The role of iSense and inspiro in the reduction of listening difficulties in children with Autism Spectrum Disorder

It is established that children with Autism Spectrum Disorder (ASD) have greater difficulties processing speech in the presence of background noise compared to their peers. Research has shown that wireless communication systems that significantly improve the auditory signal delivered to the ear are beneficial to these children. In a research study conducted at the University of Melbourne, Australia, auditory processing skills were assessed in children with ASD with and without the use of the iSense Micro ear-worn receiver paired to the Phonak inspiro transmitter. Results of the study show significantly improved listening skills, social interaction, and general attentiveness in the classroom during prolonged trial periods with the technology.

Introduction

It is well established that abnormal responses to auditory stimuli are frequently reported in children with ASD. In fact, the Diagnostic and Statistical Manual of Mental Disorders version 5, includes atypical responses to sensory stimuli across a number of modalities, including auditory, as a mandatory component of an ASD diagnosis (American Psychiatric Association, 2013). Research has shown that auditory processing deficits are common in children with ASD (Alcántara et al., 2004, 2012; Groen et al., 2009) and significant enough to compromise their ability to process speech effectively in the presence of background noise. The ability to process speech and maintain concentration in children with ASD has been suggested to be the most significant predictor of academic performance (Ashburner et al., 2008). Additionally, central auditory processing deficits can limit the development of social and communication skills in these children (Beck & Bellis, 2007). Therefore, the identification and management of auditory deficits in this population is critical.

Use of frequency modulation (FM) devices, such as the ear-level iSense Micro FM receiver paired with the inspiro transmitter, can optimize children's listening experiences in adverse environments such as noisy classrooms. By wirelessly delivering speech from the transmitter to the receiver worn by the child, the effects of distance, background noise and reverberation are significantly reduced. This in effect greatly improves the signal-to-noise ratio (SNR) delivered to the child's ear, making speech easier to attend to and process. A pilot study by Schafer et al., 2013, investigated the effects of the iSense Micro FM receiver worn on school children with ASD paired with the inspiro transmitter with the iLapel directional microphone worn by their teachers. Results of this study showed significantly higher speech recognition-in-noise scores, increased on-task behaviors, and improved teacher ratings of listening behaviors with the FM system for short periods in structured education settings (Schafer et al., 2013).

The current study is the first to explore the sustained use of FM devices in mainstream classroom environments in children with ASD. It is hypothesized that continued use of the iSense Micro FM receiver paired with the inspiro transmitter will improve speech perception in noise, aid communication, and improve educational outcomes for children with ASD.

Methodology

Twenty children (3 girls and 17 boys) aged 8 to 15 years old participated in this study. All participants had previously been diagnosed with ASD via a multidisciplinary approach using a range of diagnostic instruments. All children were able to verbally communicate and attended a mainstream school. They did not have any known coexisting disabilities and each had an IQ of at least 70 as measured by the Wechsler Intelligence Scale for Children (Needelman et al., 2006). Ten (younger) children attended primary school and the other ten (older) children attended secondary school. Twenty age and sex-matched control participants were also recruited for this study. All control participants scored less than 20 on the Childhood Autism Rating Scale (Magyar & Pandolfi, 2007), indicating they were not on the autism spectrum.

All participants, with the assistance of their parents if required, began by completing the Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander, 1995). This questionnaire gives a measure of auditory function through exploring the areas of communication difficulty, effect of background noise, effect of reverberation, and aversiveness to sound.

An audiologic battery of tests was then used to assess participants' temporal processing, binaural processing, and open-set speech perception in the presence of background noise.

Temporal processing ability was measured through detection thresholds for a range of sinusoidal amplitude modulation rates in broadband noise (Alcántara et al., 2012). Results were plotted as a temporal modulation transfer function (Viemeister, 1979).

Binaural processing was measured using the Listening in Spatialized Noise–Sentences test (LiSN-S) (Cameron & Dillon, 2007) under headphones, which assesses the participant's ability to use subtle inter-aural difference cues to detect speech in the presence of background noise (Rance et al., 2012).

