Research Request – Frequency modulation (FM) systems for ASD literature review

Brief	The University of Melbourne - Autism Spectrum Disorder (ASD) Listening Clinic, make very strong statements (See position paper attached) suggesting that all children with ASD have central auditory processing problems and all need to be fitted with an FM system which needs to be worn all day for 2 years. Is this true? They present a list of research articles to back up their claims. They are very vocal about the need for these FM systems. We receive many of these support requests in TAB. Our position has been that they do not meet R&N. We have a meeting with Melbourne Uni in the planning stages. The meeting will probably happen in early 2021. Your expert opinion is very welcome to allow us to have informed discussions.
Date	24/12/20
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Contents

Please note:

The research and literature reviews collated by our TAB Research Team are not to be shared external to the Branch. These are for internal TAB use only and are intended to assist our advisors with their reasonable and necessary decision making.

Delegates have access to a wide variety of comprehensive guidance material. If Delegates require further information on access or planning matters they are to call the TAPS line for advice.

The Research Team are unable to ensure that the information listed below provides an accurate & up-to-date snapshot of these matters

Summary

- Abnormal responses to sensory stimuli across multiple modalities are a consistently reported feature of ASD and are now a recognised component of diagnosis.
    - Hearing impairment is relatively common in this population with 2–10% of cases presenting with impaired sound detection thresholds [1, 2]
    - A high proportion (>50% of paediatric cases) show auditory processing deficits which are thought to be related to a distorted representation of temporal cues in the central auditory pathways [3, 4]
- The resources provided in the position paper are mainly of low quality. Those that conducted an investigation using FM systems are case studies (mainly without a control group, use subjects as own control) with very small sample sizes. The remaining literature are editorials, narrative reviews or thesis
- A systematic review has been conducted on FM system use in those with ASD. The authors concluded that;
    - Further research is clearly needed into improving SNR to improve classroom performance in children with ASD, and at least two warnings from the studies reviewed here should be heeded – these were
        1) Some children with ASD are unable to tolerate the personal FM systems used. This promotes the need to further investigate other technologies that could increase the signal level in the classroom without challenging the tactile sensitivities found in many students with ASD, such as the Soundfield amplification systems
        2) There is a need to include functional outcome measures in studies involving children with ASD (such as video classroom observation, sensory and listening experience-focussed questionnaires, etc) as some children included in the studies were not able to complete some of the more widely used behavioural outcome measures
- Studies commonly investigated FM systems over 5-6 weeks and for 45mins to 6 hours per day (some studies didn't even record use time). **Based on this, hard to justify 2 year usage.**

Given the level and quality of evidence provided, and the fact that less than 50 participants have been investigated in total across all studies I would not support FM systems as evidence based practice. However, the results are promising and require further investigation with bigger samples using study designs which are less prone to bias.

Author	Aim/Objective	Methods	Results	Level & Quality of evidence
Glaaser [5]	Investigate the effects of improved classroom acoustics on the educational and behavioural performance of individuals with **ADHD-Inattentive Type or Combined-Type.**	**Thesis** – unpublished, non-peer reviewed 7 participants (aged 14-18) Multiple baseline across participants design with a reversal component was used to assess the effects of the Soundfield Amplification System on the participants' educational and behavioural performance. Participants were observed across four phases: • baseline • intervention (implementation of the Soundfield system) • reversal • re-implementation of the Soundfield system Dependent variables • on-task behaviour • verbal disruptions • work accuracy	Soundfield system increased the on-task behaviour (by 10.5%) and decreased verbal disruptions (48.7%). The data on work accuracy was highly variable. Six of the seven participants, did not demonstrate improvements consistently when the intervention was implemented	**Level: N/A** **Quality = Very Low** (The true effect is probably markedly different from the estimated effect) Non-peer reviewed and unpublished. These results should not be considered accurate or reliable Very small sample. Investigated ADHD not autism or CAPD
Johnston, John [6]	Evaluate the potential benefits in speech perception and	**Case-Control study**	no longer a significant difference between the control group and APD group	**Level: III-2** **Quality: Low** (The true effect might be

