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

COMMUNICATION Sciences & Disorders

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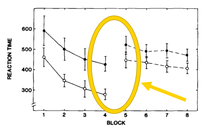
Background

The Nissen & Bullemer (1978) 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.

Nissen & Bullemer (1987)



- It has been interpreted as a measure of procedural learning ability in experimental populations because it requires the participant to perform a repeating sequence without explicit knowledge of any pattern
- Procedural learning is often implicated in studies on language learning because both processes are suspected to be served by underlying memory and processing circuits, and mastered through repeated exposure and practice (Ullman 2001; Ullman & Pierpont 2005)
- Participants who do not perform well on the SRT task are theorized to have inadequate procedural learning abilities, and therefore language learning abilities, based on this interpretation.

However, participants who perform poorly on the SRT task have been shown to perform adequately on other tasks that measure sequence learning (Siegelman & Frost, 2015).

Is the SRT task actually measuring a participant's sequence-learning abilities, or could the SRT task be a reflection of the participant detecting a deviant change during a repeating sequence of stimuli?

- We suspect that this interpretation of procedural learning on the SRT task is reflective of an 'expectation violation' to the deviant change in stimuli between repeating- and random-sequences.

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 typical 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**.** Participant 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 stimuli 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. Participant RT and accuracy was recorded.

- The *Warm-up Phase* consisted of 26 visual stimulus 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**

	Df	Sum Sq	Mean Sq	F-value	Pr (>F)
Expectation Violation	1	3243.8	3243.8	4.568	0.0408*
Residuals	30	21302.2	710.1		

Table 2 and *Figure 3b* show the SRT task and statistical learning relationship. We used our measure of statistical learning (participant accuracy in the statistical learning task) as the independent variable and our measure of procedural learning as the single predictor.

Table 2: **Statistical Learning and Procedural Learning**

	Df	Sum Sq	Mean Sq	F-value	Pr (>F)
Statistical Learning	1	573.0	572.99	1.372	0.272
Residuals	9	3758.1	417.57		

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

(β=19, t=2.14, p=.041, r^2=.10).

Figure 3a: **Expectation Violation and Procedural Learning**

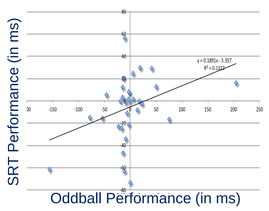
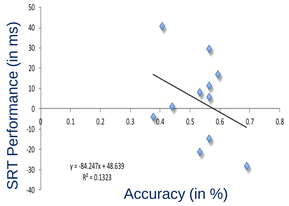


Figure 3b: **Statistical Learning and Procedural Learning**



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 process of procedural learning engages 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'Astolfo & 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

D'Astolfo, L. & Rief, W. (2017). Learning about expectation violation from prediction error paradigms- a meta-analysis on brain processes following a prediction error. *Frontiers in Psychology, 8,* 2-9.

Nissen, M. J. & Bullemer, P. (1987). Attentional requirements of learning: evidence from performance measures. *Cognitive Psychology, 19,* 1-32.

Siegelman, N. & Frost, R. (2015). Statistical learning as an individual ability: theoretical perspectives and empirical evidence. *Journal of Memory and Language, 81,* 105-120.

Ullman, M. T. (2001). The declarative/procedural model of lexicon and grammar. *Journal of Psycholinguistic Research, 30 (1),* 37-69.

Ullman, M. T. & Pierpont, E. I. (2005). Specific language impairment is not specific to language: the procedural deficit hypothesis. *Cortex, 41,* 399-433.