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Communication for **C**hildren with **H**earing **I**mpairment to optimise **L**anguage **D**evelopment

Workshop 4

Abstracts of ESR's presentations

Leuven, February 8-10, 2023

WORK PACKAGE 1

Biological diversity in plasticity and adaptation

ESR1. To investigate whether cortical (a)symmetry can be restored in children with single-sided deafness following a Cochlear Implant.

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In single-sided deafness (SSD), a cortical reorganization process in response to unilateral auditory deprivation has been demonstrated in humans. It is expected that early intervention with a cochlear implant (CI) can prevent or reverse this reorganization process. The goals of the presentation are to demonstrate the aim of the study, which is assessment the possible restoration of the brain after CI in children with SSD, compared to children with SSD without a CI through electroencephalography, and the method of the study.

ESR2. Automatic landmark localization in CT images using deep learning

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For cochlear implantation, it is critical for otologists to get insight into a patient's specific anatomy through CT imaging of the temporal bone, however, manually segmenting the relevant anatomical structures in temporal bone is complicated and time consuming for both surgeons and radiologists (Neves, Tran, Kessler & Blevins, 2021). Hence, we plan to create a 3D automated classification and segmentation pipeline for anatomical structures of interests in temporal bone CT images, which requires prior manually segmented data as input to the model or as a reference (ground truth) for training and evaluating the model, the data has been labelled by using 3DSlicer software (Fedorov et al., 2017).

We currently have a preliminary result on a 2d binary classification and localization of single/multiple slice(s) of a 3D CT scan, to determine whether there is a cochlea presence on the selected slice(s). A heat map has been generated based on the probability of the presence of the cochlear in different regions given by the binary classifier. However, the above process is computationally expensive (takes 6-8 hours on M1 CPU). Therefore, the recent works have been focused on improving the localization accuracy as well as the inference time. By integrating further optimization methods and combing them with the state-of-the-art deep learning algorithm in computer vision, the updated algorithm can reduce the computational complexity to a significant extent and potentially requiring a few minutes (on a 4* TeslaV100) to complete an automatic 3D segmentation of the entire CT scan, with an error of less than 1mm. The detailed data will be presented and discussed at the Comm4CHILD workshop.

Fedorov A., Beichel R., Kalpathy-Cramer J., Finet J., Fillion-Robin J-C., Pujol S., et al. (2012). 3D Slicer as an Image Computing Platform for the Quantitative Imaging Network. Magnetic Resonance Imaging. 2012 Nov;30(9):1323-41. PMID: 22770690. PMCID: PMC3466397.

Neves C. A., Tran E. D., Kessler I. M., & Blevins N. H. (2021). Fully automated preoperative segmentation of temporal bone structures from clinical CT scans. Sci Rep,11(1):116. https://doi.org/10.1038/s41598-020-80619-0

ESR3. Time-frequency analysis of local field potentials in DZ and MLS

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Congenital deafness affects the normal development of the auditory cortex, and this affects cross-sensory interactions between the auditory and other sensory areas. The presence of such changes after congenital deafness becomes especially important when hearing input is restored later in life with cochlear implants. On a neuronal level, it is not clear, how these adaptive cortical changes affect the restoration of hearing with cochlear implants for normal functioning. These plastic changes can lead to changes in sensory responsiveness in auditory and visual areas and specifically changes in interaction, connectivity, and coupling. To study these questions, we measured audiovisual interactions in the sensory cortex of CI-implanted congenitally deaf cats. We recorded cortical neural activity with 16 site microelectrode arrays on both sides along the suprasylvian sulcus, a border zone between auditory (DZ) and visual (MLS) areas. Specifically, we acquired local field potentials (LFPs) in normal hearing and congenitally deaf cats during CI stimulation and visual stimulation.

