The Role of Attention and Working Memory in Speech Segregation in Typically Developing Individuals: A Comparison with Young Adults with Down Syndrome

*Didulani Dantanarayana, Kumari Anshu, Shelly P. Godar, Sara M. Misurelli, Sigan L. Hartley, & Ruth Y. Litovsky
University of Wisconsin-Madison, Waisman Center, Madison, WI
**** Presenting Author e-mail: ndantanaraya@wisc.edu***

Binaural Hearing and Speech Laboratory

American Auditory Society – 2025
Poster no: 205

Printing courtesy of the Friends of the Waisman Center

INTRODUCTION

- The auditory system undergoes significant maturation from birth to adulthood.
- Speech recognition is one of the critical communication abilities that undergoes maturation in typically developing (TD) children, with evidence for significant variability when measured both in quiet and in noise[1,2].
- Speech recognition is even more varied in individuals with developmental disabilities such as in Down Syndrome (DS)[3].
- The sources of this variability are not well understood and are likely determined by a complex interaction of auditory and non-auditory processes, the latter including cognitive abilities such as attention and working memory.
- Here, we investigated the improvement in speech recognition when target speech and speech interferers are spatially separated vs. spatially co-located (spatial release from masking, SRM). We also investigated associations between cognitive processes and individual variability in speech recognition and the magnitude of SRM in individuals with TD and DS.

Study Objectives

- A cross-sectional study across age was designed to investigate differences in speech recognition and SRM in TD individuals, and to compare performance with that of young adults with DS.
- SRM data were examined in relation to cognitive skills in TD individuals to begin understanding the potential contributions of cognitive skills to speech recognition in the presence of speech interferers.
- Here we also began to examine these associations in young adults with DS.

METHODS

Participant Demographics:

- TD individuals (total N=81): [5-8 years, N=15]; [9-12 years N = 13], [13 to 17 years, N = 13], [18 to 25 years, N = 40]. Participants had normal hearing across all frequencies tested.
- Young adults with DS (total N=22): Recently published data (Anshu et al., 2024; N = 15) and newly collected unpublished data (N=7). Pure tone audiometric thresholds ranged from within-normal-limits to profound hearing loss. Data from one of the participants with DS was excluded from all the regression analyses due to a unilateral profound hearing loss. Regression analyses include N=14 published data and N = 7 newly collected unpublished data.

Speech Recognition Task:

- A closed-set four alternative forced choice task[4] (see Figure 1) was used to estimate speech reception thresholds (SRTs) using an adaptive tracking algorithm (3-down/1-up), estimating 79.4% correct on the psychometric function. Each adaptive track ended after five reversals, and data were fit using psignifit in MATLAB to estimate SRTs.
- Maskers were fixed at 55 dB SPL. Target speech was initially presented at 60 dB SPL and then varied following the adaptive tracking rules.

Cognitive Measures (Only for TD children and Young adults with DS):

- Digit Span Forward (WISC IV/V) was used to assess Verbal Attention
- Digit Span Backward (WISC IV/V) was used to assess Verbal Working memory
- Standardized assessments were used to assess verbal and non-verbal IQ – Stanford-Binet V and Kaufman Brief Intelligence (KBIT-2) tests

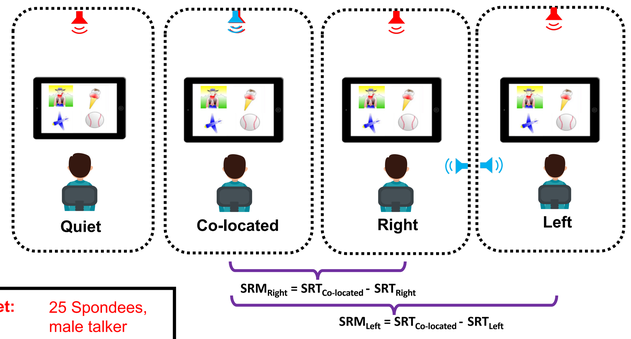

Figure 1: Children's Realistic Index for Speech Perception (CRISP)

RESULTS

TD Individuals: Is Age associated with SRT and/or with SRM?

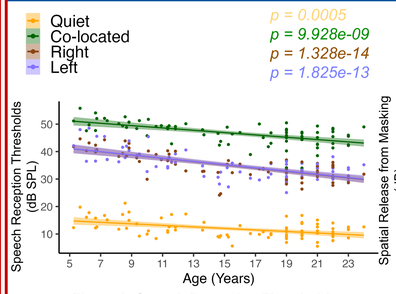

Figure 2: Speech Reception Thresholds as a function of Age in TD individuals

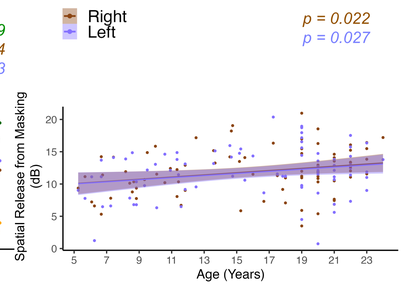

Figure 3: Spatial Release from Masking as a function of Age in TD individuals

- Regression analyses revealed significant associations between age and SRTs in all conditions tested in TD individuals (Figure 2).
- Regression analyses revealed marginally significant associations between SRM and age for spatial separation towards either right or left (Figure 3).
- The change in SRM as a function of age did not differ for conditions with interfering speech to the right vs. left.

