H2020-MSCA-ITN-2019
Grant agreement n° 860755

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

Workshop 2: Human Communication and Language

Poster Session – December 13

ABSTRACTS

WORK PACKAGE 1

Biological diversity in plasticity and adaptation

ESR1. Attempting to reconstruct auditory neural generators using EEG

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Congenital single-sided deafness (cSSD) is a condition that affects 30 out of 100.000 children. This condition is characterized by profound hearing loss in one ear and normal hearing (NH) in the other. The lack of binaural hearing generates an aural preference syndrome. In this syndrome the NH ear creates brain auditory projections into the affected ear, leading to a brain asymmetry.

Currently, there are no standard treatments for this condition. Nevertheless, based on evidence on patients with bilateral and unilateral deafness, it is expected that cochlear implants (CI) may partially restore binaural hearing. Thus, preventing the aural preference syndrome.

My doctoral research aims to investigate whether the use of CIs changes the aural preference syndrome in children with cSSD, and how this affects brain plasticity. This will be done using measures of electroencephalography (EEG) and brain functional connectivity.

To calculate the brain functional connectivity, it is necessary to first determine the neural generators associated with the integration of auditory processing. In the past, MRI has been used to determine the subcortical neural generators. However, EEG has a high temporal resolution, which makes it more adequate for the analysis of auditory processing.

Before analysing the brain's neural generators in children, it is necessary to reconstruct these generators in adults. This study aims to determine whether it is possible to reconstruct the cortical and subcortical neural generators, associated with auditory processing using EEG from normal-hearing adults. To do this, the auditory steady-state responses (ASSRs) and the minimum norm imaging (MNI) methodology were utilized. To evaluate the neural generators obtained, the apparent latency values were calculated and compared with the literature. The results from this study will be presented during the workshop.

ESR2. Data analysis, modeling, and prediction of underperforming cochlear implant patients based on individual anatomy (CT), brain signals (EEG), and audiological tests

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Understanding the causes for poor cochlear implantation outcomes is a difficult research challenge[1]. Therefore, we will investigate both technological factors (i.e. dimensions and placement of the cochlear implant, etc.) and biological factors (i.e. inter-individual variation of cochlear size and shape) and then analyse both regarding hearing outcomes in adults with cochlear implants. For cochlear implantation, it is critical for otologists to get insight into a patient's specific anatomy through CT imaging of the temporal bone[2], but it is complicated for both surgeons and radiologists to manually segment the relevant anatomical structures in temporal bone[2]. Hence, we plan to create a 3D automated classification and segmentation pipeline (on 3D temporal bone CT scan). The algorithms of histogram based intensity thresholding, or region based segmentation, different deep learning models (CNN, etc.), different machine learning models (random forest, etc.) and image registration are planned to be implemented and compared by different metrics. We currently use 3DSlicer to generate the minimum amount of manually segmented data required for each algorithm, as an input to the model or as a reference for evaluation (ground truth). Different qualitative/quantitive image assessments (DSC, etc.) will be integrated to compare the performance of different algorithms. We currently have a preliminary result (with low accuracy) on a 2d binary classification of single/multiple slice(s) of a 3D CT scan, to determine whether there is a cochlear 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. We are planning to implement different approaches to improve the performance of this algorithm. Results will be shown and discussed during the poster session of the Comm4CHILD workshop.

1. Pisoni D. B., Kronenberger W. G., Harris M. S., Moberly A. C. (2017). Three challenges for future research on cochlear implants. World Journal of Otorhinolaryngology-Head and Neck Surgery, 3(4), 240–254. https://doi.org/10.1016/j.wjorl.2017.12.010