We tested whether the cross-modal visual responses in the auditory cortex reflect any unspecific visual reactivity or whether they are sensitive to visual features. we assessed orientation selectivity to oriented phase-reversal gratings in 12 different orientations (0°, 15°, 30°, …,150°,165°). We used the power of the phase-reversal frequency to calculate orientation tuning curves. Although some recording sites showed some indication of orientation selectivity, most sites were unspecific to orientation. This was also proved by calculating the orientation selectivity index. Then an orientation selectivity index was calculated by vector averaging the response vectors for all orientations angles in the visual stimulus. Then, we aimed to identify statistically significant orientation tuning of overall number of sites for the grand pooled data for both hearing and congenitally deaf groups. Unsurprisingly, result of this confirmed that not too many statistically significant orientation tuning exists in either visual or auditory areas. (Rayleigh test, $P<0.02$).

In our previous analysis, we focused on time-domain and frequency-domain analysis of the data. What is overlooked in the time-domain analysis can be revealed by frequency-domain analysis and what cannot be demonstrated by frequency-domain techniques, is attainable by implementing time-frequency analysis. The idea of such analysis is to simultaneously analyze the signal in time and frequency domains. We analyzed local field potentials whose spectral characteristics vary over time using a so-called time-frequency technique called Morlet wavelet. Specifically, we studied evoked, induced, and total power of LFPs between Hearing and Deaf Groups. The results of these analyses will be reported in the workshop.

ESR 4. Are neural correlates of audio-tactile speech measurable with functional near-infrared spectroscopy?

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The presence of a vibrotactile stimulus conveying speech information to the skin has been found to enhance the intelligibility of speech-in-noise, in normal-hearing and cochlear-implanted listeners. However, only few studies have investigated this effect so far, and the neural mechanisms underlying the enhancement are unknown.

Therefore, we investigated whether a tactile enhancement effect as reported in Fletcher et al.[1,2] could be replicated, extending the paradigm by another difficulty level and an audio-tactile control condition in which a tactile stimulus was presented, but whose information content was unrelated to the speech stimulus. Furthermore, the study aims to identify neural correlates of a possible audio-tactile enhancement effect using functional near-infrared spectroscopy.

Speech intelligibility was measured in 23 German native speakers with normal hearing and 14 cochlear implant patients. Sentences were presented in a 2x3 task design with *auditory alone, auditory + tactile envelope*, *auditory + tactile noise* conditions played in 2 difficulty levels (*easy* and *difficult* SNR), respectively.

Due to ceiling effects within the *easy* SNR conditions, the statistical analysis was focused on the three *difficult* SNRs conditions. For both participant groups, we found a significant enhancement for sentences presented in the *auditory + tactile envelope* over *auditory + noise* conditions, which is in line with findings in previous literature.

Preceding the main analysis of cortical activations related to an audio-tactile enhancement effect, it will be tested whether auditory and tactile sensory areas can be distinguished with the current paradigm. Further exploratory analyses will target subject-specifically selected regions-of-interest and testing for an audio-tactile enhancement effect in the posterior superior temporal sulcus.

In summary, we could replicate a small tactile enhancement in both participant groups. With fNIRS data analysis being ongoing, no final conclusions can be drawn yet on whether this effect can be explained by audio-tactile integration in posterior temporal regions.

Fletcher, M. D., Hadeedi, A., Goehring, T., & Mills, S. R. (2019). Electro-haptic enhancement of speech-in-noise performance in cochlear implant users. *Scientific Reports*, *9*(1), 11428. https://doi.org/10.1038/s41598-019-47718-z

Fletcher, M. D., Mills, S. R., & Goehring, T. (2018). Vibro-Tactile Enhancement of Speech Intelligibility in Multi-talker Noise for Simulated Cochlear Implant Listening. *Trends in Hearing*. https://doi.org/10.1177/2331216518797838

WORK PACKAGE 2

Multimodality and optimisation of cognitive resources

ESR 5. The integration of Cued-Speech cues to speech sounds in the presence of noise in severely hearing-impaired adults