Open-set speech perception in noise was measured using the Consonant-Nucleus-Consonant word test (CNC words) (Peterson & Lehiste, 1962). For this particular assessment, the participant was positioned in between two speakers facing them; one in front and one behind. CNC monosyllabic words were presented in the free field from the speaker in front, which was calibrated to reach the child's head at 65 dB SPL. 4-talker babble was simultaneously played from the speaker behind the child's head, also calibrated to reach the head at 65 dB SPL to create a 0 dB SNR overall. Percentage correct phonemes were calculated based on the child's attempted repetition of each word.

Each participant was then fitted with one iSense receiver with a small, open dome, paired to an inspiro transmitter for speaker use. A free field CNC word test was then repeated in an aided condition whereby the inspiro was suspended 20 cm in front of the front speaker that delivered the words of interest.

The ten primary school-aged participants then began a 6-week trial of the iSense and inspiro devices. The trial period was balanced (ABBA) to involve 2-week periods of device use (B) and 2-week periods of device non-use (A) to allow for learning effects. During device use periods, children and their teachers/parents respectively, were encouraged to wear the device continually throughout the day. 4–6 hours was typical across participants. At the conclusion of each 2-week phase, each child (with parental assistance if required) was asked to complete the APHAB questionnaire. In addition, each child's teacher was asked to complete the Listening Inventory For Education (LIFE) questionnaire (Anderson & Smaldino, 1999) at the conclusion of the trial to provide an appraisal of the degree of educational benefit of the FM system for each child.

Results

APHAB pre-device trial (unaided hearing disability)

Compared to the control group, children with ASD reported a much greater proportion of difficult hearing and communication situations, as indicated by their significantly higher mean APHAB scores ($p < 0.001$) (Figure 1).

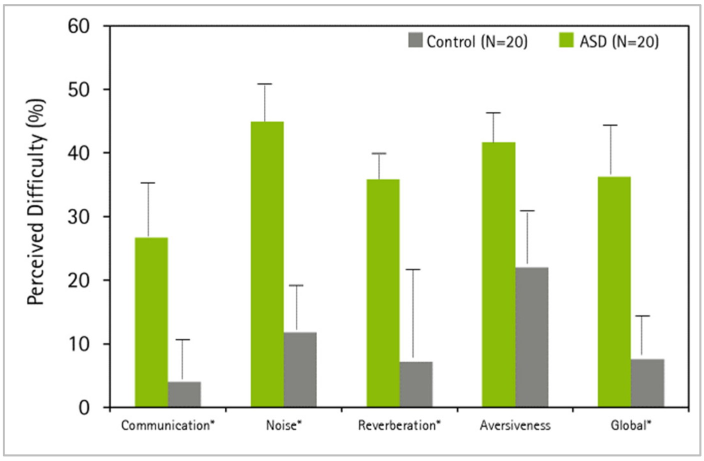

Figure 1: Mean APHAB hearing disability survey results for 20 children with ASD and 20 controls. Error bars represent 1 SD from the mean. Asterisks show the metrics in which there was a significant difference between groups ($p < .001$). Mean global APHAB score for the ASD group was 36.3% ± 17.2%, and that for the control group was 7.6% ± 6.6% (95% CI 19.3% – 38.1%; $p < .001$).

Regression analyses revealed no associations between mean APHAB score and participant age (p = 0.060) and/or hearing level (p = 0.799).

Amplitude modulation detection task (auditory temporal processing)

Fourteen of the twenty children with ASD were able to complete the temporal processing task successfully. These children were less sensitive to amplitude modulations, showing higher detection thresholds across all modulation rates tested. Mean amplitude modulation thresholds for both ASD and control groups are displayed in Figure 2 (−16.3 ± 2.5 dB for ASD group compared to −19.9 ± 3.7 dB for the control group (95% CI −6.4 to -0.8 dB; p = 0.014). Regression analyses showed no association between performance on this task and hearing level (p = 0.200). However, a relationship between higher amplitude modulation detection thresholds and younger age was found (p = 0.006), which suggests that temporal sensitivity tends to mature with age.