	psychosocial function of a new personal FM system, the Phonak EduLink, when used in mainstream classroom environments by children with **APD.**	Intervention group: Ten children (eight male, two female) with a positive diagnosis of APD. Mean age of 11 years, 8 months. Control group: Thirteen children (nine male and four female) with normal hearing & no APD. Mean age of 10 years, 6 months. Intervention group fitted binaurally with Phonak EduLink FM systems. Used for approx. 5 months Use time In school for all lecture based classroom situations Home use was not required but encouraged Fitting Fitted by researchers and instructed on how to use the system Outcome measures • Speech-perception: Hearing in Noise Test (HINT) • Academic performance: listening inventory for education (LIFE) and screening instrument for targeting educational risk (SIFTER)	at the post-fit evaluation for the APD group in the academic domain.(subjectively graded by parents and not teachers) Results of the LIFE self-report evaluation revealed that students in the APD group significantly improved for questions 1, 3, and 5, which relate to the following classroom situations: teacher talking in front of room, teacher talking with back turned, and other students making noise Speech perception: benefit of 3.62 dB (SD_4.63) from use of the FM system Psychosocial: student reported comparisons reflect improvements in psychosocial function for the APD group, specifically in areas related to locus of control, anxiety, depression, and interpersonal relationships.	markedly different from the estimated effect) Small sample of convenience, no blinding, subjective measures used, lack of precision due to no confidence intervals, The present study does not provide data for establishing the duration of time necessary for an adequate trial period of FM use.

		• Psychosocial: behaviour assessment system for children: second edition (BASC-2)		
Keith and Purdy [7]	No aim or objective, however, a "learning outcome" is provided. The participant will be able to (1) list the assistive and therapeutic benefits of remote microphone hearing aids for children with auditory processing disorder, and (2) Explain the importance of expert intervention to support teachers to achieve successful outcomes with amplification for children with APD.	**Editorial** Opinion based, no aims or methods as to how literature was chosen. Predominantly gives an overview of some study findings and what FM systems are.	*"Personal remote microphone hearing aids are currently the only evidence-based amplification treatment shown to improve hearing in classrooms for children with APD."* The literature cited to back this up includes a study published on an FM manufacturer's website, 2 case-control studies, a conference presentation and a quasi-randomised trial (level III evidence). This is not enough to make claims of it being an evidence based practice. There are major biases in these study designs, and further large scale RCTs are needed.	Level: N/A **Quality = Very Low** (The true effect is probably markedly different from the estimated effect Editorial – authors opinion, not based on stats. Can't verify methods.
Rosenberg [8]	N/A	Abstract only - Unable to obtain full text article	Can't comment. Abstract doesn't provide any results.	N/A

Schafer, Mathews [9]	To examine the potential benefit of a frequency modulation (FM) system for 11 children diagnosed with autism spectrum disorders (ASD), attention-deficit hyperactivity disorder (ADHD), or both disorders	**Case-Control study – repeated measures design** <u>Intervention group:</u> 11 children (7 ASD and 4 ADHD) (9-12 years) were included in five separate investigative measures: • Speech recognition in noise • classroom observations of behaviour • teacher questionnaire to assess educational need • teacher questionnaire to assess listening behaviours • Social validation measures (i.e., informal questionnaires) with the teacher and each participant <u>Control group:</u> 11 gender- and age-matched (9-12 years), typically functioning peers participated in the speech recognition in noise measure in a no-FM system condition. All recruited from a single private school classroom (lack of generalisability and causes sampling bias)	Not all participants completed all trials (x2) so their data was removed. 20% removed the FM receiver for some period of time because • the receiver was ‘‘bothering his or her ear(s)” • the receiver was ‘‘uncomfortable’’ • the child was asked by the teacher to remove the receiver and leave the room for behaviour issues Speech recognition in noise varied across participants. Improvement of at least 3dB was seen in one of the 2 trial sessions. <u>On-task behaviours</u> were significantly higher in both FM trial periods as compared to both no-FM trial periods ($p < .05$). <u>Off-task behaviour:</u> only 2/8 codes were significant (Does not follow teacher direction, but engages in distractible behaviours and Does not sit quietly when expected or asked, but instead,	**Level: III-2** **Quality: Low** (The true effect might be markedly different from the estimated effect) Small sample of convenience (2 drop outs), no blinding, and subjective measures used, lack of precision due to no confidence intervals and descriptive statistics used in some instances. Limitations provided by author 1) unable to generalise to public school students 2) Participants in this study were all high-functioning children with relatively few behavioural issues 3) Social consequences of

