during the last two Chat conditions was the inclusion of a guest lecturer during conditions 3, 9, and 10. That is, students may have not engaged in more vocal-verbal responses due to the novelty of a guest lecturer or students may have been more hesitant to ask questions (e.g., jump in to immediately ask a question or wait until the guest lecturer asked the class for questions).

Evaluating engagement during synchronous online lectures is challenging as students may be oriented towards the computer, but may not have lecture slides displayed, may not have their camera on, or may be engaging in off-task class behavior (i.e., checking e-mail or checking social media) while still oriented towards the computer screen. There is little to no research that has evaluated a method to measure student engagement during synchronous online sessions. Future research may consider the effects of displaying simple instructions on the lecture slide (e.g., if you can see this, wave in the camera) as an analogue to student engagement during online lectures. Future researchers may also assign point contingences for vocally contributing during synchronous lectures.

One consideration is the data collection method to assess for engagement. For example, the engagement prompt appeared on the PowerPoint slide and students were required to write down the words and submit it to the co-instructor as a proxy to engagement. It is possible that there may be a less effortful, yet discrete method to measure engagement during a synchronous graduate level course. Future researchers are encouraged to evaluate measures of engagement in online formats. Moreover, point contingencies were not assigned for submitting engagement prompts. As such, future research should evaluate the effects of assigning point contingences on student engagement. Furthermore, while the intent of the current study was to make synchronous lectures similar to in-person lectures, which typically includes guest lectures, it is also possible that the one baseline condition and the two Chat conditions that involved guest lecturers may have impacted student engagement. A potential limitation to the current study was the inability to monitor all student responding during the Chat active responses. That is, when an active response and the cue was presented all student responses rapidly appeared in the public Chat form. Thus, the researchers did not explicitly monitor if all 17 students responded in the Chat, rather once a large portion of the group responded either behavior specific praise or the error correction preceded. As such, future researchers should develop systems that closely monitors all student performance in the public Chat forum and assign points to active student responses across both conditions.

Given experience with various response modalities for active student responding (i.e., Response Cards and written responses in the chat), what are the stated perceptions of the various modalities by participants enrolled in the synchronous online course?

Interestingly, even though students performed better on the post-lecture queries following the Chat conditions, the majority of students indicated that the RC conditions were most preferred and more engaging. Moreover, students believed that the inclusion of the “secret words” (i.e., engagement prompts) had little to no impact on their level of engagement. There are several factors that may have contributed to these perceptions related to the ASR modalities and engagement.

One factor that may have contributed to the RC condition being more preferred was the format of the active student response. That is, within the RC conditions students had a 33% chance of selecting the correct answers as three answers were simultaneously displayed for each active response. It is possible that the examples and non-examples on the active response slides contributed to the RC conditions being more preferred as it increased the probability of students selecting the correct answer. A second factor that may have contributed to the RC being more preferred is the anonymity or lack thereof between both conditions. Due to students actively responding by holding up response cards and the format of the Cisco Webex screen, if a student responded incorrectly only the co-instructor and potentially four students were aware of the incorrect response. As such, when a student responded incorrectly during the RC conditions, there was a certain degree of anonymity which may have functioned as a perceived benefit to the students (Zayac et al., 2015). On the other hand, if a student responded incorrectly in the Chat conditions, it was more salient to the other students in the course who responded incorrectly as all active responses were publicly displayed in the Chat forum. While there was not a large difference between accurate responding within each condition (RC M= 75%; Chat M=76%), students reported that the social pressure to respond correctly was more significant in the Chat conditions compared to the RC conditions.

The final factor that may have contributed to students preferring the RC conditions over the Chat conditions was the response effort. When comparing the response effort between the two conditions, the Chat condition required students to correctly type one to three words in a 5 to 10 second timeframe. Given the variability of accurate typing speed, this may have been a variable that impacted the procedural acceptability of the Chat conditions. As response effort produces shifts in response allocation (Friman & Poling, 1995), there is value in further analyzing selection-and-production based responding in both public and private online forums to determine its impacts on student performance and perceptions. While the current study suggests higher performance outcomes occurred following the Chat conditions and previous research demonstrates a poor correlation between exam scores and student's options on the enjoyment and usefulness of activities (Wesp & Miele, 2008), further research is warranted in this area.

