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Visual Speech in hearing recovery with Cochlear Implant

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Deafness and cochlear implants: According to the WHO estimates, 278 million people worldwide have moderate to profound hearing loss in both ears. In consequence hearing impairment and deafness have a strong social-economic impact on individuals families and communities. Children with hearing impairment often experience delayed in the development of speech, language and cognitive skills, which may result in slow learning and difficulty progressing in school. When hearing aids are ineffective to help profoundly deaf patients retaining speech-based communicative abilities, cochlear implantation has become the only efficient method (Deggouj et al., 2007). While hearing aids amplify sounds to be detected by damaged ears, cochlear implants bypass the damaged portions of the ear and directly stimulate the auditory nerve. Signals generated by the implant are sent by way of the auditory nerve to the brain, which recognizes the signals as sound. Modern cochlear implants allow deaf individuals to better understand spoken speech, environmental sounds and even in some cases to listen to music. However, auditory information delivered by the implant remains spectrally degraded (Shannon et al., 1995) and lacks some of the fine temporal acoustic structure important for speech comprehension (Lorenzi et al., 2006).

Auditory recovery and cochlear implants: During the subsequent months following the implantation, auditory performance increases significantly to reach a plateau of about 80% in word comprehension then showing no significant improvement in the following years (UKCISG 2004). Cochlear Implanted patients (CIP) remain, however, highly sensitive to noisy environments and their speech recognition in the presence of masking sounds is impaired (Munson and Nelson, 2005). To overcome this handicap we have shown that patients are developing "supra-normal" audiovisual integration skills, leading to a more synergic combination of auditory and visual speech cues (Rouger et al., 2007). Thus visual and visuo-auditory integration remains a central mechanism for speech comprehension in CIP even several years after the restoration of auditory functions. Those behavioral results clearly indicate a progressive reorganization of speech processing strategies after cochlear implantation, therefore we strongly believe that a rehabilitation built on visual and visuo-auditory training will improve and fasten the recovery of patients for auditory speech comprehension.
In deaf children, cochlear implant constitutes the only treatment allowing normal oral language acquisition, provided the implant is placed within 2-4 years after birth. Beyond this period, auditory centers partially reduce some of their capacities of adaptive plasticity to build coherent percepts from the coarse information delivered by the implant. Furthermore, the capacity to fuse correctly visual and auditory speech information is also dependent on a "critical period" during the first 4-5 years of life (Schorr et al 2005). In this context of crossmodal compensation, Cued-speech (CS) will be central to our investigations because it constitutes an efficient strategy to compensate to the limited auditory and visual speech information available to a CIP.

Auditory recovery and vision: role of cued-speech. The benefit of visual information for speech perception ("lip-reading") is widely spread and it is a well established that the visual information from the speaker's face is used to enhance speech perception under noisy environment (Sumby and Pollack 1954, Summerfield, 1979; Summerfield et al., 1989). However, without knowledge about the semantic context, even with high lip-reading performances, speech cannot be thoroughly perceived. On average, only 40 to 60% of the phonemes of a given language are properly recognized by lip reading (Montgomery & Jackson, 1983). This limitation is mainly due to the ambiguity of the visual pattern. It led Cornett (1967) to develop the Cued Speech system as a complement to lip information. CS is a visual speech communication system that makes use of hand-shapes placed in different positions near the face in combination with the natural speech lip-reading to enhance speech perception from visual input. This is a system where the speaker, facing the perceiver, moves his hand in close relation with speech (See Attina et al., 2004). The hand (held flat and oriented) is a cue that corresponds to a unique phoneme when associated with a particular lip shape. Two components make up a manual cue: the hand-shape and the hand placement in relation to the face. Hand-shapes are designed to distinguish amongst consonants whereas hand placements are used to distinguish amongst vowels. A single manual cue corresponds to phonemes that can be discriminated with lip shapes, whilst phonemes with identical lip shapes are cued with different manual cues (See below).

