Neurophysiological Correlates of Sequential Learning May Differ for Children with a Cochlear Implant

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Introduction

- Sequential Learning (SL) is the implicit ability to recognize patterns in the environment that unfold over time.
- Language is a pattern that unfolds over time, which is why SL is seen as a significant component of language development.
- Experience with sound has been hypothesized to be important for the development of SL (Conway et al., 2009).
- Previous research has demonstrated that deaf children with cochlear implants may have disturbances to sequential learning abilities (Conway et al., 2011).
- A cochlear implant (CI) is a device that stimulates the auditory nerve electrically to produce hearing percepts, allowing children who at first did not have access to sound to be able to learn spoken language.
- However, it may be that early sound deprivation may alter brain development and detrimentally affect sequential learning abilities, which could negatively impact language acquisition even after receiving a cochlear implant (Conway et al., 2009; 2011).
- To examine brain differences in SL between TH children and in children with CIs, we measured event-related potentials (ERPs) to a sequential learning task, and compared the ERP results to results found by Jost et al. (2015), who examined SL in TH children.
- We expected that ERPs to SL for our TH children would be very similar to those from the Jost et al. (2015) study, showing a late (400-700ms) positive ERP effect. On the other hand, consistent with previous behavioral findings, we expected that children with CIs would show minimal ERP learning effects.

Method

- 24 typically developing children in two age groups, 7 years and 11-12 years, and one 9-year-old child with a CI participated, all with English as their first language.
- The children completed an SL task called the Magician Task, based on a task by Jost et al. (2015), in which a series of stimuli were presented and they were told to respond to a specific target by pressing a button.
- Participants did not know that two predictor stimuli were statistically paired with the target: the high probability predictor (HP) was followed by the target 90% of the time and the low probability predictor (LP) was followed by the target 20% of the time (See Figure1).
- As a control, the target also occasionally appeared without a predictor directly after a standard (no predictor- NP).
- Children completed this task while wearing a 32-sensor electroencephalograph (EEG) net (see Figure 2).
- ERPs were calculated in the POz region of interest (ROI; see Figure 3) from portions of EEG recordings time-locked to the stimulus preceding the target (HP, LP, or standard for NP), with a focus on the 400-700 ms timeframe.
- The ERP data from our participants was compared with the younger (6-9 years) and older (9-12 years) participants from the Jost et al. (2015) study.

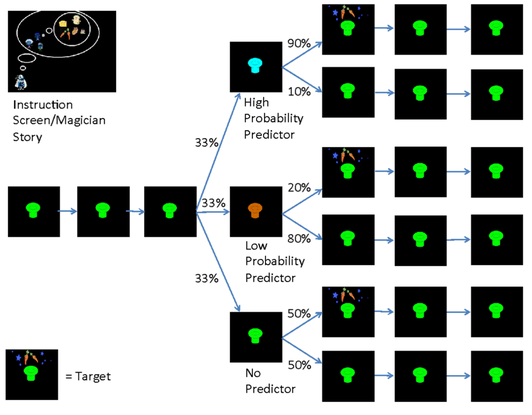

Figure 1: A diagram of the SL task children had to complete: the Magician Task. The target followed the high predictor on 90% of high predictor trials but only on 20% of low predictor trials. In the no-predictor condition, the target was presented immediately after a standard with no preceding predictor.

Results

Figure 2: A child wearing the EEG sensor-net.

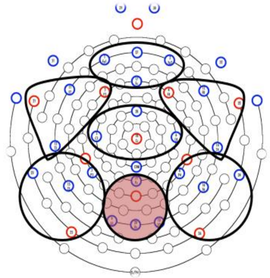

Figure 3: Map of the 32-channel sensor net used during the SL task. The POz region is shaded.

- Very similarly to Jost et al. (2015), visual inspection of the ERP waveforms for the three experimental conditions (HP, LP, and NP) showed a large positivity from approximately 400-700ms post-predictor presentation, during which the three conditions were differentiated, with HP being the most positive (See Figures 4-7).
- A 3x2x2 mixed measures ANOVA conducted with predictor (HP, LP and NP), and block (first and second block of SL task) as within subject factors; and participant age (older and younger) as a between subject factor; indicated a predictor main effect *(F(2,44) = 7.801, p = .001, ηp2 = .262*) in the POz ROI during the 400-700ms time window.
- Post-hoc pairwise comparisons for the main effect (Sidak corrected) showed that HP was significantly greater than NP (*p=.007*), LP was significantly greater than NP (*p=.036*), however, there is no significant difference between HP and LP (*p=.358*).
- The mean amplitude values for each predictor in TH children can be seen in Figure 8.
- There was also a significant block*predictor interaction (*F(2,7) = 3.875, p = .030, ηp2= .147*).
- To further examine interaction effects, we conducted pairwise comparisons between predictor conditions separately for the first block and second block, with Sidak adjustments for multiple comparisons.
- This comparison indicated that for the first block, HP was significantly greater than NP (*p=.043*), and LP was significantly greater than NP *(p=.023*), but there was no significant difference between HP and LP (*p=.998*).
- For the second block of the task, HP was significantly greater than NP (*p<.001*), LP was significantly greater than NP (*p= .048*) and HP was significantly greater than LP *(p=.006*).
- The fact that all predictors were significantly different from one another in the second block shows that SL occurred throughout the task, especially when observing the increase in HP.
- In addition, Figure 9 shows the mean amplitudes for each predictor condition collected from the single child with a CI who has participated so far.