		Ear-level FM receivers worn on both ears (i.e., Phonak iSense Micro FM receivers), <u>Multiple trial periods</u> Trial 1 = 2 weeks Trial 2 = 3 weeks Only 45 minutes per day	engages in other distractible behaviours) <u>Formal questionnaire results</u> SIFTER questionnaire: no significant differences in the teacher ratings from the no-FM to the FM system conditions (i.e., $p > .05$) for all comparisons. Children's Auditory Performance Scale: small to medium effect sizes. Not all significant.	wearing an FM system 4) Control group only used for speech recognition measures 5) Trial periods were short – hard to determine what effect that might have 6) Participants did not receive full audiological evaluations just prior to the study Future research is warranted to examine potential benefits of FM system use for children with ASD and ADHD in other school environments.
Schafer, Florence [10]	To provide research evidence to support the educational hearing needs of APD, ASD, ADHD and dyslexia populations.	**Combined Editorial/Narrative Review** No methods – only includes evidence in support of FM systems (this is inherently flawed)	Descriptive results of reviewed studies include: *"Across most of the studies, there is a clear improvement in speech recognition performance in background noise in conditions with versus without the FM*	Level: N/A **Quality = Very Low** (The true effect is probably markedly different from the estimated effect

		• Provide an overview of the auditory deficits reported for these populations • Review published studies that support remote-microphone, hearing-assistance technology • Recommend an evidence-based assessment and fitting protocol • Present a case study to demonstrate how the recommended protocols may be used to assess and fit remote microphone HAT on children with normal hearing and disabilities.	*system, with FM gains ranging from 17% to 86% (pretty significant variation – shows uncertainty in results) for fixed-intensity stimuli and 6 to 10 dB for adaptive test stimuli."* *"Results of these questionnaires lend strong (subjective questionnaires are never considered strong evidence) support for the use of FM systems in order to improve communication, comprehension, attention, and listening abilities, particularly in noisy or reverberant environments."* Have copied table with evidence in this paper and pasted below. In total, only 29 participants with ASD have been investigated. This is not a significant number to base practice off.	Editorial – authors opinion, not based on stats. Can't verify methods. Author is the editor of the journal that published the paper. Cannot tell whether peer reviewed. High level of bias
Schafer, Traber [11]	A series of case studies on children diagnosed with APDs, ADHD, ASDs, and/or language disorders will be presented to (1) support specific remote microphone-	**Case study -** Unable to obtain full text article Can't comment on methods 12 participants included	Results taken from the Table provided in Schafer, Florence [10] 1. Sentence recognition in babble at -5 dB SNR: Right ear FM, left ear FM and bilateral FM significantly better than no-FM condition by an average of 65	**Level: IV** Quality: Difficult comment with only abstract details. Likely low to very low due to sample size, lack of generalisability and

	fitting procedures and (2) to report speech-recognition performance in noise; listening comprehension; and participant-, parent-, and teacher-rated listening behaviors following a trial period with the technology.		to 86% 2. Listening comprehension in classroom noise at -5 dB SNR: Significant improvement with FM vs. no FM on main idea, details, reasoning, vocabulary, and understanding messages subtests 3. Student LIFE-R (n=8) and CHILD (n=7): Significant benefit of FM at school in classroom situations on LIFE; significant benefit of FM at home when in noise and in social situations on the CHILD 4. Parent CHILD: Significant benefit of FM in quiet, in noise, at a distance, in social situations, and for media	high possibility of bias due to study design
Rance [12]	No aim/objective	**Opinion piece/Journal club**	Discusses a couple of papers relevant to the area. States that Schafer paper should be interpreted with caution due to the study limitations (which are listed above in the Schafer study). Makes a good point about the Schafer study: *"Participants in this study were all high-functioning children with*	Level: N/A Quality: N/A

