Using simulated hearing loss to experimentally examine the effects of hearing quality, long-term phonological knowledge, and short-term phonological memory in language performance

Caitlin A. Ross, M.S., CCC-SLP and Michelle W. Moore, Ph.D., CCC-SLP
West Virginia University, Morgantown, WV

Introduction

Nonword repetition (NWR) is an important diagnostic tool for language impairment, likely because it involves several of the processes involved in word learning. NWR is thought to involve both short-term and long-term phonological memory processes (Cody & Evans, 2008; Moore, Fitz, & Tompkins, 2017).

Children with hearing loss generally perform worse on NWR tasks than their typically hearing peers. This finding has been observed in children with cochlear implants (CI) (e.g., Audichon, Pisoni, & Konstemberger, 2019; Burkholder, Dillon, Levi, & Pisoni, 2007), children with hearing aids (e.g., Stelmachowicz, Pittman, Hoover, & Lewis, 2004), and children with varying degrees of sensorineural hearing loss (e.g., Briscoe, Bishop, & Norbury, 2001). However, natural hearing status and phonological short-term and long-term memory are confounded so that it is difficult to parse hearing and phonological deficits in children with hearing loss.

The purpose of this study was to address this confound by experimentally examining these variables using a CI simulation in typically hearing adults.

Research Question

Does varied quality of auditory input affect performance on linguistic tasks that vary in their phonological short-term and long-term memory demands using word length and consonant age of acquisition (CAoA) manipulations, respectively?

Methods & Procedures

Participants

30 undergraduate students (4 M, 26 F) enrolled in study
Mean age: 19.6 years (range: 18.0 – 21.3 years)
All self-reported native English monolinguals with no history of a speech, language, hearing, or cognitive disorder, and no extensive formal phonetics training

Study Design

Experimental, within-subjects design using nonword repetition (NWR) and auditory lexical decision (ALD) tasks
Randomly presented stimuli varied in hearing quality (normal vs. spectrally-degraded), consonant age of acquisition (CAoA), early- vs. acquired consonants), syllable length, and lexical status

Task Order

1. Hearing screening
2. Speech screening (GFTA-3)
3. Nonword repetition* • Memory for Digits
4. Auditory lexical decision* • Vocabulary
5. Phonological Memory subtests (CTOPP-2)
   - Vocabulary
   - Memory for Digits
6. Auditory lexical decision (WASI-II)
   - Vocabulary
   - Matrix Reasoning
   - Nonword Repetition

*Nonword repetition assessment was conducted as a pre-screening tool, with any participants who performed at more than 5 standard deviations below the mean excluded from further participation in the study.

Experimental Tasks

• NWR and ALD tasks adapted from Moore et al., 2017
• Four independent variables, measures of: 1. Hearing quality: • Normal vs. spectrally-degraded • Stimuli spectrally degraded via Angel Sim simulation software akin to a 16-channel CI simulation 2. Long-term phonological memory: • Stimuli with only earlier-acquired vs. only later-acquired consonants • In previous work (e.g., Moore et al., 2017; Moore, 2018), CAoA effects persist in many tasks with varied input and output demands, suggesting a representational level effect
• Derived from Shriberg and Kwiatowski’s (1994) consonant groupings: • Earlier-acquired consonants: s, t, p, m, n, f • Later-acquired consonants: z, s, th, f, l, v 3. Short-term phonological memory (NWR only): syllable length 4. Lexical status (ALD only): word vs. nonword

Nonword Repetition

• 32 words, 1-syllables in length (see Table)

Descriptive Results

Table 1: Mean and SD (range) scores for each task

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Mean</th>
<th>SD (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTOPP-2</td>
<td>Memory for Digits SS</td>
<td>11.1</td>
<td>2.9 (5-17)</td>
</tr>
<tr>
<td></td>
<td>Nonword Repetition SS</td>
<td>8.4</td>
<td>2.4 (4-14)</td>
</tr>
<tr>
<td></td>
<td>Phonological Memory Composite</td>
<td>99.2</td>
<td>13.6 (61-125)</td>
</tr>
<tr>
<td>WASI-II</td>
<td>Vocabulary SS</td>
<td>10.2</td>
<td>1.8 (6-13)</td>
</tr>
<tr>
<td></td>
<td>Matrix Reasoning SS</td>
<td>10.1</td>
<td>2.7 (4-15)</td>
</tr>
<tr>
<td>FSIQ-2 Composite</td>
<td>Vocabulary SS</td>
<td>10.07</td>
<td>10.1 (84-122)</td>
</tr>
</tbody>
</table>

Results (continued)

Auditory Lexical Decision

2x2x2 (hearing quality x CAoA x lexical status) repeated measures ANOVAs
Significant main effects for each factor: accuracy decreased for degraded stimuli (p < .001), stimuli comprising later-acquired Cs (p < .001), and generally for longer nonwords (p < .005)
Syllable length x hearing quality interaction (see Figures)
Only for participants with ALD-NWR task order
Magnitude of degradation effect greater in shorter nonwords and decreased as nonword length increased

Auditory Lexical Decision (continued)

Lexical status x CAoA for Accuracy

Lexical status x CAoA x syllable length interaction for response time

Future considerations

Findings here about the role of short-term and long-term phonological memory in linguistic performance may not reflect the pattern observed in children with hearing loss since their phonological representations develop as a result of different experience with low-quality auditory input. Future work could investigate performance patterns in children with hearing loss using a similar battery of tasks and experimental variables to compare and contrast typical and clinical models of phonological processing.

Future work could utilize different stimulus sets to rule out the impact of idiosyncratic stimulus characteristics from the robustness of the degradation effect.

Disclosure: Author #1, Caitlin A. Ross: No conflict of interest; Author #2, Michelle W. Moore: No conflict of interest

Conclusion

• Hearing experience affected magnitude of spectral degradation effect
• Repetition capabilities varied depending on how well acclimated the listeners were to the degradation
• New experience with low-quality auditory stimuli may elicit robust auditory perceptual effects that mute other patterns of performance
• Spectral degradation effects tended to be more robust in ‘simpler’ phonological conditions:
  - When short-term memory demands were minimized
  - Consistent with Barkhuizen-Hulsaas and colleagues’ (2007) claim based on their work with adults performing under CI simulation that CAoA is the auditory quality of stimuli that affects working memory tasks rather than deficits in short-term memory processes
• Suggests that, even in nonwords, longer stimulus items may provide more phonetic context to help distinguish between phonemes (e.g. f vs. v)
• With long-term phonological knowledge that typically results in more accurate linguistic performance (i.e. stimuli comprising earlier-acquired consonants)

References & Acknowledgments

• West Virginia University, Morgantown, WV

This work was funded in part by the Robert E. Stitzel Graduate Student Research Award. A sincere thank you to Dr. Jeremy Moore, M. W. (2018). Consonant age of acquisition effects are robust in children’s nonword repetition performance. Ear and Hearing, 39(4), 403-414.