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The Cued-Speech is a communication system that transduces speech sound into a visual code composed by manual gestures. Complementary information provided by CS cues circumvent ambiguities inherent to lipreading mitigating missing or distorted auditory information. In this sense, the compromise between lipreading and CS cues enables precise speech perception without sound. Nowadays, with the advance of cochlear implants, speech therapists may wonder the effect of CS exposition on audio-visual speech perception. One previous study showed that CS cues associated to lipreading improves speech in noise reception in adults who are fitted with cochlear implants. However, it remains unclear whether CS cues provide a gain to auditory speech perception. Another possibility could be that CS users only use visual information provided manual gestures and lipreading and ignore the acoustic signal. The present study aimed at investigating whether CS cues isolated from lipreading improve speech in noise perception. Twenty-nine hearing impaired adults equipped with cochlear implants or hearing-aids and mastering CS participated to the study. We used an adaptive method for measuring speech reception threshold using speech-shaped-noise (SSN) in an audio-only condition. Followingly, listeners reported what they heard and we determined the signal-to-noise ratio (SNR) enabling the reception of 40% of correct keywords. Individual signal-to-noise ratio was used to select the set of prepared test stimuli. Each participant was exposed to 110 trials which were presented in eleven conditions randomly mixed : Audio-only (10); Audio-Lipreading (10); Lipreading-only (10); Lipreading-CS cues (10); Audio-Lipreading-CS cues (10); Audio-CS cues (10); CS cues-only (10); Audio-only + noise (10); Audio-Lipreading + noise (10); Lipreading-only (10); Lipreading-CS cues (10); Audio-Lipreading-CS cues + noise (10); Audio-CS cues + noise (10) and CS cues-only (10). Moreover, to control for item effect, we created two orders counterbalancing sentences among conditions. We compared speech perception score obtained in Audio-only to Audio-only + CS cues condition and in Audio-only + noise condition to Audio-only + CS cues + noise condition. Preliminary results will be presented during the workshop.

ESR 6. Role of orofacial somatosensory inputs in speech perception and production in individuals with hearing impairment

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Hearing impairment (HI) can lead to difficulty in acquiring speech production and perception without the help of hearing devices. This can also affect interaction between production and perception. Considering the role of orofacial somatosensory inputs in the interaction between speech production and perception in normal-hearing individuals (NH), this could also intervene in the development of hearing and speaking in HI ones. We here explored this question in three related studies.

First, we investigated the relationship between speech production and auditory-somatosensory integration in speech perception. We examined whether the variability in speech production might be related to the variability in the magnitude of the somatosensory effect in speech perception. Although the somatosensory effect appeared limited in HI subjects, we found that perceptual performance related to vowel identification was dependent on their hearing profile and hearing threshold in noise. The NH group showed that larger acoustic distances between vowels in production were associated with larger somatosensory effect in perception.

Secondly, we investigated whether speech production was changed when orofacial somatosensory inputs were received in perceptual training. We compared speech production performance before and after perceptual training with somatosensory stimulation related to facial horizontal gestures. A control group was tested with no somatosensory stimulation. The third formant of the target vowel, related to lip spreading, increased after perceptual training with somatosensory stimulation but not in the control group, suggesting that repetitive exposure to somatosensory inputs paired with speech sounds can play a role in speech learning.

Thirdly, we examined whether HI participants adapt their production through altered auditory feedback training. In addition to the adaptation task, we measured vowel identification performance and hearing threshold in noise. The pilot test showed a tendency that adaptation performance can vary depending on the HI hearing profile.

These studies confirm the role of auditory-somatosensory integration in NH participants where the somatosensory effect in speech perception appears to be related to the production performance and likely recalibrates production mechanisms. This effect appears limited in HI participants. Since speech perception abilities and production performance are jointly related to the hearing ability, it is likely that the development of auditory-somatosensory integration may be related to the development of their hearing ability. This should be the topic of further evaluations of speech perception and production in relation with somatosensory inputs in individuals with hearing-impairment.

ESR 7. Speech-in-noise understanding and cognitive factors in children with normal hearing and hearing impairment

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Understanding speech in noise is an everyday task for adults and children alike. Many factors are known to affect how well one can understand speech in the presence of background noise, such as sound levels and spatial separation of speech and noise sources. Cognitive factors such as attention and working memory are also understood to play a role, but how these factors' effect on speech understanding in noise develops in children is not well understood, particularly in the case of children with hearing loss. As a first step towards shedding light on these questions, we developed a paradigm that aims to recruit attention and working memory in a speech-in-noise task by requiring participants to switch or maintain attention to different speakers in a realistic scene. Here, we present the first set of data from adults with typical hearing as a validation of the paradigm and discuss the implications of its results.