2. 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

ESR 3. Neural mechanisms of cross-modal plasticity in hearing impairment

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Congenital deafness affects the normal development of the auditory cortex. This often leads to a compensatory 'take over' of the auditory cortex by the remaining sensory systems in the form of cross-modal plasticity. Such cross-modal plasticity will likely lead to changes in cortical functional connectivity between sensory areas and may later interfere when hearing is restored with cochlear implants. To study this, we investigated cross-modal changes in a higher auditory area and a visual area of congenitally deaf cats. Specifically, we aimed to characterize deafness-induced changes in visual and auditory responsiveness in the 'deaf' auditory cortex of congenitally deaf cats in comparison to normal hearing cats. We analyzed 16-site microelectrode arrays at multiple positions along the suprasylvian sulcus. LFPs were filtered between 1-300 Hz and then bipolar re-referencing between neighboring electrodes was used to eliminate far-field effects in the LFP signal. Implementing this resulted in 15 bipolar re-referenced sites for each penetration in each cortical area. To measure how many of the electrode sites within the auditory cortex were responsive to both auditory and visual stimulation, a thresholding method was used. This method selected recording sites with evoked activity exceeding a threshold of ± 3 STD for at least 10 milliseconds above the prestimulus baseline. These sites were then labeled as responsive. Finally, we calculated the percentage of responsive channels per each recording site for all deaf cats (n=4) and hearing cats (n=4). The strongest responses for each stimulus modality were found in the corresponding (homologous) cortical area. However, also heterologous responses were found (visual in auditory cortex and vice versa). This provides the basis for the next step of the project, computation of functional connectivity between areas in presence of visual and auditory stimulation. It's also worth mentioning that while there was a trend for more visual responsiveness in the auditory cortex of deaf animals, responsiveness based on LFPs did not provide significant differences between the animal groups. This documents that the extend of the reorganization is modest, as reported by Land et al. (2016). The next specific step of the project would be to analyze the strength of the responses in these identified positions and their sensitivity to stimulus features.

ESR 4. Neural correlates of audio-tactile speech perception

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The presence of a vibrotactile stimulus conveying acoustic speech features to the skin has been found to enhance speech recognition in noise. This has been shown in participants with normal hearing thresholds listening to vocoded speech[1,2] as well as in cochlear implant users[3,4] . However, the neural processes underlying the reported enhancement effect remain to be identified. Therefore, the current study will investigate 1) whether improved audio-tactile speech comprehension triggers neural activation previously related to speech intelligibility for auditory and audio-visual stimuli, and 2) whether tactile intelligibility enhancement can be explained by multisensory integration effects in the superior temporal sulcus (STS). Neural activation associated with audio-tactile speech perception will be measured in approximately 20 German native speakers with normal hearing, using functional near-infrared spectroscopy (fNIRS). Participants will perform a speech-in-noise intelligibility task with vocoded Hochmair-Schulz-Moser[5] sentences in noise as the auditory stimulus. Additionally, amplitude envelopes of low frequency bands of the sentences will be presented via a vibrating probe to the right index finger. Speech intelligibility will be tested in a 2x3 task design with factors of auditory task difficulty (low SNR, high SNR) and audio-tactile congruency (auditory alone, congruent audio-tactile, incongruent audio-tactile).

We anticipate a behavioral enhancement effect of speech recognition for sentences presented in a congruent audio-tactile condition over incongruently combined stimuli or auditory alone conditions, comparable to Fletcher et al.[1]. This is hypothesized to be accompanied by stronger brain activations in the left superior and medial temporal gyri, inferior frontal gyrus and supramarginal gyrus. In line with the principle of inverse effectiveness of multisensory integration, we anticipate brain activity in the left STS to exceed an additive differences criterion when comparing the two SNR levels.

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3. Huang, J., Sheffield, B., Lin, P. & Zeng, F.-G. Electro-Tactile Stimulation Enhances Cochlear Implant Speech Recognition in Noise. *Sci. Rep.* **7**, 2196 (2017).