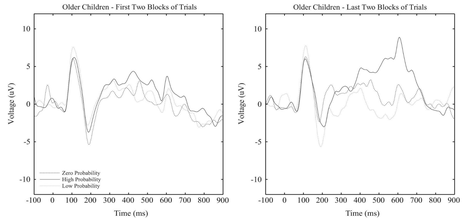

Figure 4: ERP waveforms in POz region from the Jost et al. (2015) study for children 9-12 years old.

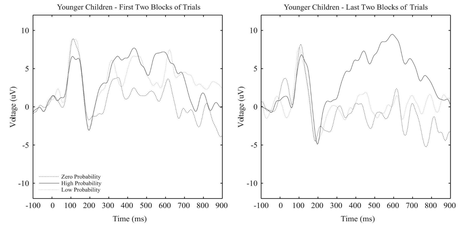

Figure 5: The ERP waveforms in POz region from Jost et al. (2015) study, from the 6-9 year olds.

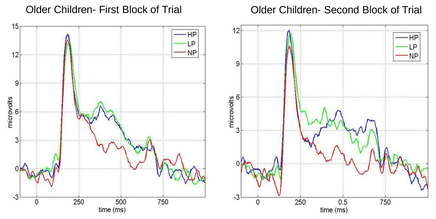

Figure 6: ERP waveforms in POz region from 11-12 year old children.

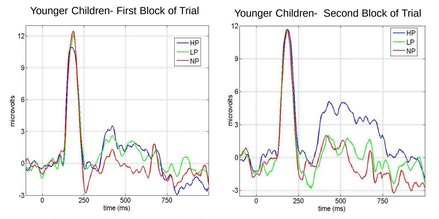

Figure 7: ERP waveforms in POz region from children 7 years old.

Conclusions

- The ERP results we collected are similar to previous ERP results found in the children from the Jost et al. (2015) study.
- The differences from the first block of the task to the second block of the task (mainly with an increase in positivity with the High Predictor) show that sequential learning has occurred, particularly in the younger children in our study.
- Based on predictor condition means from ERP results collected from a participant with a CI who completed the same SL task, it is evident that the learning pattern is different. Rather than an increase in HP and a slight decrease in LP amplitude, all three conditions decrease.
- Considering previous studies done with children with a CI (e.g., Conway et al., 2011), it is not surprising that we found a pattern suggestive of atypical sequential learning for the participant with a CI.
- With links between SL and language development, it may be that as we continue to collect data from children with CIs, we may find that atypical SL could be a cause for some difficulties with language, which in turn may lead to a direction for research on language interventions, as seen in a present study by Smith et al.

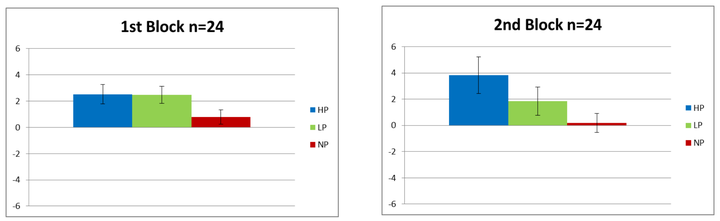

Figure 8: Graph of mean amplitudes for predictor type from the first and second blocks of the SL task for the TH participants.

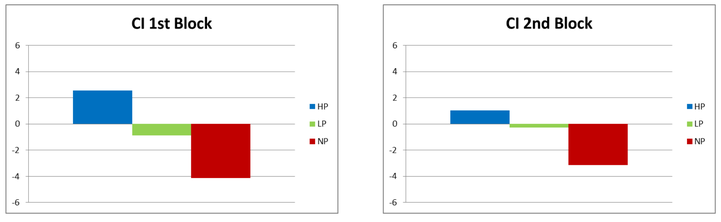

Figure 9: Graph of mean amplitudes for predictor type from the first and second blocks of the SL task for the participant with a CI.

References

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Acknowledgments

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