Moreover, given that 88% (15 out of 17) of students completed the procedural acceptability questionnaire and 23% (4 out of 17) of students attended the roundtable discussion, the perceptions for all students enrolled in the study are not displayed in results. Nonetheless, it is recommended that future researchers embed point contingencies for student to complete the procedural acceptability questionnaire and to attend the roundtable discussion to receive a more comprehensive assessment of the procedural acceptability. As student perceptions are a critical factor to the procedure, it is valuable to continue to seek out student perspectives and perceptions on their educational experience, especially given the sudden shift to a novel online education environment.

Summary

In closing, the impact of active student responding and opportunities to respond have proven to be effective across many educational settings and are appropriately referred to as best-practice instructional strategies. Given the swift change to teaching in online formats, there is value in analyzing the effects of procedures that have been experimentally validated in traditional learning format to online formats. Furthermore, as online education formats have been the primary educational forum, evaluating best-practice instructional strategies through an online format would provide useful research to the community. This study demonstrates that students responded more accurately on knowledge assessments following conditions that required students to type out the correct response when an instruction was presented. Moreover, the skills and concepts taught in this condition accurately maintained during the exams and the cumulative final exam.

When evaluating instructional methods during synchronous online formats, additional research is warranted. This study serves as an attempt to systematizing and increasing instructional quality through synchronous online educational formats. Dewey (1916) noted that students learn by doing and that learning is an active process. As such, there is value evaluating methods to keep students actively engaged to increase student and instructor capacity especially through online instructional formats.

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Appendix A: Human Subjects Institutional Review Board

[redacted]

Human Subjects Institutional Review Board

Date: September 4, 2020

To: Stephanie Peterson, Principal Investigator
Nicole Hollins, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 20-08-19

This letter will serve as confirmation that the change to your research project titled "On Blending Active Student Responding with Synchronous Instruction to Evaluate Response Accuracy" requested in your memo received September 3, 2020 (to add research question, increase number of questions on Query, modify student engagement and accuracy of responses operational definition) has been approved by the [redacted] Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of [redacted] University.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: **August 28, 2021**

[redacted]

Appendix B: Informed Consent

IRB Approved

Approved for use for one year from this date:

AUG 29 2020

Psychology Department

Principal Investigator: Stephanie Peterson, Ph.D., BCBA-D, LBA
Student Investigator: Nicole Hollins, M.A., BCBA, LBA
Title of Study: On Blending Active Student Responding with Synchronous Instruction to Evaluate Response Accuracy

You are invited to participate in this research project titled, "*On Blending Active Student Responding with Synchronous Instruction to Evaluate Response Accuracy*"

STUDY SUMMARY: This consent form is part of an informed consent process for a research study and it will provide information that will help you decide whether you want to take part in this study. Participation in this study is completely voluntary. This project will serve as Nicole (Student Investigator) dissertation project for the requirement of the Doctor of Philosophy degree in Behavior Analysis. If you take part in the research, you will be asked to complete a social validity survey and a demographic survey. Your time in the study will take 10-minutes. There are no costs or risks to you participating in this project and potential benefits of taking part may be assisting instructors that are shifting to synchronous instruction with feedback on a preferred and effecting teaching format. Your alternative to taking part in the research study is not to take part in it.

You are invited to participate in this research project titled *"On Blending Active Student Responding with Synchronous Instruction to Evaluate Response Accuracy"* and the following information in this consent form will provide more detail about the research study. Please ask any questions if you need more clarification and to assist you in deciding if you wish to participate in the research study. You are not giving up any of your legal rights by agreeing to take part in this research or by signing this consent form. After all of your questions have been answered and the consent document reviewed, if you decide to participate in this study, you will be asked to sign this consent form.

What are we trying to find out in this study?
The purpose of this project is to identify the most effective teaching formats through synchronous instruction. Outside of what is already apart of the course structure, you will not be asked to complete additional tasks other than a social validity survey and a demographic survey.

Who can participate in this study?
Any student enrolled in a synchronous graduate-level course at [redacted] can enroll in the current project.