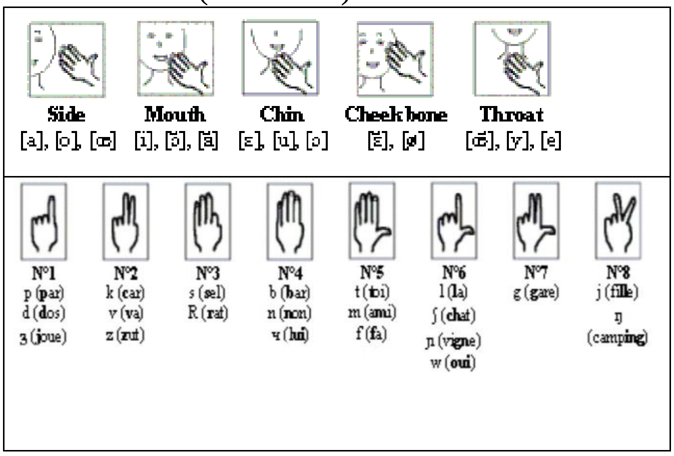

Figure: *CS Hand position for the vowels and handshapes for the consonants (adapted from Attina et al. [2004]).*

Research shows that, with Cued Speech, 96% of spoken language can be lipread accurately (Nicholls, 1979; Nicholls & Ling, 1982, Uchanski et al., 1994). Moreover, CS offers to deaf people a thorough representation of the phonological system, inasmuch as they have been exposed to this method since their youth. Therefore because CS has a positive impact on language development (Leybaert, 2000) it is essential to understand how deaf children develop the abilities to process the visual information contained in Cued-speech, and how it is related to auditory processing following cochlear implantation.

<u>The proposed work</u>

The access to language for deaf people obviously does not necessarily imply oral language, sign language being by large the preferred system in deaf communities. The focus on assessing and enhancing the access of CIP deaf to oral language of course puts no pressure on the orientation of deaf communities towards oral language, but acknowledges the importance of facilitating this access in case of a demand by the deaf. In this case, the access to oral language uses a first privileged channel, which is vision for lipreading. However, lipreading is not enough for a complete understanding speech and additional information is needed. This can involve substitution, additional hand gestures superimposed on speech movements. It can also involve auditory recovery enabled by cochlear implantation.

In our study, we aim at better assessing and possibly enhancing speech production and speech perception abilities in deaf people equipped with cochlear implants. A crucial question in this area concerns the link between perception and production abilities. This is of course a practical matter: how do perception and production cooperate and possibly coordinate in the evolution of speech communication performances after cochlear implantation? Many studies have addressed this question with mixed results, often showing some cross-improvements between perception and production, but not always successfully disentangling what comes from external factors such general cognitive abilities, nature of the teaching scenarios, etc, and what comes from possible direct links between perception and action.
The question of possible links between perception and action is also a theoretical question of increasing importance and interest in the context of old debates in the speech community about auditory vs. motor theories, and new findings on mirror neurons and motor resonance (see a review by Schwartz, Sato & Fadiga, 2008). Both prelingually and postlingually deaf subjects will be involved, though differently in the various experiments.

Therefore to investigate this crucial question, the proposed study will determine whether hearing recovery in CIP helps improving spoken language abilities, during perceptuo-motor tasks, implying both automatic and repetition processes. The study will involve close shadowing abilities. We shall assess the gain provided by visual information in the production/perception speech loop with implanted deaf people. The hypothesis is that even if the subject is equipped with the implant, the visual information (lip-reading with or without Cued Speech) still increases the performances of the loop. To test this hypothesis, we will compare the performance of deaf participants when their implants are on or off, in a close shadowing experiment (Reisberg, 1987). They will be asked to repeat, as fast as possible, the word or pseudo-word that will be presented only visually (no sounds) or audition only or as a visual-auditory stimulus (sound is on). The stimuli will be made of the audio and the face of the speaker complemented or not by Cued Speech while uttering unpredicted speech. In the different experimental conditions, the response times in the audio repetition of the stimuli will be measured and we will analyze the errors and the error ratio. For each of the stimuli, a stereo numerical recording system will be used in which the first line will record the audio part of the stimulus at the same time of the stimulus presentation to the subject. The audio response of the subject will be recorded with a microphone connected to the second line of the recording system, thus assuming a common reference time with the stimulus. The response times will be calculated as the duration interval between the beginning of the audio stimulus and the beginning of the participant’s response. The participant will carry an ear phone in the cases of audio presentation. When the implant is off, the participants will rely only on visual information which will make the cued speech information crucial to be able to repeat the stimuli. When the implant is ON, the participants will be able to use both the audio and visual information. Their response time will be significantly faster and their accuracy will improve dramatically for difficult stimuli. The results will be compared to those of a group of normal hearing participants.

The work will be done at GIPSA-lab in the Speech and Cognition Department under the supervision of Denis Beautemps (MAGIC Team) and Olivier Pascalis (PCMD Team). The Department has a strong expertise in language development and in multi-modal automatic processing of Speech and has been collaborating with the service ORL of Grenoble Hospital for now 10 years.

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