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Explorations of Sequence Learning in an Undergraduate Class

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To navigate their world successfully, organisms must often anticipate events occurring in a reliable order through time. Sequential pattern learning research suggests that sequences according to a rule or possessing structure are learned more easily than those that do not. Undergraduates explored firsthand the advantage of structure to learning a sequence. To this end, students completed two computerized pattern production tasks (structured and unstructured; order randomly assigned) assessing performance errors in choices of sequential stimuli within a two-dimensional circular space. Specifically, students viewed eight small circles arranged into a larger circle. They learned to pick the correct choice from among the eight possible choices according to either a fixed structured (12345678) or a fixed unstructured (17356428) pattern (digits refer to the location of the correct circle in the clockwise direction). For both patterns, irrelevant stimuli (denoted X) in the form of one circle randomly selected from the set of eight circular stimuli was inserted between each pattern element to give rise to the interleaved patterns: 1X2X3X4X5X6X7X8X and 1X7X3X5X6X4X2X8X. Incorrect choices were corrected via immediate screen feedback. Following the pattern production tasks, students reflected on their experiences and identified potential mechanisms underlying their performance. Students noted that while the structured pattern accorded to a rule, the unstructured pattern did not. Additionally, they identified associative learning and rule learning as potential explanations, indicating that associative learning could not easily explain their facilitated structured pattern performance. Students' hands-on experiences improved their understanding of how organisms might abstract the structure of ordered event sequences.

Keywords: *Teaching, pattern learning*

In navigating their world, organisms must often learn to anticipate events that occur in a reliable order through time. Research exploring how organisms accomplish this suggests that sequences according to a rule or possessing structure (structured sequences) are learned more easily than sequences (unstructured sequences) that do not possess such a structure (e.g., Restle & Brown, 1970; Fountain & Rowan, 1995). Moreover, this work suggests that humans and other animals have much in common in their processing of organized sequences (e.g., Kesner, 2002; McGonigle & Chalmers, 2002; Sands & Wright, 1980, 1982).

Such research spawned general debate regarding the nature of learning, memory, and representation, as well as more specific debate concerning whether nonhuman animals employ nonassociative symbolic processes (i.e., rule induction) to learn about patterned sequences (e.g., Hulse & Dorsky, 1977, 1979; Capaldi & Molina, 1979; Fountain, Rowan, & Benson, 1999; Fountain, Rowan & Carman, 2007; Fountain & Kundey, 2010; Martins, Miller, & Capaldi, 2008). The abilities of humans and nonhuman animals alike to learn sequential patterns are noted often in the texts utilized for undergraduate learning courses (e.g., Domjan, 2006). However, the possible mechanisms underlying such learning often remain unclear to undergraduates.

In an attempt to improve undergraduates' understanding of the potential mechanisms underlying sequential pattern learning, students enrolled in an undergraduate learning course explored structured and unstructured patterns firsthand in a pattern production paradigm. To this end, students completed two computerized pattern production tasks (structured and unstructured; order randomly assigned) assessing performance errors in choices of sequential stimuli within a two-dimensional circular space. Importantly, these tasks

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utilize a methodology analogous to a pattern-production paradigm within the spatial domain employed with rats (e.g., Fountain et al., 1995). Students self-rated their understanding of the related course material before completing any pattern production task, after completing one pattern production task (structured or unstructured, randomly assigned), and after completing the remaining pattern production task. Following all pattern production tasks, students reflected on their experiences, as well as identified potential mechanisms underlying their performance for each pattern type.

Method

Participants

Twelve students enrolled in an elective learning course for psychology majors served as the participants (*M [SD]* = 20.90 [2.02] years; age range 19 to 25 years; 2 participants declined to report this information). The participants were predominantly female (*n* = 7) and Caucasian (*n* = 10; 2 participants declined to report this information). Students were all juniors or seniors at the time of course enrollment. All procedures were approved by the institution's review board.

Materials and Procedure

Our procedure follows that utilized by Kundey, De Los Reyes, and Taglang (in press). We utilized three IBM-compatible computers located in a separate testing room (3m X 3m) with flat, touch screen monitors for data collection. SuperLab 4.0 (Cedrus; San Pedro, CA; code and stimuli available upon request) was utilized for all stimulus presentations. Prior to completing the first pattern production task, all participants rated their understanding of the section of the text related to sequential learning on a 7-point Likert scale from 1 (very confused) to 7 (understand completely).

Next, instructions appeared on the center of the computer screen. The instructions noted that participants would see eight circles and to choose a circle using mouse clicks or their index finger. Participants also read that they would receive feedback regarding their choices and not to be concerned if they made numerous errors, guessing when necessary.

After the participant indicated they had read the instructions, eight circles (13mm in diameter) appeared on the screen. The eight circles were spaced equally in a circular arrangement (circles opposite each other were 104mm apart) and were white in color (see Kundey et al., in press). Participants selected a circle from the array. If the selection was correct, a "smiley face" appeared on the screen during the 300ms intertrial interval (ITI). If the selection was incorrect, the seven incorrect circles were removed and the correct one remained, along with the text "Incorrect" displayed in the center of the screen. The participant was required to choose the correct circle before moving to the next trial. This correction procedure always provided the participant with feedback regarding the correct alternative.