Association between Speech Recognition and Attention in TD Children

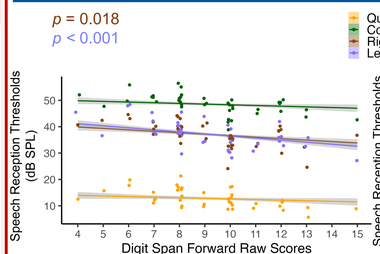

Figure 4: Speech Reception Thresholds as a function of Digit Span Forward Scores in TD Children (statistically controlled for age)

Association between Speech Recognition and Working Memory in TD Children

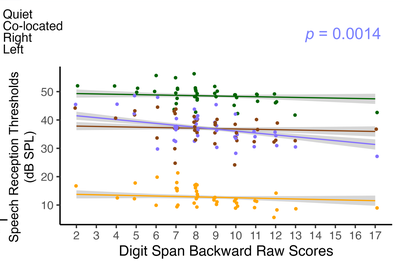

Figure 5: Speech Reception Thresholds as a function of Digit Span Backward Scores in TD Children (statistically controlled for age)

- Significant association was found between SRTs, and digit span forward scores which assessed attention, for the conditions tested with interferers spatially separated to the right (+90-deg) or left (-90-deg) (Figure 4).
- Significant association was found between SRTs, and digit span backward scores which assessed working memory, only for the condition tested with interferers to the left (-90-deg) (Figure 5), and this may indicate an association between source segregation and working memory when right ear advantage is present with interferers spatially separated to the left (-90-deg).

Is SRM associated with Attention and/or Working Memory?

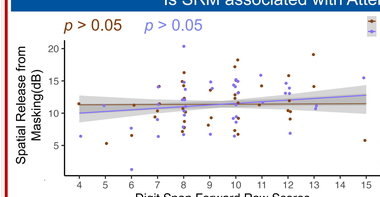

Figure 6: SRM as a function of Digit Span Forward Scores in TD Children (statistically controlled for age)

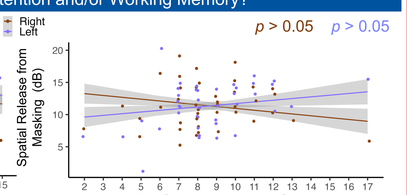

Figure 7: SRM as a function of Digit Span Backward Scores in TD Children (statistically controlled for age)

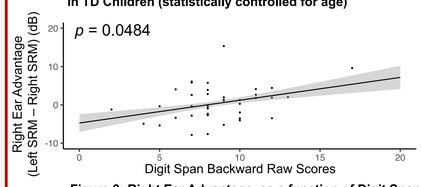

Figure 8: Right Ear Advantage as a function of Digit Span Backward Scores in TD Children (statistically controlled for age)

- Although, SRM was not significantly associated with attention and working memory, a difference was observed between SRM with interferers to the left vs. right. This may indicate a right ear advantage and an association with working memory.
- A larger sample size with an equal representation of all age groups is required to better understand this trend.

Speech Recognition and SRM in Young Adults with DS in Comparison to TD

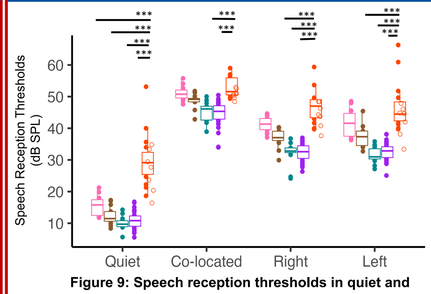

Figure 9: Speech reception thresholds in quiet and with interferes co-located or separated to either right or left in TD Individuals and Young Adults with DS

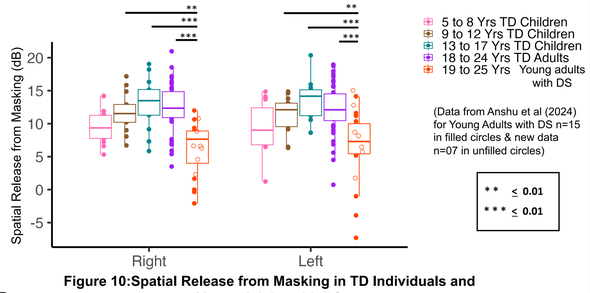

Figure 10:Spatial Release from Masking in TD Individuals and Young Adults with DS

Young Adults with DS: Are there associations between SRTs and/or SRM with Pure Tone Average (PTA) in either ear and/or Cognitive measures?