			relatively few behavioural issues. It could be argued that youngsters at the other end of the disability spectrum would have an even greater need for better hearing, but expecting these kids to tolerate any device, even for a short period of time, may be unrealistic."	
Rance, Chisari [13] Dr Rance is associate professor at the University of Melbourne, where he coordinates the Master of Clinical Audiology Program.	to objectively evaluate the effect of auditory intervention on the stress response in children	**Case study – pre-test/post-test outcomes** Twenty-six children (6 girls) with ASD participated 16 children (ASD1-16) participated in Study A (mean age 9.5 years) 10 children (ASD17-26) took part in Study B (mean age 14.9 years) Children were assigned to each Study based on their age and educational setting. Convenience sample, non-randomised Participant anxiety levels were evaluated using the Achenbach System of Empirically Based Assessment. For children in Study A, the parents completed the Child Behaviour	Study A *Speech Perception* Mean score for the aided listening condition (M = 76.5, SD = 8.2%) was significantly higher than for the unaided (M = 55.5%, SD = 13.8% (P < 0.001). *Hearing Disability* Hearing disability ratings for the Background Noise subscale were significantly lower for the device-aided listening condition (M = 28.7%, SD = 11.3%) than for the unaided (M = 51.6%, SD = 20.0% (P < 0.001). Ease of Communication subscale were lower for the aided listening condition (M = 15.0%, SD = 15.7%) than for the unaided (M = 26.5%, SD = 21.3% (P = 0.025).	**Level: IV** **Quality: Low** (The true effect might be markedly different from the estimated effect) Small participant numbers, missing parent data, only high functioning children involved, non-randomised, no control group – all these factors lead to uncertainty around results

		Checklist (CBCL) and for Study B, the Teacher Report Form (TRF) was used. Hearing disability survey (Abbreviated Profile of Hearing Aid Benefit) and an audiometric assessment Study A: Each participant was then afforded 1–2 weeks of device experience (M = 8.8 days, SD = 2.1 days) in which the listening system was worn at school and home for 4–6 h per day. Salivary Cortisol concentrations were obtained from saliva samples collected before and after each structured listening session. Study B: Each child participated in three test sessions carried out in a standard classroom. The first involved audiometric assessment carried out one-on-one in a quiet (empty) classroom and expectoration training as per Study A. Subjects then underwent two, 20 min listening sessions in a standard (otherwise unoccupied) classroom	*Parent-Reported Anxiety* Only 6 parents completed the questionnaire. Only 25% reported changes in anxiety level. *Cortisol Concentration* comparison of within-session cortisol change for each individual revealed a significant difference between unaided and aided listening conditions (P = 0.003). Study B *Cortisol Concentration* Comparison of within-session cortisol change for each individual revealed a significant difference between unamplified change and amplified change (P = 0.005) Participants with the poorest functional hearing ability showed the highest physiological stress levels in structured listening/comprehension sessions and also demonstrated the greatest stress reduction with the provision of auditory intervention.	

Rance, Saunders [4]	To evaluate both monaural and binaural processing skills in a group of children with ASD and to determine the degree to which personal FM listening systems could ameliorate their listening difficulties.	**Case study - pre-test/post-test outcomes (control group only used to determine differences of baseline measures)** Intervention group: Twenty children with ASD participated (mean age 12 years, range 8 to 15.4 years). Only children with no known coexisting disabilities and Full-Scale IQ, Wechsler Intelligence Scale for Children values >70 were referred for the study. Control group: age- and sex-matched control participants was also evaluated. Age at data collection was within 12 months of the ASD partner. Outcome measures - Hearing disability questionnaire—the Abbreviated Profile of Hearing Aid Benefit (APHAB). - Basic auditory processing and functional hearing - Listening in Spatialized Noise test - Consonant-Nucleus-Consonant-Word test. Following this "unaided" assessment, the child was fitted with a Phonak Inspiro FM transmitter paired with iSense receivers (Phonak Org,	20 ASD and 20 normal controls <u>Hearing Disability Survey</u> Mean APHAB scores were significantly higher in this group than in controls across a range of perceptual and communication subscales (P < .001). <u>Auditory Temporal Processing</u> Detection of amplitude modulation in ASD subjects was significantly impaired relative to matched controls. <u>Spatial Processing</u> Mean spatial advantage for the ASD group was 9.2 ± 3.2 dB and that for the control group was 11.9 ± 1.4 dB (95% CI 1.0-4.4 dB; P = .003). <u>Open-Set Speech Discrimination</u> Speech perception in noise was poorer in participants with ASD than in matched controls (P = .009). **<u>FM Device Trial</u>** Only primary school group completed the device trial (other group used for baseline	**Level: IV** **Quality: Low** (The true effect might be markedly different from the estimated effect) Small participant numbers, only high functioning children involved, non-randomised, no comparison group – all these factors lead to uncertainty around results.