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WORK PACKAGE 2

Multimodality and optimisation of cognitive resources

ESR 5. The effect of cued speech (CS) perception on auditory processing in typically hearing adults

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Cued Speech (CS) is a communication system that was designed to facilitate lipreading in hearing impaired people (HI). Within this system, manual gestures placed in different places around the face code for syllables that would be ambiguously perceived by lipreading only. In CS production, manual gestures are provided some milliseconds in advance to labial gestures providing predictive information to lipreading. Interestingly, experienced CS speakers fitted with cochlear implants (CI) merge manual gesture information to the audiovisual speech. Moreover, in hard listening conditions, the presence of manual gestures facilitates speech perception enhancing the benefit of CI. Although the advantages of exposure to CS are recognized, the effect of CS expertise on auditory processing in HI and typically hearing (TH) people remains unclear. In the present study, we investigated the effect of CS perception in auditory processing in TH adults that were either experts or naive towards CS. Participants were presented 3 syllables /pa/, /ta/, /ka/ in unimodal (audio or visual) and in bimodal (audiovisual and audiovisual with CS gestures) conditions. We used an auditory Evoked Response Potential (ERP) paradigm to compare the effect of unimodal and bimodal speech perception on the latency and amplitude of the auditory N1-P2. Initial results from this study will be presented in this poster session.

ESR 6. Auditory-somatosensory integration in speech perception and speech production performance

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Orofacial somatosensory inputs modify the perception of speech sounds (Ito et al., 2009; Trudeau-Fisette et al., 2019). Such auditory-somatosensory integration likely develops along speech production acquisition. Thus, the somatosensory effects in perception might vary depending on individual characteristics of speech production. To address this hypothesis, we here investigated relationships between auditory-somatosensory integration in speech perception and speech production performance. Somatosensory effects in speech perception were examined using a vowel identification task with somatosensory stimulation as done in Trudeau-Fisette et al., (2019). In the test, the participants were asked to identify the presented sound as /e/ or /ø/. When the stimulus sound was presented, somatosensory stimulation was applied as facial skin deformation in backward direction, likely favoring /e/ responses, considering that a horizontal articulatory movement is key in the contrast between /e/ and /ø/. The perceptual boundary between /e/ and /ø/ was obtained respectively with and without somatosensory stimulation. Amplitude of auditory-somatosensory integration in speech perception was quantified as the difference in the categorical boundaries between these two conditions. Speech production performance was quantified by evaluating differences in the first, second and third formant frequencies (F1, F2 and F3) between /e/ and /ø/ produced by the participant. We confirmed that orofacial somatosensory stimulation significantly increased the amount of /e/ responses as found in Trudeau-Fisette et al., (2019). We found that amplitude of auditory-somatosensory integration in speech perception was correlated with a difference in F2 and F3, but not in F1, in speech production. This suggests that the acquisition of large formant differences between target vowels in speech production can lead to a large effect of somatosensory interaction in speech perception. This supports the idea that speech production ability is related to the development of auditory-somatosensory integration in speech perception.

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2. Trudeau-Fisette, P., Ito, T., & Ménard, L. (2019). Auditory and Somatosensory Interaction in Speech Perception in Children and Adults. Frontiers in Human Neuroscience, 13, 344. https://doi.org/10.3389/fnhum.2019.00344

ESR 7. Adapting AVATAR to research audio-visual integration in children

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The present study describes the development and evaluation of changes made to the AVATAR system (Devesse et al., 2018, 2020, 2021) to investigate audio-visual integration on speech understanding in noise in children with and without hearing loss, with particular regard to the patterns of attention maintenance and switching. AVATAR (Audio-Visual True-to-life Assessment of Auditory Rehabilitation) is a paradigm developed to assess audio-visual integration in an ecologically valid setting. It uses computer-generated 3D environments and human models who articulate their mouths realistically according to the auditory stimuli being played.

To address our research question, we first adapted the 3D scene and auditory stimuli to allow for competing speakers (one male and one female). In addition, speech reception thresholds in noise will be determined for a subset of LIST sentences (van Wieringen & Wouters, 2008) considered suitable for children to have reference values for 8-12 years of age. Also, we integrated Pupil Core (Pupil Labs, GmbH, Germany) eye-tracking technology to AVATAR and will evaluate its precision and feasibility of using both children and adults. The eye-tracking data collected from children with normal hearing will also correlated to scores on a standardised test of attention to evaluate the appropriateness of using eye-tracking as a proxy for attention in complex, realistic listening environments.

