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Online demonstration experiments as experiential learning

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Abstract. Demonstration experiments are commonly used as a teaching tool in courses in experimental linguistics, cognitive psychology and cognitive science. This paper presents an inquiry into the impact of participating in demonstration experiments on student learning. This inquiry frames demonstration experiments as a form of experiential learning. As such, the experiment exercises were designed following the Co-Constructed Developmental Teaching Theory (Shenk & Cruikshank 2015), a model of experiential teaching inspired by the cognitive neuroscience of learning. One demonstration experiment exercise on the concept of categorical perception is presented in the context of an introductory-level course in cognitive science.

Keywords. experiential learning; cognitive science; experimental linguistics; undergraduate teaching

1. Introduction. It is implicitly accepted in linguistics and related programs that participation in demonstration experiments has positive impacts on learning. There are many relevant demonstrations online for teaching purposes (e.g., Kenneth Forster's masked priming demonstration; Forster 2003, and the Interactive Sensory Lab Exercises; Schwartz & Krantz 2015, companion to Schwartz & Krantz's 2023 textbook). However, there has been little inquiry into students' experience of experiment participation, and how that experience relates to course goals. This work endeavours to fill that gap. The findings presented here are from an introductory course in cognitive science, focusing on a demonstration experiment on speech perception. Although this is not a linguistics course, the course material has a focus on the cognitive science of language. The findings presented here could be applied to many courses in introductory linguistics, psycholinguistics, and speech science.

The course under study serves as an introduction for students entering a cognitive science major or minor program, but is often taken as an elective by students in other disciplines. In summer 2022, when this inquiry was conducted, sixteen out of eighty-two students were pursuing a degree in cognitive science or one of the subfields included in Simon Fraser University's interdisciplinary program. One theme of the course is that much of the human mind's information processing is not accessible to our conscious awareness. For example, some processes proceed at too short a time course to allow for conscious reflection. A *science* of cognition, in which psychological experiments, findings from neuroscience, and computational models are brought to bear on the architecture of the human mind, is therefore critical. Having students compare their subjective experiences to the findings from the scientific literature can serve to emphasize this theme. Introductory courses in linguistics often emphasize a similar point, that language users have implicit knowledge of the structure of a language that can be made explicit through linguistic analysis.

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With this theme in mind, the guiding question for this inquiry is *in what ways does the use of demonstration experiments support students' ability to compare their conscious experiences of cognition to the findings and theories in cognitive science literature in a first-year cognitive science course?* My hypothesis is that participating in the demonstration experiment activities will invite students to engage in metacognitive reflection. The exercises will encourage students to reflect on their conscious experiences during the exercise and any strategies they used, and then compare this experience to existing findings. Ideally this will result in deeper understanding of the course material. Although the activity is experiential in the sense that it provides students with the experience of participating in experiments, it is different from some other examples of experiential learning. For example, the goal of the activity is not to improve students' performance on the experiments themselves. Nonetheless, following a current model of experiential teaching, the Co-Constructed Developmental Teaching Theory (CDTT) by Schenk & Cruikshank (2015), provides a structure to the inquiry and increases comparability with other SOTL inquiries on experiential learning. The CDTT takes findings from the neuroscience of learning into account in developing effective experiential learning exercises. Below, I will describe one demonstration experiment activity on speech perception in relation to the CDTT framework before presenting the findings of the inquiry. The critical concept to be learned is categorical perception: although some distinguishing acoustic aspects of speech sounds can be manipulated continuously, perception for those sounds follows a categorical pattern (see, e.g., Liberman et al. 1957).