		Murten, Switzerland). Speech testing repeated after fitting of FM system. Day-to-day listening ability was investigated in the primary-school ASD group (n = 10) across a **6-week**, take home device trial. A balanced design (ABBA) was used, involving 2-week periods of device use (B) and 2-week periods of non-use (A) to allow for learning/experience effects. During "device-on" phases, the children (and teachers/parents) were encouraged to wear the system throughout the day. **Four to 6 hours of sustained use per day was typical.**	comparisons). 8/10 completed the study. FM device use afforded significant listening and communication benefits (P = .001). Listening Inventory For Education Questionnaire shoed positive improvements ("highly beneficial)	
Schafer, Wright [14]	To conduct assistive technology evaluations on 12 children diagnosed with ASD to evaluate the potential benefits of remote microphone (RM) technology	**Case study – within subject design** 12 participants who completed the study (age 6 to 17 years) 5 participants did not complete the study due to one or more of the following reasons: 1) the inability to tolerate wearing the RM technology (n = 3) 2) parent and teacher questionnaires were not returned following the trial period, and the child was unable to do behavioural testing (n = 1)	The individual and group teacher (n = 8–9), parent (n = 8–9), and participant (n = 9) questionnaire ratings revealed substantially less listening difficulty when RM technology was used compared to the no-device ratings. Medium to large effect sizes and significant benefit across all questionnaires On the behavioural measures, individual data revealed varied findings (missing data).	**Level: IV** **Quality: Low** (The true effect might be markedly different from the estimated effect) small sample of children across the ASD spectrum, actual use time was not recorded, no control group, certain statements on the questionnaires did not

		3) the child was identified with a profound sensorineural hearing loss during the study (n = 1) Digital Phonak Roger inspiro transmitter synced to bilateral, digital Phonak Focus receivers with SlimTubes and open SlimTip domes <u>Questionnaires and test measures</u> A total of five questionnaires were given to teachers, parents, or participants to complete before and after a six-week trial period with the RM technology. • Listening Inventory for Education-Revised • Children's Auditory Performance Scale • Children's Home Inventory for Listening Difficulties • L.I.F.E.-R Student Version • Short Sensory Profile <u>Behavioural measures</u> Laboratory-based behavioural test measures included speech recognition in noise, auditory comprehension and working memory, and acceptable noise levels.	Variability in the data and the inability of some children to complete the behavioural measures indicates that individualized assistive technology evaluations including functional questionnaires will be necessary to determine if the RM technology will be of benefit to a particular child who has ASD.	directly apply to situations that the child experienced at home or at school Author concludes "it should be noted that the device does not cure children of attention deficits, language disorders, and auditory processing issues."

		Children asked to use system 2 hours per day. Actual use time was not recorded		
van der Kruk, Wilson [15]	Reviews the literature to determine if improving the signal-to-noise ratio (SNR) improves classroom performance in students with ASD	**Systematic Review** Six databases: PubMed, Scopus, Embase, ERIC, CINAHL and PsychInfo. No publication time limit was applied, but publications in languages other than English and/or in non-electronic sources and grey literature were excluded. Participant inclusion criteria: 1) school-aged children ASD with or without other comorbid developmental disorders such as ADD/ ADHD 2) Exposed for any duration to some form of SNR enhancement be that device (e.g. personal FM or soundfield amplification) or environmental (e.g. acoustic treatment of the classroom) in nature.	5 research studies included Limitations of these studies (which have been reviewed above) • Lack of randomized controlled trials • Lack of explicit descriptions of how ASD was diagnosed in participating children • Small sample sizes • Potential participant bias in some questionnaire data • Low teacher response rates • Relatively low number of 'low-functioning' children with ASD. While further research is clearly needed into improving SNR to improve classroom performance in children with ASD, at least two warnings from the studies reviewed here should be heeded.	**Level: IV** (only low level studies included) **Quality: Moderate** (the authors believe that the true effect is probably close to the estimated effect) Sold methods used. Studies included were of low quality which impacts the certainty of results.