Where will this study take place?
This project will take place during the pre-determined synchronous course time period.

What is the time commitment for participating in this study?
The time commitment for this project will range in the length of time it takes to complete a social validly survey and a demographic survey. Thus, the total approximate time commitment is 10-minutes.

What will you be asked to do if you choose to participate in this study?
During the project, you will be asked to attend every synchronous session as indicated on the syllabus. You will also be asked to complete a social validity survey and the demographic survey.

What information is being measured during the study?
During this project, data will be collected on the instructor's various evidence-based teaching formats, including low-technological and standard teaching formats. Data will also be collected on the total percentage of check-in and check-out queries throughout the different formats and student engagement. Concluding the project, data will be collected on the preference of each teaching format and relevant demographic information.

What are the risks of participating in this study and how will these risks be minimized?
Participation in this project does not involve any risks other than breach of confidentiality. Confidentially will be ensured by de-identifying all electronic data sheets and surveys, excluding all identifiable descriptions, and collecting data in a private office.

What are the benefits of participating in this study?
The primary objective of this project is to disseminate to other professionals different teaching formats that are most effective in obtaining high response accuracy. Currently, there is minimal research for synchronous instruction and varying teaching formats; thus, the educational outcomes of this project may provide foundational data and serve to guide future research.

Are there any costs associated with participating in this study?
There are no costs associated with participating in this project.

Is there any compensation for participating in this study?
There is no additional compensation for participating in this project.

Who will have access to the information collected during this study?
The principal investigator and student investigators will have access to the information. The investigators will keep all data and recorded lectures collected for this project in a secure online platform. Concluding the semester, data will be stored in locked office, in a locked filling cabinet

IRB Approved

Approved for use for one year from this date:

AUG 29 2020

at [redacted] on an encrypted flash drive. We may present the educational outcome data from this research project at conferences and use it in theses and dissertations. All data will be de-identified to protect all information participant information.

What will happen to my information collected for this research after the study is over?
After information that could identify you has been removed, de-identified information collected for this project may be used by or distributed to investigators for other research without obtaining additional informed consent from you.

What if you want to stop participating in this study?
You can choose to stop participating in the study at anytime for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study.

The investigator can also decide to stop your participation in the study without your consent. Should you have any questions prior to or during the study, you can contact the primary investigator, Stephanie Peterson at 269-387-4479 or stephanie.peters[redacted]. You may also contact the Chair, Human Subjects Institutional Review Board [redacted] or the Vice President for Research at [redacted] if questions arise during the course of the study

This consent document has been approved for use for one year by the [redacted] indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

Please only sign one of the following options.

By signing this, **I consent** for my anonymous data to be used for this research project:
Please Print (type) Your First and Last Name:____

Participant's Signature　　　　　　　　Date

By signing this, **I do not consent** for my anonymous data to be used for this research project:
Please Print (type) Your First and Last Name:____

Participant's Signature　　　　　　　　Date

Appendix C: Operational Definitions for Secondary Variables

Appendix C

Variable	Operational Definition
Planned OTR	Any instance where the instructor presents a PowerPoint slide with the typed-out question and an image of the modality to respond.
Unplanned OTR	Any instance where the instructor presents a question that does not include a PowerPoint slide with the typed-out question and an image of the modality to respond (e.g., "Can anyone think of an example of…?").
Number of Lecture Slides	The total number of lecture content slides, excluding the title slide and the active student responding slides.
Duration of Lecture	The total amount of time the instructor is lecturing on course content.

Secondary Operational Definitions

Note. Total of 4 secondary operational definitions. OTR = Opportunity to Respond.