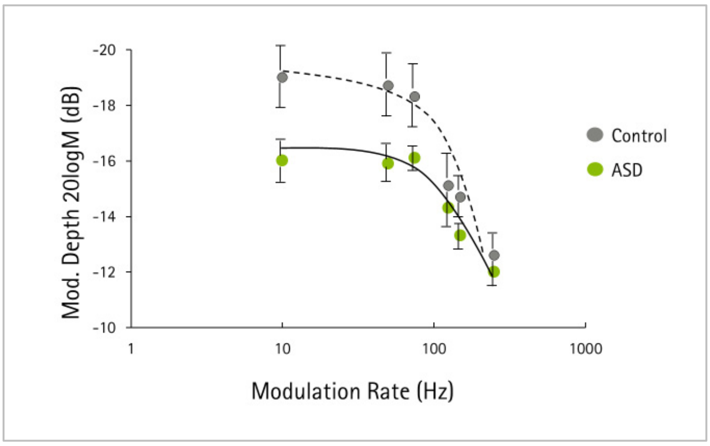

Figure 2: Mean amplitude modulation detection thresholds (dB) plotted as a function of modulation rate (Hz) for the ASD group and controls. Error bars denote ±1 SEM.

LiSN-S (spatial processing)

Children with ASD were not able to take advantage of spatial separation of target speaker and distractor speaker (spatial advantage) as effectively as the children in the control group. Therefore, their ability to listen to the target speaker in this condition was poorer (9.2 ± 3.2 dB speech-in-noise improvement in the ASD group compared to 11.9 ± 1.4 dB in the control group ([95% CI 1.0–4.4 dB; p = 0.003]). Regression analyses revealed no association between spatial advantage and either age (p = 0.192) or hearing level (p = 0.484).

Unaided CNC words (open-set speech discrimination)

CNC word phoneme scores were significantly lower in children with ASD compared to the control group (p = 0.009), indicating poorer speech perception in noise in the former group. Figure 3a displays phoneme scores for each child in the ASD group. Regression analyses revealed no association between CNC phoneme score and either age (p = 0.722) or hearing level (p = 0.074).

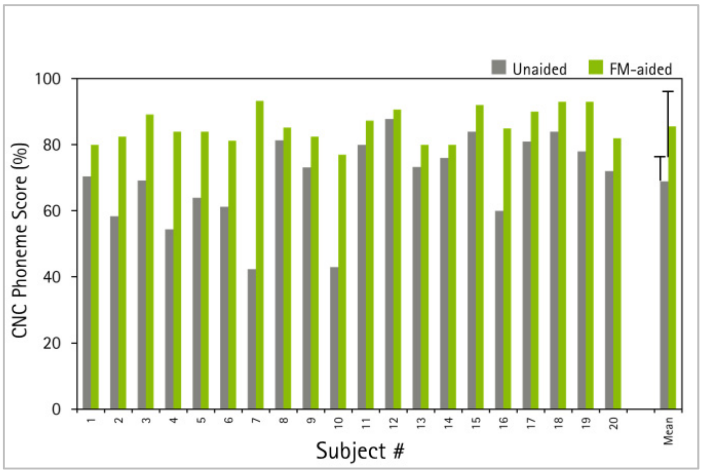

Figure 3a: Unaided and FM-aided Consonant-Nucleus-Consonant-Word scores for each of the children with ASD. Mean phoneme score for the unaided condition was 68.9% ± 11.7%, and that for the aided condition was 85.6% ± 5.1% (95% CI −21.7% to −11.6%; p < .001).

Aided CNC words (open-set speech discrimination with use of iSense and inspiro)

Participants of this study across both the ASD group and the control group demonstrated significant improvements in speech perception when aided with an iSense device paired to an inspiro transmitter. Children with ASD showed a mean aided improvement in phoneme score of 16.9% ± 10.6% (95% CI 11.6%–21.7%; p <0.001) while children in the control group showed a mean improvement of 10.1% ± 7.0% (95% CI 6.9%–13.4%; p < 0.001) (Figure 3a). Regression analyses revealed participants with ASD benefitted more from the iSense and inspiro compared to their peers in the control group (p = 0.039). However, no associations between aided improvement and both age (p = 0.539) and hearing level (p = 0.425) were found.

iSense and inspiro trial

Eight out of the ten primary school-aged participants with ASD who began the device trial consistently wore the iSense paired to the inspiro for prolonged periods across a range of listening environments throughout the 6 weeks. The other two participants' data beyond the first fitting session were eliminated as they did not use the devices past the first two-week phase. One of these children could not tolerate the iSense receiver due to tactile sensitivity while the other was newly diagnosed with ASD and lacked family support.