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van Wieringen, A., & Wouters, J. (2008). LIST and LINT: Sentences and numbers for quantifying speech understanding in severely impaired listeners for Flanders and the Netherlands. *International Journal of Audiology, 47*(6), 348-355.

ESR 8. Effortful Listening, Cognitive Energy and Learning in Children Fitted with Cochlear Implants

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Background: Learning novel words is dependent on the listener's ability to compare the phonetic patterns of an input signal with the phonetic and semantic representations in the lexicon [1]. In cochlear implants users, the uncertainty that accompanies underspecified and undistinctive inputs can enhance lexical competition [2] and challenge the identification of novel versus known words.

Objective: In our first pilot study, we investigate the relation between phonemic discrimination, novel word detection and novel word learning rate in the Danish language.

Methods: nonwords respecting Danish phonology were generated as proxies for novel word learning. Lexical similarity assessments were completed on the corpus by Native Danish speaking adults with normal hearing (n=14). Based on this material, a test battery addressing phonological discrimination, novel word detection and rapid word-learning in different phonemic contrasts, was performed with simultaneous pupillometry, in a pilot group of six adults with normal hearing. Audio input was degraded using an 8-channel noise vocoder.

Results: Performance on the discrimination task had no important influence of signal degradation, with almost ceiling results. Errors in the detection task were related to wrong localization of the nonwords in the non-vocoded condition, and a mixed pattern the vocoded condition. In the rapid novel word learning, the number of trials to learn all words to the criterion were around two times larger when the stimuli are degraded and 1.75 larger when the stimuli are phonologically similar.

Conclusion: The ability to easily discriminate multiple phonological inputs (as in the two conditions of the rapid word-learning task) and contrast them with previous lexical knowledge (as in the detection task) seems to be determinant for the learning of new words. Even when the degraded signal has non-significant impact on speech discrimination, it seems to cause substantial decay in tasks that require more cognitive resources, as learning of new words.

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ESR 9. Theory of mind in deaf and deafblind children (Usher syndrome) with cochlear implants

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Theory of mind (ToM) is the ability to understand other people's mental states and it is related to language and cognitive skills both in typically developing (TD) children and children with atypical development, such as deaf children with cochlear implants (CIs) who show delay in the ToM development. Deaf and deafblind children (Usher syndrome) with CIs also achieve lower results on some language tasks and have poorer cognitive skills that are central for information processing in most language-related activities. One way of enhancing those skills could be auditory verbal therapy (AVT) that focuses on teaching auditory, speech, language, and cognitive skills. However, this method hasn't been investigated enough to be said that it is evidence-based. Additionally, providing early access to listening and language through early implantation can be beneficial for improving language and cognition. That is why the aim of this research is to compare ToM, cognitive and language skills in deaf and deafblind children (Usher syndrome) with CIs with hearing parents to TD children to determine the relationship between those variables and to examine the effect of implantation age and AVT on the said variables. Participants will be deaf and deafblind children with Usher syndrome (age 6-9) with CIs born to hearing parents and age-matched TD hearing children. Deaf children with CIs will form subgroups according to their implantation age (relatively early – up to 3 years and late – above 3 years) and whether or not they have been included in AVT. The data collection will consist of individual assessments (up to 45 minutes) during which ToM, language and cognitive tests will be administered. Testing of cognitive skills will be computer based and it will assess working memory, phonological skills and lexical access. Language will be assessed using standardized test for receptive and expressive vocabulary and ToM will be examined using widely-adopted ToM scale.