Appendix D: Procedural Fidelity

Appendix D

Procedural Fidelity

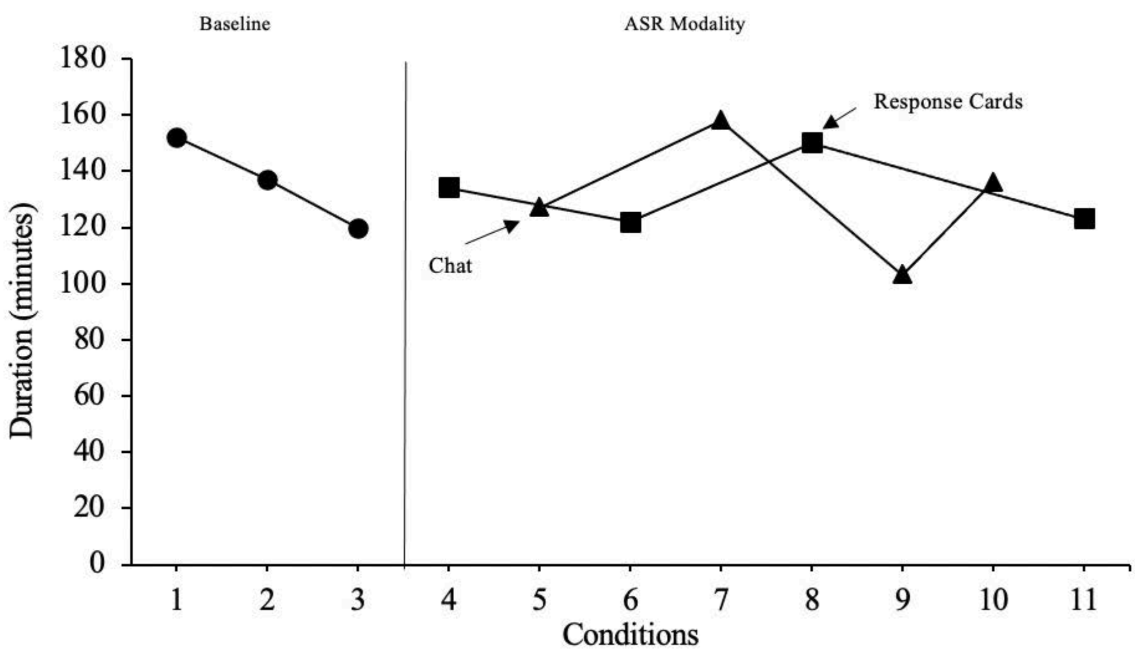
Date					
Initials					
Condition					
Before Class					
Pre-Query Available					
Present Expectation Slide and Modality					
During Class					
Planned OTR					
Wait 5 to 10 seconds					
Signal					
Error Correction					
Present Engagement Prompts					
After Class					
Post-Query Available					

Note. Occurrence (1) or non-occurrence (-) data were collected for each condition. Opportunity to Respond = OTR.