APHAB post-device trial (aided hearing disability)

Aided global APHAB scores of the eight trial participants with ASD significantly improved across all four questionnaire categories when compared to the corresponding APHAB scores collected prior to device trial. The iSense in combination with the inspiro resulted in significant perceptual improvements in listening and communication. Mean unaided and aided scores across the four APHAB categories are displayed in Figure 3b.

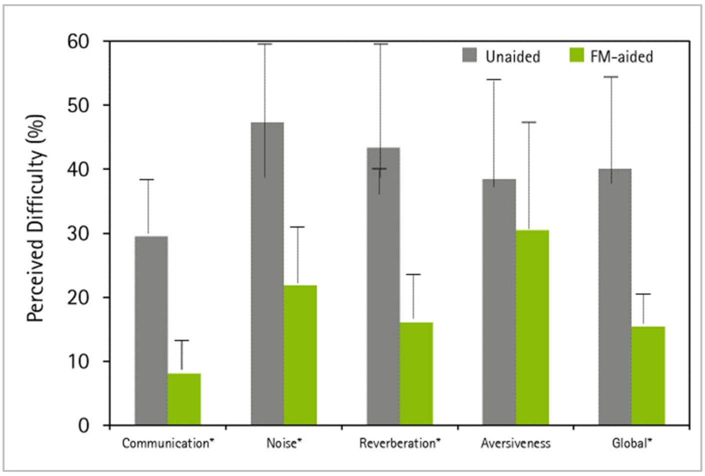

Figure 3b: APHAB hearing disability questionnaire results for unaided and aided conditions. Error bars represent 1 SEM. Asterisks represent the metrics in which there was a significant difference between conditions (p < .001). CNC, Consonant-Nucleus-Consonant.

LIFE post-device trial (classroom listening)

The LIFE total appraisal scores of each child with ASD who participated in the iSense/inspiro trial were within the positive range. The teachers who completed the questionnaire believed the technology resulted in an improvement in listening/ comprehension, classroom behavior and general attentiveness. The mean score of the children was 24.2 ± 8.2, indicating the teachers believed the FM technology to be "highly beneficial".

Discussion

Even though the children in this study were not selected based on hearing history, twelve of twenty met the clinical definition of central auditory processing disorder, scoring > 2 standard deviations poorer than age-related norms on temporal processing and speech-in-noise tests.

Temporal processing was compromised in the majority of the children tested with ASD. Sensitivity to envelope changes over time was strongly correlated with speech perception in noise, with those showing poor temporal processing ability also scoring poorly in phoneme detection (r = –0.440, p = 0.022). This finding supports past literature linking auditory temporal deficits with figure-ground difficulties (Alcántara et al., 2012; Rance et al., 2010).

Impaired temporal processing can also affect the individual's capacity to take advantage of spatial cues including timing, amplitude and frequency differences between the ears, when listening in background noise. Ability to localize sound is compromised when the listener is not able to make use of these cues in their environment. The current study has demonstrated this effect with children with ASD scoring significantly lower than their matched controls in spatial processing. Furthermore, their scores in the LiSN-S (spatial processing) test were correlated with their poor temporal processing scores (r = –0.500, p = 0.015).

The iSense paired with the inspiro was able to improve the speech perception scores of all children tested by providing a greater SNR. Half of the children with ASD scored outside age-related norms on initial CNC word testing. However, their scores on the same test improved to either equivalent or better than the unaided score of their matched control participant when fitted with the iSense device.

Children with ASD reported less difficulty listening in background noise and greater ease of social interaction during the aided phases of their iSense/inspiro trial. All teachers of the children with ASD who trialed the technology found improvement in attentiveness, comprehension, and behavior in the classroom during aided phases.

Limitations of this study that should be addressed and considered in future research include the small sample size, the possibility of participant bias in questionnaires, and the test materials used such that only children with "high-functioning" ASD could be included. Auditory intervention should be considered on a case-by-case basis.

Conclusions

This study provides further evidence of the auditory processing difficulties commonly experienced by individuals with ASD. Use of the ear-level iSense Micro FM receiver paired with the inspiro transmitter addressed these problems through significant improvements in listening, attention, and social engagement. Therefore, these devices should be considered as a management strategy for children with ASD who experience listening difficulties.