2. Framework.

2.1. THE CO-CONSTRUCTED DEVELOPMENTAL TEACHING THEORY. The CDTT is a theory of experiential teaching. A key goal of the CDTT is to provide a model based on important results in the cognitive (neuro)psychology of learning. These include the idea that the human brain has limited resources for information processing at any given moment, and these resources must be allocated selectively. Instructors create an environment for effective learning through an experience by drawing attention to important information, setting explicit goals, and priming key concepts. Experiential learning can provide multiple modalities of information processing and create an emotive connection to the information, both factors which can improve memory retention. The model further assumes that much of information processing happens below the level of conscious awareness, and that instructor's choices can guide these unconscious processes, thereby freeing up resources for the more intensive, conscious processes of learning. These ideas inform the five components of an experiential education activity proposed in the CDTT: *Framing, Activity, Direct Debriefing, Bridge Building* and *Assimilation*. In the next sections, I will describe how I implemented each of these five components in the current inquiry.

2.2. FRAMING THE EXERCISE. Instructor framing of an experiential exercise engages learners and reduces students' cognitive load by explicitly setting a high-level goal for the exercise. For this exercise, students were divided into pairs consisting of a Partner A and a Partner B. These pairs were assigned at random and maintained for the entire term. Only Partner A participated in this demonstration experiment before the direct debriefing. Because the students were meant to be experiencing this type of psycholinguistic experiment for the first time, it was ideal for them to be fairly naïve to the purpose of the experiment before debriefing with Partner B after participation. Therefore, Partner A was only given instructions on how to complete the experiment and was told that they may find some of the decisions difficult. In class, the instructor explained that the experiment would be relevant to the class topic for the following week, which was perception.

2.3. THE ACTIVITY. The demonstration experiment was a phoneme identification task (see, e.g., Liberman et al. 1961). In this task, Partner A listened to computer-synthesized syllable sounds on a spectrum from /da/ to /ta/, with Voice Onset Time (VOT) values at set increments from 0 to 60ms.[1] On each trial, the student chose whether they heard /da/ or /ta/, and their responses were recorded. Each student completed a total of sixty experimental trials across the VOT increments. The experiment was implemented via the Penn Controller for Internet Based Experiments (Zehr & Schwarz 2018). Partner B instead read a one-page summary of the phenomenon of categorical perception. After the Direct Debriefing portion of the exercise, Partner B was also given an opportunity to complete the experiment.

2.4. DIRECT DEBRIEFING. Each pair of students met during class time to complete a set of response prompts. In some of these, one partner 'interviewed' the other and some were meant to be completed together with discussion.

2.5. BRIDGE BUILDING. Aggregate data were presented by the instructor as a part of a lecture on perception of spoken language. Students were invited to compare their own results with the published literature and speculate about any discrepancies found. This part of the exercise also provided an opportunity to discuss the diversity of students' language backgrounds and how these may have influenced individuals' responses. Figure 1 shows a lecture slide with a graph of student results. The average line shows a classic pattern of categorical perception, where there is a sinusoidal curve with a sharp increase in the number of 'ta' responses past a threshold.

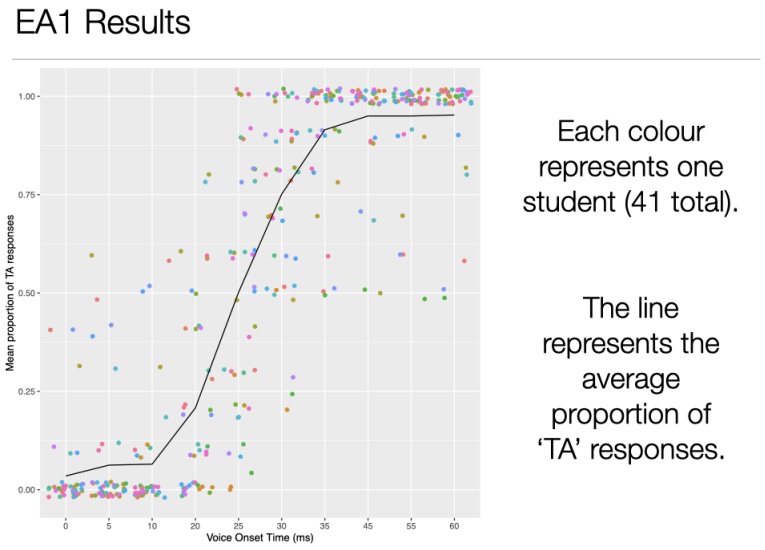

Figure 1. Slide presenting results in class

2.6. ASSIMILATION. Assimilation involves the integration of the learning event into autobiographical memory (Schenk & Cruikshank 2015). Assimilation in this activity was assessed via a post-activity reflection survey. In the survey, students rated statements about their learning related

