The Serial Reaction Time Task: A Measure of Sequence Learning or Expectation Violation?

Kristen Black & F. Sayako Earle

Background

The Nissen & Bullemer (1997) Serial Reaction Time (SRT) task is often referred to as an implicit sequence learning task. Sequence learning in the SRT task is determined by subtracting participant reaction time (RT) during the final repeating-sequence block from the first random-sequence block [S-R] in the SSSS-RRRR task design.

Subjects

43 participants
- 8 male and 35 female (Mean age=21.606 years, SD=1.33)
- Participants were recruited across campus through flyer advertisements with inclusion criteria displayed
- Participants had to be within the ages of 18-35 with normal vision and hearing abilities
- Participants were excluded if they had a history of neurological disorder, or socio-emotional and/or cognitive impairments

Procedures

Experimental tasks were completed in the Memory and Perception of Speech lab room and from home using an assigned laptop computer.
- The SRT task and Cross-Modal Oddball Task were completed in the lab around 8:00PM and 8:00AM respectively
- The Statistical Learning Task was completed at home around 8:00PM on a different day

The Serial Reaction Time Task

Participants were instructed to press the keyboard key corresponding to a visual stimulus (a clipart ‘smiley face’ icon appearing in one of four spatial locations on a laptop screen) as quickly and accurately as possible. Participants RT and accuracy was recorded.
- The Encoding Phase consisted of 40 warm-up trials and five blocks (4 repeating-sequence blocks, 1 random-sequence block) of 80 stimulus presentations
- The Test Phase consisted of 40 random stimulus presentations, followed by 80 repeating-sequence and 80 random-sequence stimulus presentations.

The Cross-Modal Oddball Task

Participants were exposed to visual stimuli on a laptop screen and instructed to press the right mouse button if the number was ‘even’ and the left mouse button if the number was ‘odd’ as quickly and accurately as possible. Participants RT and accuracy was recorded.
- The Warm-up Phase consisted of 26 visual stimuli presentations in which participants were provided accuracy feedback.
- The Test Phase consisted of 400 stimulus presentations without accuracy feedback. During this phase, participants were exposed to pseudorandomized standard or deviant auditory tones prior to a visual stimulus.

The Statistical Learning Task

Participants observed visual stimuli (letters) in two sets, and were asked to determine if the triplet contained a word. Each set contained four base triplet groups of three letters (i.e. ABC, DEF vs. BID, ELA). Participants were instructed to identify familiar sets as quickly and accurately as possible.
- The Familiarization Phase exposed each base triplet 24 times for a total of 96 triplets.
- The Test Phase contained familiar triplets and four ‘foil’ triplets that participants were exposed to 8 times each across 32 test trials.

Hypothesis

Expectation violation will predict performance on SRT above sequence learning.
- The Cross-Modal Oddball task will be used as our measure of ‘expectation violation’.
- A visual statistical learning task will be used as our measure of sequence learning.
A finding that the Cross-Modal Oddball task is a better predictor of performance on SRT over the Statistical Learning task will taken as support for our hypothesis.

Experimental Design

Subjects

43 participants
- 8 male and 35 female (Mean age=21.606 years, SD=1.33)
- Participants were recruited across campus through flyer advertisements with inclusion criteria displayed
- Participants had to be within the ages of 18-35 with normal vision and hearing abilities
- Participants were excluded if they had a history of neurological disorder, or socio-emotional and/or cognitive impairments

Procedures

Experimental tasks were completed in the Memory and Perception of Speech lab room and from home using an assigned laptop computer.
- The SRT task and Cross-Modal Oddball Task were completed in the lab around 8:00PM and 8:00AM respectively
- The Statistical Learning Task was completed at home around 8:00PM on a different day

The Serial Reaction Time Task

Participants were instructed to press the keyboard key corresponding to a visual stimulus (a clipart ‘smiley face’ icon appearing in one of four spatial locations on a laptop screen) as quickly and accurately as possible. Participants RT and accuracy was recorded.
- The Encoding Phase consisted of 40 warm-up trials and five blocks (4 repeating-sequence blocks, 1 random-sequence block) of 80 stimulus presentations
- The Test Phase consisted of 40 random stimuli presentations, followed by 80 repeating-sequence and 80 random-sequence stimulus presentations.

The Cross-Modal Oddball Task

Participants were exposed to visual stimuli on a laptop screen and instructed to press the right mouse button if the number was ‘even’ and the left mouse button if the number was ‘odd’ as quickly and accurately as possible. Participants RT and accuracy was recorded.
- The Warm-up Phase consisted of 26 visual stimuli presentations in which participants were provided accuracy feedback.
- The Test Phase consisted of 400 stimulus presentations without accuracy feedback. During this phase, participants were exposed to pseudorandomized standard or deviant auditory tones prior to a visual stimulus.

The Statistical Learning Task

Participants observed visual stimuli (letters) in two sets, and were asked to determine if the triplet contained a word. Each set contained four base triplet groups of three letters (i.e. ABC, DEF vs. BID, ELA). Participants were instructed to identify familiar sets as quickly and accurately as possible.
- The Familiarization Phase exposed each base triplet 24 times for a total of 96 triplets.
- The Test Phase contained familiar triplets and four ‘foil’ triplets that participants were exposed to 8 times each across 32 test trials.

Results

We ran two separate simple linear regression analyses to determine respective relationships between participant performance on the SRT task to performance on the cross-modal oddball and statistical learning tasks. Analyses were ran separately because only two participants completed all three tasks.

Table 1 and Figure 3a show the SRT task and cross-modal oddball task relationship. We used our measure of expectation violation (participant reaction time to the standard-deviant structure in the oddball task) as the independent variable and our measure of procedural learning (participant reaction time to the standard-deviant structure in the SRT task) as the single predictor.

Table 1: Expectation Violation and Procedural Learning

<table>
<thead>
<tr>
<th>Df</th>
<th>Sum Sq</th>
<th>Mean Sq</th>
<th>F-value</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3243.8</td>
<td>3243.8</td>
<td>4.568</td>
<td>0.0408</td>
</tr>
</tbody>
</table>

Table 2 and Figure 3b show the SRT task and statistical learning relationship. We used our measure of statistical learning with our measure of procedural learning as the single predictor.

Table 2: Statistical Learning and Procedural Learning

<table>
<thead>
<tr>
<th>Df</th>
<th>Sum Sq</th>
<th>Mean Sq</th>
<th>F-value</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>572.9</td>
<td>572.9</td>
<td>1.372</td>
<td>0.272</td>
</tr>
</tbody>
</table>

The inclusion of expectation violation significantly accounted for the variance in SRT performance.

Conclusions

We found that the inclusion of expectation violation significantly accounted for the variance in SRT performance. These preliminary results suggest that participant behavior during the shift between repeating- and random-sequences of stimuli in the SRT task is more reflective of an ‘expectation violation’ to a deviant stimulus in a repeating pattern of stimuli.

We suggest that ‘expectation violation’ or distraction to deviant patterns may play a crucial role in implicit sequence or procedural learning and therefore language learning. Whereas the processes of procedural learning engage temporal lobe and left frontal-basal ganglia regions of the brain to statistically detect and retain regularities, the processes of expectation violation activate areas of the striatum, insula, thalamus, and fronto-medial structures (Ullman, 2001; D’Astolfi & Rief, 2017).

If ‘expectation violation’ does play a role in language learning, we may be able to better understand how language learning occurs in both typical and atypical populations.

The results of our pilot study suggest the relationship between SRT performance and language ability may need to be reinterpreted, especially in cases where poor SRT performance is linked to disordered language abilities.

References