Authors & Investigators

Philippa James is working within the Global Phonak pediatric team, and with the Sonova HQ Science & Technology team, to develop a clinical model for the audiologic management of children with autism. Her prior work history includes hearing aid fitting and counseling, and auditory processing assessment and management. She earned a MClinAud in 2012 from the University of Melbourne and an Au.D. from the University of Florida in 2017.

Associate Professor Gary Rance is an audiologist, a full-time researcher and teacher at the University of Melbourne and a part-time sculptor. He is currently Director of Academic Programs and Coordinator of Clinical Research for the Department of Otolaryngology. His current research areas involve various aspects of auditory evoked potential measurement, assessment of long-term communication outcomes in hearing-impaired children, and the diagnosis and management of auditory pathway disorder.

References

Primary reference: Rance, G., Saunders, K., Carew, P., Johansson, M., & Tan, J. (2014). The use of listening devices to ameliorate auditory deficit in children with autism. *The Journal of Pediatrics*, *164*(2), 352–357.

Alcántara, J. I., Weisblatt, E. J., Moore, B. C., & Bolton, P. F. (2004). Speech-in-noise perception in high-functioning individuals with autism or Asperger's syndrome. *Journal of Child Psychology and Psychiatry, 45*(6), 1107–1114.

Alcántara, J. I., Cope, T. E., Cope, W., & Weisblatt, E. J. (2012). Auditory temporal-envelope processing in high-functioning children with autism spectrum disorder. *Neuropsychologia, 50*(7), 1235–1251.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (DSM-5®). American Psychiatric Pub.

Anderson, K., & Smaldino, J. (1999). Listening Inventories for Education: A classroom measurement tool. *The Hearing Journal, 52*(10), 74–76.

Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with autism spectrum disorder. *American Journal of Occupational Therapy, 62*(5), 564–573.

Beck, D. L., & Bellis, T. J. (2007). (Central) auditory processing disorders: overview and amplification issues. *The Hearing Journal, 60*(5), 44–46.

Cameron, S., & Dillon, H. (2007). Development of the Listening in Spatialized Noise–Sentences test (LISN-S). *Ear and Hearing, 28*(2), 196–211.

Cox, R. M., & Alexander, G.C. (1995). The Abbreviated Profile of Hearing Aid Benefit. *Ear and Hearing, 16*(2), 176–186.

Groen, W. B., van Orsouw, L., Ter Huurne, N., Swinkels, S., van der Gaag, R. J., Buitelaar, J. K., & Zwiers, M. P. (2009). Intact spectral but abnormal temporal processing of auditory stimuli in autism. *Journal of Autism and Developmental Disorders, 39*(5), 742–750.

Magyar, C. I., & Pandolfi, V. (2007). Factor structure evaluation of the childhood autism rating scale. *Journal of Autism and Developmental Disorders, 37*(9), 1787–1794.

Needelman, H., Schnoes, C.J., Ellis, C.R. (2006). The new WISC-IV. *Journal of Developmental Pediatrics, 27*, 127–128.

Peterson, G. E., & Lehiste, I. (1962). Revised CNC lists for auditory tests. *Journal of Speech and Hearing Disorders, 27*(1), 62–70.

Rance, G., Corben, L. A., Du Bourg, E., King, A., & Delatycki, M. B. (2010). Successful treatment of auditory perceptual disorder in individuals with Friedreich ataxia. *Neuroscience, 171*(2), 552–555.

Rance, G., Ryan, M. M., Carew, P., Corben, L. A., Yiu, E., Tan, J., & Delatycki, M. B. (2012). Binaural speech processing in individuals with auditory neuropathy. *Neuroscience, 226*, 227–235.

Schafer, E. C., Mathews, L., Mehta, S., Hill, M., Munoz, A., Bishop, R., & Moloney, M. (2013). Personal FM systems for children with autism spectrum disorders (ASD) and/or attention-deficit hyperactivity disorder (ADHD): An initial investigation. *Journal of Communication Disorders, 46(*1), 30–52.

Viemeister, N. F. (1979). Temporal modulation transfer functions based upon modulation thresholds. *The Journal of the Acoustical Society of America, 66*(5), 1364–1380.