Participants trained first on either a structured or an unstructured sequence (randomly assigned) and then repeated the procedure for the alternative sequence within one week of the initial sequential learning experience. In the structured sequence, the correct ordering of choices was 12345678; digits represent the clockwise location of circles within the array beginning with the topmost circle. One could easily describe this sequence by a rule such as "start at the top, then move one in the clockwise direction". In the unstructured sequence, however, the correct ordering of choices was 17356428. The unstructured sequence cannot be described easily by a rule in the same way that the structured sequence can. Each trial began with the 8-circle display. The participant then made a choice. If correct, they saw a smiley face and moved to the next trial. If incorrect, they received the feedback procedure described above.

Between the elements of the structured or unstructured sequence, one irrelevant stimulus (drawn from circles 1-8) was displayed on the screen. Irrelevant stimuli were included within the task to simulate more closely real-world learning experiences in which intervening information is often irrelevant to the task. Which of the 8 stimuli was chosen was determined randomly with replacement and varied across both participants and sequences. Importantly, the participant was not required to learn these stimuli; they only needed to choose them when they appeared before moving on to the next trial.

Thus, participants encountered a structured and unstructured pattern (experienced during separate learning experiences) interleaved with irrelevant, randomly selected information. The interleaved structured sequence was 1X2X3X4X5X6X7X8X while the interleaved unstructured sequence was 1X7X3X5X6X4X2X8X (where X represents a randomly selected irrelevant stimulus). Participants completed 20 patterns of each type. Errors on each element within each pattern were recorded by the computer for later analysis.

Following the first pattern production task (structured or unstructured), all participants again rated their

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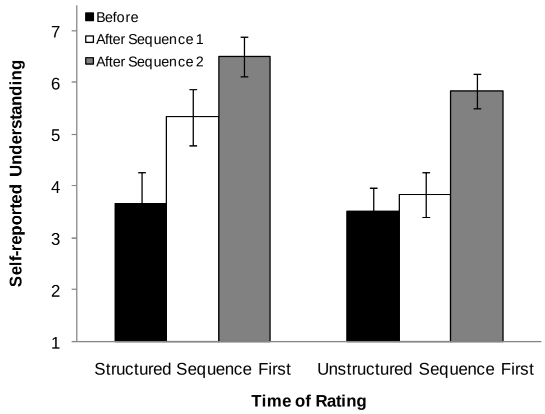

Figure 1. Mean student self-rating of understanding on a scale from 1 (very confused) to 7 (understand completely) for material related to sequential pattern learning presented in their text. Error bars represent standard error of the mean.

understanding of the section of the text related to sequential learning on a 7-point Likert scale from 1 (very confused) to 7 (understand completely). Following completion of the second pattern production task, participants rated their understanding of the section of the text related to sequential learning for a final time on the same 7-point Likert scale, were asked to compare the two pattern production tasks (Prompt: Compare the task you completed today with the task you completed previously.), as well as identify potential explanations for their performance (Prompt: Generate potential explanations for your performance on the task today and the task you completed previously.). Students' evaluations of their performance were coded by looking for indicators reflecting their own performance (e.g., easier, harder, faster, slower, similar, etc.), as well as how they described the sequences (e.g., rule-based, structured, random, unstructured, pattern). Students' responses regarding potential explanations were scored according to key terms (e.g., associative learning, rule learning, etc.).

Results & Discussion

The students evidenced facilitated learning of the structured sequences relative to the unstructured sequence. However, these data are not included here as they are not germane to the focus of this paper. Students' understanding of the material presented in their text related to serial pattern learning, as reflected by self-ratings, significantly improved over the course of the two pattern production tasks. These results are reflected in Figure 1 and described below.

Students' rating of their understanding of the material was analyzed utilizing a repeated measures Analysis of Variance with one within-participants factor, rating time (rating before task, after sequence one, after sequence two), and one between-participants factor, sequence order (structured pattern first, structured pattern second). The results of the analysis indicated a significant main effect of rating time ($F(2,20) = 89.39$, $p < 0.001$) and a significant interaction between rating time and sequence order ($F(2,20) = 5.98$, $p = 0.09$). No significant main effect was found for sequence order ($F(1,10) = 1.89$, $p = 0.20$). Subsequent paired-samples t-tests indicated students' self-ratings of their understanding of the related material presented in their text were significantly more favorable following completion of the structured ($t(11) = 9.38$, $p < 0.001$) and unstructured sequences ($t(11) = 3.64$, $p = 0.004$) compared to their pre-task completion level. However, no significant difference was detected between students' self-ratings of understanding between the two sequences ($t(11) = 0.83$, $p = 0.42$).

In comparing the two tasks, all students mentioned in their response to the probe questions that while the structured pattern accorded to a rule, the unstructured pattern did not. When asked to identify potential explanations for their performance in the probe questions, 10 of 12 students identified associative learning and rule learning as potential explanations, while 2 indicated only rule learning as a potential explanation. Of the 10 students that indicated both associative learning and rule learning as potential explanations, 9 indicated that associative learning could not easily explain their facilitated structured pattern performance.

Together, these results suggest that students' hands-on experiences improved students' self-reported understanding of how organisms might abstract the structure of orderly event sequences. However, these results do not suggest that experience with a structured pattern facilitates performance more than experience with an unstructured pattern. Additionally, these results suggest that perhaps other abstract concepts within the learning course might be clarified for students through brief demonstrations.

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