[1] I thank Phillip Monahan for the use of his experimental stimuli.

to the experiments, written summaries, partner discussion, and instructor discussion. These statements were chosen to address the impact of the experiment activity with the learning objectives of the course, and the hypothesis that such activities would foster metacognition.

3. Results. In this section, I will focus on analysis of student responses relevant to the hypothesis that demonstration experiment exercises have an impact on students' metacognition. Students consented individually to have their responses included in this inquiry. For the direct debriefing, only those pairs where both partners gave their consent are included.

3.1. DIRECT DEBRIEFING RESULTS. Responses from 22 pairs of students were in-cluded in an informal qualitative analysis.[2] In the first prompt, Partner A described their experience completing the experiment to Partner B. Examining themes from the students' submitted responses, most found the experiment easy (10 responses) although some found it hard and some had mixed impressions. Many found the experience to be odd or unusual (7 responses). In terms of guessing the purpose of the experiment, several students thought the purpose was to tell how well similar sounds are distinguished. The majority of students who participated said that they gave instinctual or intuitive responses during the experiment (12 responses). Many (10 students) found the experiment to be repetitive. Some students noted in their discussion that they wondered whether the language background of the participant would matter. One (abridged) response indicative of a students' thinking about their own thinking is included below in Figure 2.

"I found it relatively easy because it was just looking at our instinctual responses so I didn't overcomplicate whether the sound was (ta) or (da). I presumed the purpose to evaluate our perception of sounds based on the languages that we know. So essentially how languages can influence the perception of sounds we hear. The way I decided to respond was instinctually as soon I heard a sound I decided whether or not it was (ta) or (da) and went with first interpretation."

Figure 2. Sample student response to the experience description prompt.

In the second prompt, Partner B summarized the phenomenon of categorical perception as outlined in the one-page summary. While there was a range of levels of understanding demonstrated, many provided satisfactory summaries of the phenomenon. For those that did not provide an accurate summary, some contained misunderstandings about the phenomenon and some provided a response that was too general.

In a third prompt, students reflected on what they had learned. The themes that emerged were surprise at the phonetic similarity of [t] and [d] sounds (15 responses) and surprise at the importance of Voice Onset Time in speech perception (15 responses). Thirteen pairs mentioned finding the phenomenon intuitive, while nine pairs found it unintuitive.

Finally, students were asked to address the impact of the paired interview exercise and their impression of the exercise overall. The prompt asked students to include three words to summarize their experience; the words that emerged frequently were *interesting, educational, novel, informative* and *simple*. A sample response for this prompt that relates to a major course theme is shown in Figure 3.

[2] All prompts in the inquiry are available in an online supplement here:
https://drive.google.com/file/d/1pBvHar9vKYd4bWR2vnVohRd3LGkebPOn/view?usp= sharing

"It's astonishing to us how so much power is given to our perception of things. Much of our perception can happen subconsciously without us putting a lot of thought into it."

Figure 3. Sample student response to the impact prompt.

3.2. ASSIMILATION RESULTS. Survey responses from 61 students are included. In the quantitative portion of the survey, students rated 12 statements on a Likert scale with response options *Strongly Disagree, Somewhat Disagree, Neutral, Somewhat Agree* and *Strongly agree*. Histograms for statements relating to metacognition are shown in Figure 4. A one-sample, one-sided sign test was conducted for responses to each statement to test whether the median response was reliably above 'Neutral'. For all tests, medians were above 'Neutral' with all p-values < 0.001.