ESR 8. Pupil insights during novel word detection and dynamic learning: a study in school-aged children

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The learning of novel word forms is dependent on the accurate detection and categorization of the input's phonemes and the formation of a stable representation of the phonological sequence in multiple exposures. Whilst the measure of the pupil dilation during a listening task can reveal information both about detection of new and deviant stimuli, as well as the effort allocated during language processing. Hence, we hypothesize that pupillometry can give objective insights on how novel word learning process occurs.

This is an exploratory study with the goal to investigate the pupil behavior during the detection and learning of novel word forms which present minimal phonological contrast.

Twenty-nine normal hearing Danish speaking children, with age between 7 and 12 years old, performed a test battery composed by phonological discrimination, word recognition, nonword detection in sentence, and dynamic novel word learning. Performance data as well as objective data from pupillometry were registered.

We could validate the feasibility of the protocol for use with children in the evaluated age-range as well as the difference between the data registered in this population and in normal hearing adults from the previous study. Comparison with children with hearing impairment is planned as the following step.

ESR 9. Theory of mind, language and working memory in typically developing school-aged children

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Research on theory of mind (ToM) has been predominantly focused on its development in preschool years. That is when the cognitive change in false-belief understanding occurs. However, more researchers agree that ToM development is not limited to the preschool years, expanding their interest to middle childhood. During that period, children acquire complex understanding of mental life.

Numerous studies have investigated and found the relationship between ToM and receptive vocabulary. Fewer studies have looked into different language aspects that might contribute to ToM development in different ways. Nonetheless, children's general language skills could be more important than any single aspect when understanding mental states and complex social situations.

Working memory has also been found to play a role in ToM development.

The aim of this study is to examine the relationship between ToM, language (expressive vocabulary and general language ability) and working memory in typically developing children.

For that purpose, thirty Norwegian-speaking children aged 6 to 12 participated in the study. During the two testing sessions, ToM, language and working memory tests have been individually administered. The results will be presented and discussed.

ESR 10. Exploring deep learning techniques to analyse the attention mechanism for ACSR

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In 2021, we explored and proposed a light model for automatic Cued Speech recognition (ACSR) which outperforms our previous approach and competes with other recent approaches and published a paper with this study at ICASSP 2022. We found that recent neural language models and the use of larger and multi-speaker datasets could lead to significant improvements in decoding performance. Therefore, in 2022, we started collecting data to expand the Cued Speech (CS) dataset in French and also began recording for the American English CS corpus. Having collaborated with Ives for my Secondment in 2022, we have finished recording 1220 sentences with a single speaker for the French CS corpus. We were able to obtain upto 65% accuracy with the new (uncleaned corpus) on the ACSR model published at ICASSP and expect to get better results after data pruning. We will continue to record more for the French corpus remotely for a multispeaker corpora with the help of the Handz'Up application developed by Ives and explore the advantages of having a multispeaker dataset to finetune the architecture. Meanwhile I will continue to explore different methods for cued speech recognition using attention mechanism to realize our aim to compare human attention and that of neural network's in the context of cued speech. Further, I will also be testing the limits on CS generation with the new and clean corpus.

WORK PACKAGE 3

Environment and enhancement of language skills

ESR 11. The Ethical Approval Journey: challenges and useful lessons

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The process of obtaining Ethical Approval from the competent authority is an important and necessary milestone in the development of any research study, and a personal achievement – whether small or more meaningful - for any researcher. In the UK, obtaining Ethical Approval from the Health Research Autority (HRA) is a mandatory step for any researcher who choose to investigate people part of the National Health Service (NHS) caseload. Unfortunately, this process has been known to be very long and challenging, even to the extent of almost becoming a deterrent for the researchers themselves. However, this journey can spark meaningful discussion and promote researchers' insight.