ESR 10. Multistream neural architectures for cued speech recognition usinga pre-trained visual feature extractor and constrained ctc decoding

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Cued Speech (CS) is a visual communication tool developedby Cornett [1] in 1967 to help people with hearing impair-ment to better understand the spoken language. It encodes speech as a combination of visible hand shapes (for consonants) and hand positions (for vowels) to highlight the uttered phoneme and complement lip-reading [1]. The purpose of this study is to automate the process of transcripting Cued Speech. We propose a simple and effective approach for automatic recognition of CS. The proposed approach is based on a pre-trained hand and lips tracker used for visual feature extraction and a phonetic decoder based on a multistream recurrent neural network trained with connectionist temporal classification loss and combined with a pronunciation lexicon. The proposed system is evaluated on an updated version of the French CS dataset CSF18 [2] for which the phonetic transcription has been manually checked and corrected. The use of an efficient pre-trained feature extractorallowed to reduce the complexity of the (visual) phonetic decoder. Also, cleaning the CSF18 dataset to account for differences in cueing and pronunciation of certain phonemes improves the performance significantly. With a decoding accuracy at the phonetic level of 70.88\%, the proposed system outperforms the previous CNN-HMM decoder developed by our lab [2] and competes with more complex baselines [3][4].

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WORK PACKAGE 3

Environment and enhancement of language skills

ESR 11. Multiple language acquisition in children who are deaf and use Cochlear Implants who grow in plurilingual homes

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This research focuses on the context for language development in children who are d/Deaf, wear Cochlear Implants and come from plurilingual and multicultural families. To this day, scientific literature about children who are d/Deaf and hard of hearing has focused on estimating their linguistic development quantitatively, in order to compare them to their hearing, *'typically developed*' peers. This has been done by assessing d/DHH children with tests ideated and standardised on a hearing (and often) monolingual population. Until this moment, few researchers focused on the role of context and amount of exposure to each language as significant for these children's language development. We aim to bring attention to these aspects as we believe they are crucial to understanding their language and communication development.

This study will focus on young children who have been fitted with cochlear implants and grow up in plurilingual and multicultural families. A questionnaire will be specifically created to gather data about the family linguistic background and habits, together with parental semi-structured interviews. SOLOM will be used to gain a general understanding of the child's linguistic skills in the language other than English. LENA technology will be used to record the exposure the child has to each language during two typical days, to see if and how these data relate to the child's linguistic abilities reported by both professionals and parents.

ESR 12. Multimodal Communication Among Deaf and Hearing Interactants in the Presence of Sensory and Communication Asymmetries

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In a social-constructivist approach, we investigate how individuals with different experiences and resources of language and communication draw on multimodal communication strategies in order to accommodate sensory and communicative needs. We focus on episodes of joint attention in early parent-child interactions in the time prior to cochlear implantation when access to auditory input and/or sign language is often not yet available to children with severe to profound hearing loss. Moving away from predominantly language-driven approaches of the past, the current project picks up on the multimodal nature of communication and, in a more holistic approach, goes beyond the bimodal distinction of spoken and/or sign language(s) when looking at early interactions. The aim of the project is (1) to reveal the potential of multimodal communication strategies in making communication accessible to children who are deaf or hard of hearing while facilitating interactions with their hearing family members and peers; and (2) to understand how multimodal communication strategies are influenced by individual affordances, context and the interactional situation. Video-recorded data of unstructured play sessions between parents and children (9-18 months of age) with severe to profound hearing loss will be collected prior to cochlear implantation in collaboration with the Yorkshire Auditory Implant Service (YAIS) at the Bradford Royal Infirmary, NHS (UK). Detailed multimodal analysis with ELAN, an annotation tool for audio and video recordings, will be used to identify and understand how multimodal communication strategies are involved in initiating and sustaining episodes of joint attention while offering a more systematic approach to multimodal analysis of early interactions. The application of findings, emphasizing individual resources rather than deficits, will be relevant to early intervention with families and will provide parents with informed guidance on how to make communication more accessible to their child, especially within the critical period of the first year/s of life that form the building blocks for later (language) development.