			1) Some children with ASD being unable to tolerate the personal FM systems used in. This promotes the need to further investigate other technologies that could increase the signal level in the classroom without challenging the tactile sensitivities found in many students with ASD, such as the soundfield amplification systems 2) The need to include functional outcome measures in studies involving children with ASD (such as video classroom observation, sensory and listening experience-focussed questionnaires, etc) as some of these children will not be able to complete some of the more widely used behavioural outcome measures.	

Table 1. Evidence Regarding Benefit of Remote-Microphone Technology in Children with Normal Hearing and Auditory Differences

Disorder; Participants	Authors, Year	Test Measure: Results
APD: • 10 APD • 13 controls	Johnston et al., 2009	1. Sentence recognition in speech-shaped noise at +5 dB SNR: Improved significantly by 10 dB with FM vs. without FM with greater FM benefit for APD vs. control group 2. Parent SIFTER: At baseline, APD significantly worse than controls for 'Academics', but the difference no longer existed for Academics after the FM trial 3. Participant LIFE: Significant benefit of FM over no FM when teacher talking in front of room, teacher talking with back turned, and other students making noise 4. Psychosocial function BASC-2: Improved ratings for locus of control, anxiety, depression, and interpersonal relationships
ASD: • 10 ASD with FM • 10 controls	Rance et al., 2014	1. Word recognition in babble at 0 dB SNR: Average improvement of 17% from no-FM to FM condition for ASD group and 10% improvement for control group 2. Child APHAB: Significantly less difficulty with communication, in noise, and in reverberation 3. Teacher LIFE: Teachers rated FM as "highly beneficial" for each child; FM improved listening/comprehension, classroom behavior, and general attentiveness
ASD/ADHD: • 7 ASD (2 ADHD; 2 APD) • ADHD (2 APD) • 11 controls	Schafer et al., 2013	1. Sentence recognition in babble, decreasing SNRs: Improved significantly by 6 dB over 2 separate test sessions; performance significantly worse than controls with no-FM, but with FM, performance similar to controls 2. Examiner-observed classroom behavior: Significant improvement of on-task behavior with FM vs. no FM 3. Teacher SIFTER: No significant improvements with FM vs. no FM 4. Teacher CHAPS: Significant improvements for noise, quiet, ideal, auditory memory sequencing, and auditory attention span with FM vs. no FM
ASD, ADHD, LD, or SLI • 12 subjects	Schafer et al., 2014	1. Sentence recognition in babble at -5 dB SNR: Right ear FM, left ear FM and bilateral FM significantly better than no-FM condition by an average of 65 to 86% 2. Listening comprehension in classroom noise at -5 dB SNR: Significant improvement with FM vs. no FM on main idea, details, reasoning, vocabulary, and understanding messages subtests 3. Student LIFE-R (n=8) and CHILD (n=7): Significant benefit of FM at school in classroom situations on LIFE; significant benefit of FM at home when in noise and in social situations on the CHILD 4. Parent CHILD: Significant benefit of FM in quiet, in noise, at a distance, in social situations, and for media
ADHD/ADD: • 31 subjects	Updike, 2006	1. Closed-set word recognition in white noise at +4 dB SNR: Average improvement of 34% with FM over no FM 2. Teacher questionnaires: Significant improvement in attention and listening skills
Friedreich Ataxia: • 10 subjects	Rance, 2010	1. Word recognition in babble at 0 dB SNR: Average improvement of 27% from no-FM to FM condition 2. Child APHAB: Significantly less difficulty with communication, in noise, and in reverberation
Dyslexia: • 38 subjects • 19 used FM • 19 controls with Dyslexia	Hornickel et al., 2012	1. Phonological processing and reading: Significant improvements after 1 year trial with FM while controls had no improvements 2. Auditory brainstem response to stop consonants: FM group had significantly improved neural consistency (i.e., repeatability) relative to the control group, particularly in children who showed the greatest gains in phonological awareness

Note. ADHD=Attention-Deficit Hyperactivity Disorder; APD=Auditory Processing Disorder; ASD=Autism Spectrum Disorder; APHAB=Abbreviated Profile of Hearing Aid Benefit; BASC-2=Behavior Assessment System for Children, 2nd edition; CHAPS=Children's Auditory Performance Scale; FM=frequency modulation system; LIFE=Listening Inventory for Education; LD=language disorders; SIFTER=Screening Instrument for Targeting Educational Risk; SLI=Specific Language Impairment; SNR=signal-to-noise ratio.

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