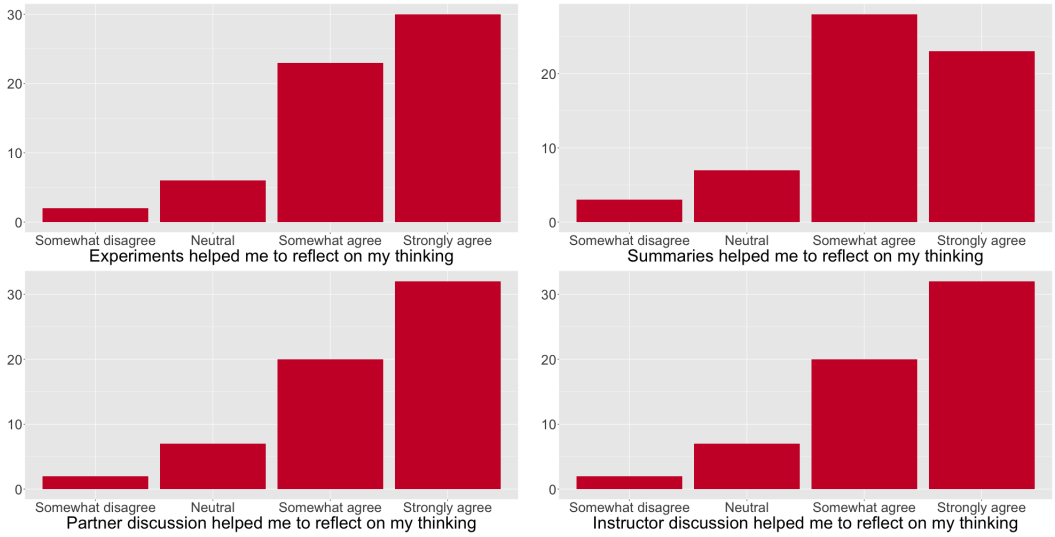

Figure 4. Histograms of student responses on Likert scale prompts. The possible answer "Strongly disagree" was never selected.

In open-ended prompts covering both of the demonstration experiment assignments in the course, students were asked to reflect on their experiences. In describing the impact of the experiment assignments on their learning, students largely reported a positive impact. Common reasons reported were the active/engaging nature of the assignment and the opportunity to discuss with a partner. However, there is some evidence that the experiment helped students connect their own experience to course concepts. Figure 5 shows student response on this theme.

"They allowed me to see the affects[sic] of certain human cognitive characteristics through the application of the experiment on myself, offering a first-person point of view of our concepts discussed in class."

Figure 5. Sample student response on the impact of the experiment assignments on their learning.

4. Discussion and conclusions. This article presented a demonstration experiment exercise in an introductory cognitive science course through the lens of a model of experiential teaching,

the CDTT. The design of the exercise was inspired by the empirically-supported paths to effective learning described by Schenk & Cruikshank (2015). The demonstration experiment provided students with an experience of identifying speech sounds across a VOT continuum. The written summary and debriefing with a partner provided further pathways to understanding the phenomenon of categorical perception. Because students' understanding was sometimes imperfect after the direct debriefing, the instructor's presentation of aggregate results alongside discussion was essential. Finally, students reflected on their experiences later in the term which allowed for assimilation of critical information. The quantitative results of the reflection survey show that students generally felt that the experience helped them toward the goal of developing their metacognition on class topics.

This inquiry supports the conclusion that demonstration experiments support students in relating their experiences of phenomena in cognitive science to the empirical findings in the literature, although simple participation may not be enough. Framing, debriefing, bridge building and assimilation components of the exercise are crucial to maximizing the impact of experiment participation. This inquiry could be used to guide the design of demonstration experiment assignments in other linguistics courses. While many ready-made demonstrations are currently available, it is also possible to program custom experiments that can be administered online with anonymized student data then available for analysis and presentation.

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