Appendix E: Duration of Synchronous Sessions

Appendix E

Duration of Synchronous Sessions

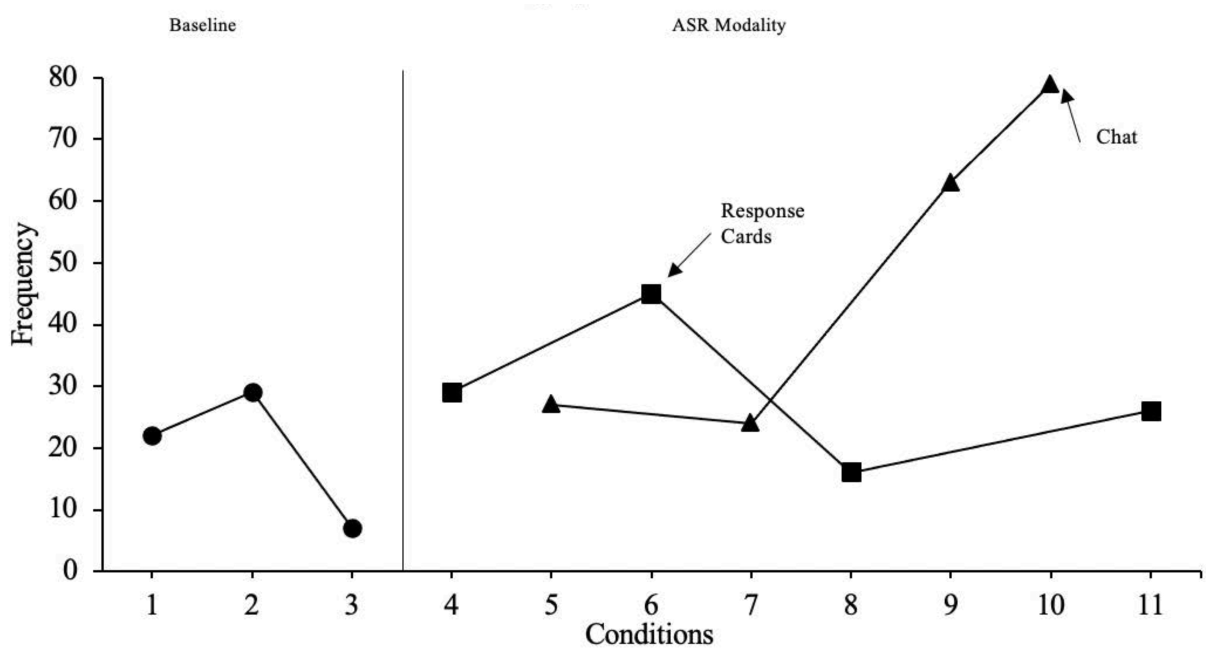


Note. All sessions were synchronous at the same virtual location.

Appendix F: Slides Presented During Synchronous Sessions

Appendix F

Synchronous Lecture Slides

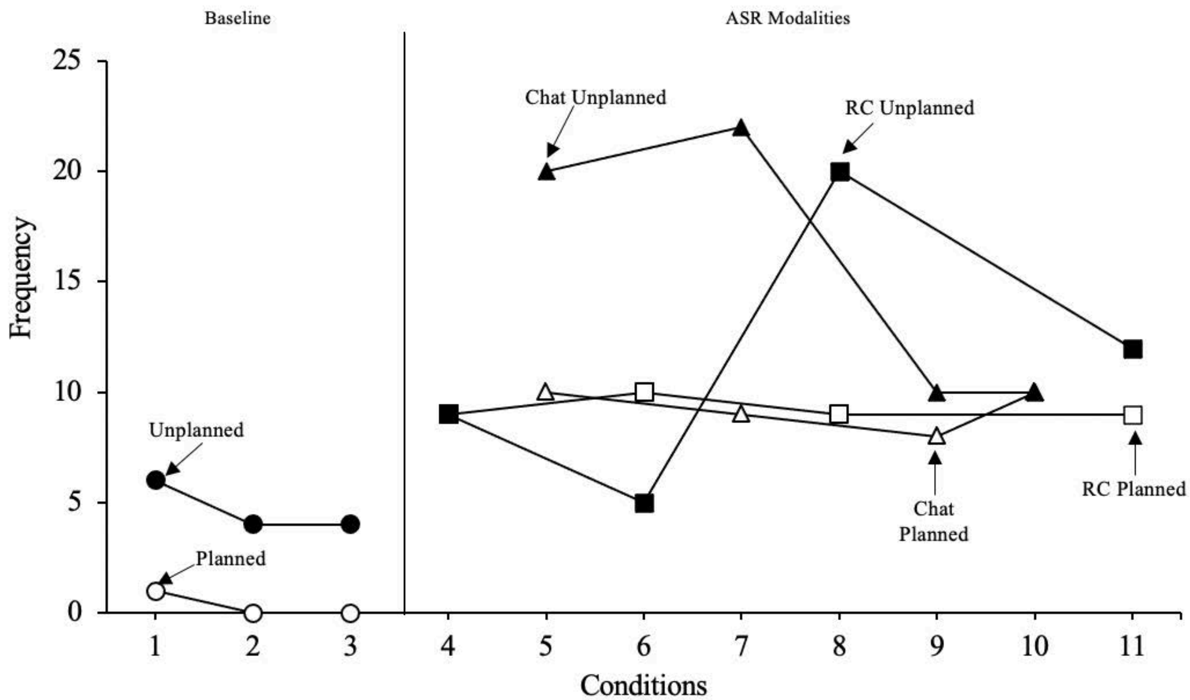


Note. Guest lecturers were present for conditions 3, 9, and 10.

Appendix G: Opportunities to Respond During Synchronous Sessions

Appendix G

Opportunities to Respond During Synchronous Sessions



Note. Baseline condition did not include preprogramed active student responses. RC = Response Cards.