(Data from Anshu et al (2024) for Young Adults with DS n=14 in filled circles & new data n=07 in unfilled circles)

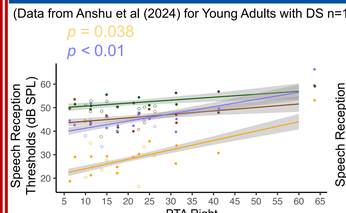

Figure 11: Speech reception thresholds as a function of PTA Right in Young Adults with DS

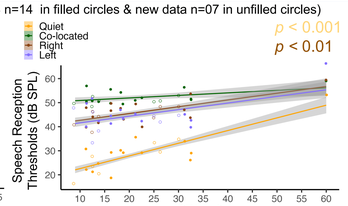

Figure 12: Speech reception thresholds as a function of PTA Left in Young Adults with DS

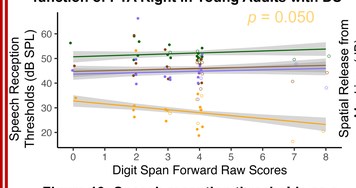

Figure 13: Speech reception thresholds as a function of Digit Span Forward Raw Scores in Young Adults with DS

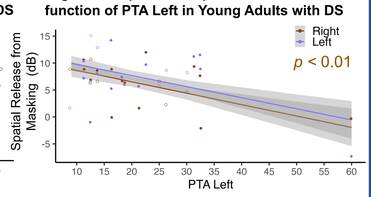

Figure 14: Spatial Release from Masking as a function of PTA Left in Young Adults with DS

- SRTs in quiet were significantly higher in young adults with DS than TD individuals of all groups. However, in the co-located condition, young adults with DS had higher SRTs only compared with TD adults and children ages 13-17 years (Figure 9).
- When spatially separating the interferers to right or left, SRTs of young adults with DS were significantly higher than TD adults, and two groups of TD children: 13-17 years and 9-12 years (Figure 9). The same trend was observed in SRM (Figure 10).
- Lack of significant differences between young adults with DS and TD children 5-8 years of age suggests similarities in maturation of speech recognition in noise in these two groups.
- SRTs in young adults with DS in quiet and with interferers spatially separated to the left were associated with PTA of right ear (Figure 11); and PTA of left ear was associated with SRTs in quiet and with interferers spatially separated to the right (Figure 12).

- Cognitive measures of attention and working memory of young adults with DS were not significantly associated with either SRT (Figure 13) or SRM which indicates a significant role of hearing sensitivity to explain the variance observed in speech recognition and SRM in young adults with DS.
- A significant association was observed between SRM with interferers spatially separated to the right and left ear PTAs in young adults with DS (Figure 14) which may indicate the benefit of head shadow decreased with hearing loss in the ear with better signal-to-noise ratio. However, this was not observed between SRM with interferers spatially separated to the left and right ear PTAs and this could be due to the asymmetrical hearing in young adults with DS in this sample. A larger sample size is required to further understand these findings.

Conclusions and Future Directions

- Age is a significant factor in speech recognition skills in quiet and in noise in TD individuals.
- Children between 5 to 7 years of age have demonstrated adult like SRM for both right and left; this indicates maturation of spatial hearing and source segregation skills in young children.
- Attention and working memory of TD children were significantly associated with speech recognition (SRTs) with interferers either spatially separated to right or left.
- The difference between left and right SRM was marginally associated with working memory; may provide insight into how right ear advantage could be associated with working memory to benefit from spatial separation when interferes were spatially separated to the left which provides head shadow with better signal-to-noise ratio to the right ear; a larger sample size is required to confirm this finding.
- Young adults with DS show significantly higher (worse) SRTs and significantly lower (worse) SRM in comparison to TD groups. Young adults with DS and TD children of 5-8 years of age showed similarities in maturation of speech recognition in noise.
- Significant associations were found between PTAs of young adults with DS and their SRTs which indicate the importance of hearing sensitivity to access spatial cues in speech recognition .
- **Future Directions:** Data collection is ongoing in young adults with DS; note that a large sample size is required to understand the role of cognitive skills for effectively using spatial cues in noisy environments.

REFERENCES

1. McCreery, R.W., Miller, M.K., Buss, E., & Leibold, L.J (2020). Cognitive and Linguistic Contributions to Masked Speech Recognition in Children. Journal of Speech, Language, and Hearing Research , 63, 3525 – 3538.
2. MacCutcheon, D., Pausch, F., Fullgrabe, C., Eccles et al., (2019). The Contribution of Individual Differences in memory Span and Language Ability to Spatial Release from Masking in Young Children. Journal of Speech, Language, and Hearing Research, 62, 3741-3751.
3. Anshu, K., Kristensen, K., Godar, S.P., Zhou, X., Hartley, S.L., & Litovsky, R.Y. (2024). Speech Recognition and Spatial Hearing in Young Adults with Down Syndrome: Relationships with Hearing Thresholds and Auditory Working memory. Ear & Hearing, 45, 1568-1584.
4. Litovsky, R. Y. (2005). Speech intelligibility and spatial release from masking in young children. The Journal of the Acoustical Society of America, 117(5), 3091-3099.

This work was supported by NIH-NIDCD (R01 DC003083, Litovsky) and NIH-NIDCD (R01 DC019511, MPIs Litovsky, Hartley and Alexander). This study was supported in part by a core grant to the Waisman Center from the National Institute of Child Health and Human Development (P50HD105353). Spatial Thanks to Stephanie Sellner, Molly Osborn, and other BHSL lab members for data collection.