ESR 13. Orthographic learning by self-teaching in children with hearing impairment: focus on the nature of spelling errors

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Phonological decoding when reading new words plays a predominant role in orthographic learning. This finding has recently been reported in children with hearing impairment through a self-teaching paradigm. The purpose of the current study was to use this paradigm to investigate the development of new orthographic representations in 7-13 years-old children with hearing loss (HL) compared to typically hearing (TH) controls. In addition, we examined the nature of spelling errors during written production of novel words since it gives information about the nature of orthographic representations stored in memory. The participants were 29 children with hearing impairment and 29 controls matched on accuracy and reaction time in a lexical decision task. First, they were asked to read short stories in which a target new word (pseudowords) appeared three times (implicit learning phase). Then, orthographic learning was evaluated using a spelling task and an orthographic choice task. In the latter task, the 10 target items (e.g. *karmol*) were associated with three distractors (phonological distractor: *carmole*; orthographic distractor: *kamrol*; foil distractor: *camrole*). The experiment was carried out online due to Covid-19 restrictions. Overall, both groups of children performed poorly in the spelling task (around 11-13% of new words correctly spelled), but HL children turned out to be better than TH children in the orthographic choice task. Regarding spelling errors, children with HL produced more phonological unplausible errors (e.g., *carmone* for *karmol*: different phonological form) compared to the control group, for which 73% of their productions were homophones of the target word (e.g., *carmole*). These findings suggested that children with HL exhibit difficulties to access the accurate phonological form of the word. Finally, the results were consistent with the self-teaching hypothesis regarding the ability of children to acquire orthographic representations through reading. Furthermore, the tendency of children with HL to choose the orthographic distractor more frequently than TH children in the orthographic choice task suggests that visual cues might be more involved in spelling acquisition in children with HL.

ESR 14. Speech communication tools used for deaf and hard of hearing children in France

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As soon as a child is diagnosed with a hearing impairment, early and appropriate intervention should be provided, to avoid language deprivation and its consequences. In France, it is recommended that parents choose an educational project with their child as soon as the diagnosis is announced. This can be directed either towards the development of communication in spoken and written French, or towards learning French Sign Language, or a combination of the two (bimodal bilingualism). Many tools are used by professionals in clinical practice to support language development with deaf children in France. Among these, 3 communication tools can be integrated into family settings with an oral language orientation: Cued French (CF), Sign Supported French (SSF) and Auditory Verbal Therapy (AVT). According to literature review, some studies show that CF and AVT have a beneficial impact on the child's language skills. But there is no evidence on the effectiveness of SSF on language development. Moreover, there is no published data on the actual use of these communication aids with deaf children in France.

Two online surveys have been conducted. The first was aimed at professionals caring for deaf children. The second was aimed at parents of deaf children. Results from a population of 246 professionals and 220 parents who responded to the survey suggest that SSF is the most used tool by professionals and parents (78% & 40%). CF is used by 58% of professionals and 28% of parents. Finally, AVT is used by less than 15% of the two populations. Regarding signed communication, more than 80% of the professionals use French Sign Language, whereas less than 45% of parents use it at home.

Our survey reveals that there is a mismatch between the reported proportions of usage of communication tools, both in clinical practice and within families, and the amount of available scientific data on these tools. In the future, we plan to run perception and production tests to quantitatively measure the impact of different communication aids on oral language skills in deaf children.The long-term objective will be to provide evidence-based recommendations related to speech rehabilitation and academic support for deaf children.

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ESR 15. The phonological Body: Body Movements to Accompany Speech Perception and Production of Foreign Speech Sounds

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Beat gesture influences which speech sounds we hear[1] and impacts how we produce them[2]. However, much less is known about how body movements aiming at stimulating the articulatory qualities of speech sounds might improve perception and production of speech. To address this gap, we will explore the role of body movements in perceiving and producing foreign speech sounds. French speaking adults will be trained to perceive and produce Arabic speech sounds in the context of congruent body movement, incongruent body movement, and no body movement. Before and after training, participants will be asked to perform an ABX discrimination task[3], an identification task, to assess speech perception, and a production task. We will be looking at accuracy and reaction times before and after training. In comparison with the 'no body movement' condition, we expect that (i) congruent body movements will improve speech perception and production of Arabic speech sounds by improving accuracy and/or decreasing reaction times and (ii) incongruent body movement will affect speech perception and production of Arabic speech sounds by decreasing accuracy and/or increasing reaction times. Results will be shown and discussed during the last day of the second Comm4CHILD conference.

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