This presentation will discuss some of the steps that both Nathalie Czeke (ESR12) and myself (ESR11) had to go through to obtain HRA Ethical Approval, with a specific focus on the Ethical challenges I specifically faced to ensure the safety and protection of participants in my own study. The presentation will focus on some of the most challenging ethical issues for the construction of the study itself, what the Ethical committee objected or promoted and why those initial obstacles contributed to a better understanding of my own research practice and of the field in general.

ESR 12. Access to and Opportunities for Communication in Moments of Joint Attention

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Early detection of hearing loss does not necessarily equal early intervention – both in countries with established universal neonatal hearing screening and particularly in poorer countries where early detection and especially targeted follow-ups are less broadly available (e.g. Neumann et al., 2022). The resulting lack of systematic access to language, spoken and/or signed, between early diagnosis and successful onset of intervention often leaves deaf children at risk of language deprivation during a time that forms the critical period for (language) development. The earliest form of support, consequently, calls for accessible communication, despite and especially in the presence of sensory and communication asymmetries between hearing parents and deaf children, that have been shown to affect moments of joint attention.

In the current research, we focus on exactly these critical moments of joint attention in the presence of sensory and communication asymmetries and aim to reveal the potential of multimodal communication strategies in making communication accessible to children who are deaf or hard of hearing while facilitating joint engagement with their hearing family members and peers. We further investigate how multimodal communication strategies are influenced by individual affordances, context and the interactional situation. Systematic multimodal analysis of video-recorded play sessions with ELAN, an annotation tool for audio and video recordings, is thereby used to identify and analyse multimodal communication strategies involved in initiating and sustaining episodes of joint attention between hearing parents and deaf children (9-24 months).

In a multimodal approach, we highlight individual resources rather than deficits in early language development and echo findings that show that the latter is not impacted by deafness itself but dependent on the individual's access to language.

Neumann, K., Mathmann, P., Chadha, S., Euler, H.A. and White, K.R. 2022. Newborn hearing screening benefits children, but global disparities persist. *J Clin Med.* 11(1).

ESR 13. Orthographic learning in deaf-or-hard-of-hearing children: how to adapt a self-teaching procedure?

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Although it is generally known that phonological representations are underspecified in deaf and hard-of-hearing (DHH) children, several authors argued for the use of phoneme-grapheme knowledge to spell words in alphabetic languages. Regarding orthographic learning (i.e., the development in memory of word-specific orthographic representation that allow for faster reading), phonological decoding of new words plays a predominant role, both in typically hearing (TH) and DHH children (Wass et al., 2019). In our first study, we used a self-teaching procedure to assess the quality of orthographic learning in 29 DHH children fitted with cochlear implant(s) or hearing aid(s) matched with 29 TH children of the same chronological and reading age (mean age = 9 years). Overall, both groups of children performed poorly in the spelling task, and DHH children were better than TH children in the recognition task. Spelling errors of DHH children suggested difficulties to access accurate phonological representations, in the context of an oral dictation task. Recognition errors were primarily phonological for both TH and DHH children. The tendency of DHH children to choose the orthographic distractor more often than TH children suggests that visual cues are more involved in spelling acquisition in DHH children than in TH children. To test if our results replicate when the spelling task does not fully rely on the auditory modality, we are going to change the dictation task to a picture written naming task. In a nutshell, pictures will be associated with pseudoword in stories. This new procedure and material considerations will be discussed in the workshop. This forthcoming study will enable us to assess more specifically the weight of phonological and visuo-orthographic cues in the memorization of new orthographic representations.

Wass, M., Ching, T. Y. C., Cupples, L., Wang, H.-C., Lyxell, B., Martin, L., Button, L., Gunnourie, M., Boisvert, I., McMahon, C., & Castles, A. (2019). Orthographic Learning in Children Who Are Deaf or Hard of Hearing. *Language, Speech, and Hearing Services in Schools*, *50*(1), 99–112. https://doi.org/10.1044/2018_LSHSS-17-0146

ESR 14. Speech perception in children with cochlear implants: A study of Auditory Verbal Therapy and French Cued Speech

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Early exposure to a rich linguistic environment is essential as soon as the diagnosis of deafness is made. Although cochlear implants (CI) improve speech perception, the auditory information transmitted by the CI remains degraded (Colin et al., 2017; Leybaert & LaSasso, 2010; Machart et al. 2020). This study investigates the contribution of two spoken language rehabilitation approaches to speech perception and speech production in children with cochlear implants (CI). Auditory Verbal Therapy (AVT) is an early intervention program that relies mostly on auditory learning to enhance hearing skills in deaf children with CI. French Cued Speech, also called Cued French (CF), is a multisensory communication tool that disambiguates lip reading by adding a manual gesture. To assess speech perception and production, we used three tasks from the EULALIES battery (Meloni et al. 2017): lexicality judgment, picture naming and pseudoword repetition. This study includes children aged 5 to 11 years: 90 typically-hearing children (TH group) from the EULALIES cohort, 9 deaf children with CI who had participated in an AVT program (AVT group), 6 deaf children with CI with high Cued French reading skills (CF+ group), and 19 deaf children with CI with low Cued French reading skills (CF- group). Results from the lexicality judgment task show that children from the CF- and CF+ groups have significantly lower performance compared to TH children. Additionally, children in the AVT group also tended to have lower scores compared to TH children. However, exposition to AVT and CF seems to improve speech perception. Indeed, the scores of the children in the AVT and CF+ groups are closer to typical scores than those of children in the CF- group, as evidenced by a distance measure. Overall, the findings of this study provide evidence for the effectiveness of these two speech and language rehabilitation, and highlight the importance of using a specific approach in addition to a cochlear implant to improve speech perception. Further analysis of the data from the picture naming and the pseudoword repetition tasks is expected to provide more information on the contributions of each rehabilitation approach on speech perception and production.

Colin, S., Ecalle, J., Truy, E., Lina-Granade, G., Magnan, A., 2017. Effect of age at cochlear implantation and at exposure to Cued Speech on literacy skills in deaf children. Research in Developmental Disabilities 71, 61–69.

Leybaert, J., & LaSasso, C. J. (2010). Cued Speech for enhancing speech perception and first language development of children with cochlear implants. *Trends in Amplification*, 14:2, p. 96-112.

Meloni G., Loevenbruck H., Vilain A. & Macleod A. (2017). EULALIES, The France-Québec Speech Sound Disorders project, Actes de *14th International Congress for the Study of Child Language (IASCL)*, Lyon, France.

Machart, L., Vilain, A., Loevenbruck, H., Ménard, L., 2020. Influence of French Cued Speech on consonant production in children with cochlear implants: an ultrasound study, in: ISSP 2020 - 12th International Seminar on Speech Production. Haskins Laboratories, Providence (virtual), United States.

ESR 15. Perception and production of acoustical contrasts for pharyngeal fricatives in non-native learners: a training effect supported by embodied-based training

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This study investigates the impact of body-based pronunciation training on second-language learning (L2). The embodiment-based training aimed to expose participants to movements that were thought to be either “congruent” or “incongruent” with the articulatory information of the targeted phonetic features. Forty-five French speakers were trained to pronounce syllables containing voiced pharyngeal fricative and voiceless pharyngeal fricative. Participant were randomly allocated to one of three training types: watching someone pronounce the syllable while doing (i) “congruent” movements; (ii) "incongruent” movements; (iii) no movement. Participants were tested on perception and production in a pre-test, an immediate post-test, and a delayed post-test. Results show that embodied-based training with both kinds of movements significantly enhance the perception and production of the voiced (but not unvoiced) pharyngeal fricative.

Interestingly, at pre-test, French speakers were poorer at discriminating and producing the voiced than unvoiced pharyngeal fricative.

As part of post-hoc analysis, we want to gain further understanding about the relationships between “congruent” vs “incongruent” body movements cues and the articulatory cues of the targeted phonetics features used in this experiment. We aim to gather feedback from native speakers of Arabic on the appropriateness of several body movements with the speech sounds heard. The results of this analysis will be shared during the comm4CHILD conference. Additionally, the clinical implications of the findings will also be discussed.