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Research Paper

Emotional recognition of dynamic facial expressions before and after cochlear implantation in adults with progressive deafness

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Visual processing has been extensively explored in deaf subjects in the context of verbal communication, through the assessment of speech reading and sign language abilities. However, little is known about visual emotional processing in adult progressive deafness, and after cochlear implantation. The goal of our study was thus to assess the influence of acquired post-lingual progressive deafness on the recognition of dynamic facial emotions that were selected to express canonical fear, happiness, sadness, and anger. A total of 23 adults with post-lingual deafness separated into two groups; those assessed either before ($n = 10$) and those assessed after ($n = 13$) cochlear implantation (CI); and 13 normal hearing (NH) individuals participated in the current study. Participants were asked to rate the expression of the four cardinal emotions, and to evaluate both their emotional valence (unpleasant-pleasant) and arousal potential (relaxing-stimulating). We found that patients with deafness were impaired in the recognition of sad faces, and that patients equipped with a CI were additionally impaired in the recognition of happiness and fear (but not anger). Relative to controls, all patients with deafness showed a deficit in perceiving arousal expressed in faces, while valence ratings remained unaffected. The current results show for the first time that acquired and progressive deafness is associated with a reduction of emotional sensitivity to visual stimuli. This negative impact of progressive deafness on the perception of dynamic facial cues for emotion recognition contrasts with the proficiency of deaf subjects with and without CIs in processing visual speech cues (Rouger et al., 2007; Strelnikov et al., 2009; Lazard and Giraud, 2017). Altogether these results suggest there to be a trade-off between the processing of linguistic and non-linguistic visual stimuli.

1. Introduction

Human communication requires the ability to perceive and interpret others' feelings, intentions, and states of mind on the basis of subtle sensory cues. As early as 1872, Darwin argued that the perception of facial expressions was critical to adaptive responses and behavioral adjustment between peers. The communicative value of facial expressions is thus considered key in human communication. In acquired deafness, visual information processing is used to compensate for auditory loss, and consequently, deaf persons presumably rely more than hearing subjects on visual cues to communicate verbally and non-verbally with others, e.g. through speech reading. Visual processing of verbal information is commonly explored in deaf subjects through the assessment of specific abilities in speech reading and sign language. However, little is known about visual emotional processing in adult progressive deafness, and after cochlear implantation.

Speech reading develops during the first years of life in relation to an optimal plasticity period (around 2.5 years) for the mapping of auditory and visual speech cues, after which auditory and visual

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inputs can no longer be integrated in the brain (Schorr et al., 2005). If audio-visual mapping is properly established during childhood, the resulting audio-visual speech network is relatively resilient to sensory deprivation, and existing audio-visual representations may help disambiguate phonological visual forms in the absence of auditory input (Giraud and Lee, 2007). However, audio-visual phonological memory representations might progressively deteriorate with age when appropriate sensory input is lacking, which could explain the large inter-individual differences in speech reading performance in adults with deafness (Lee et al., 2007). In other words, speech understanding seems to rely on latent intermodal connectivity developed during childhood as well as on the functionality of the audio-visual phonological network.

When hearing loss becomes too profound to be alleviated by conventional hearing aids, cochlear implantation can be used to restore hearing. Cochlear implants (CIs) consist of an array of electrodes that are inserted inside the cochlea in order to directly stimulate the auditory nerve fibers with electrical pulses converted from the acoustic information sampled from the environment. The temporally and spectrally coded information contained in the CI signal is then transmitted to the auditory cortex via physiological neural conduction. Although CIs clearly improve the processing of auditory information in deaf people, and restore to some extend audio-visual mapping (Lyxell et al., 1994) and oral comprehension in quiet environments (Nimmons et al., 2008), the transmission of auditory information through such devices is relatively crude. Understanding speech in noise or other complex auditory tasks remains difficult for many patients with CIs. Deaf individuals therefore continue to rely on vision to maintain communication during social interactions in their everyday life. Lip and speech reading represent major communication compensation strategies before cochlear implantation and are also critical afterward, during the speech recovery process.

The fact that people with deafness strongly rely on dynamic facial cues for verbal communication both before and after cochlear implantation (Tyler et al., 1997; Lee et al., 2007; Rouger et al., 2007; Lazard and Giraud, 2017) raises the issue as to whether this detracts from the perception of nonverbal, emotional, dynamic facial cues. Several lines of evidence suggest that the dynamic nature of facial expressions contributes to the identification of facial movements mediating verbal information (Harwood et al., 1999; O'Toole et al., 2002; Roark et al., 2003). These findings emphasize the role of facial movements in speech perception. In normal hearing (NH) participants, verbal discrimination improves when dynamic visual properties are available (Ambadar et al., 2005). Similarly, in congenitally deaf people watching sign language videos, fine movements associated with facial expressions and mouth shapes of the signer are used to decode verbal information (Muir and Richardson, 2005). By principally fixating on face regions, deaf participants seem particularly sensitive to dynamic facial expressions during verbal communication. For example, in individuals with late-onset deafness, speech-reading skills continue to improve after cochlear implantation as compared with their pre-implantation skills (Strelnikov et al., 2009), and CI users maintain much higher abilities several years later as compared with normal hearing controls (Rouger et al., 2007). These findings suggest that both progressive deafness and subsequent CI increase the processing of facial movements, at least to process verbal information. However, whether enhanced use of dynamic facial cues for verbal communication in post-lingual deafness improves or hinders the use of these cues for nonverbal communication, and how CIs modify this ability, remain unclear.

Recognition of facial emotions has been explored in prelingually deaf children. Impaired emotional judgments of static facial expressions have been observed in deaf children relative to both chronological and mental age-matched NH children (Ludlow et al., 2010; Dyck et al., 2004; Dyck and Denver, 2003; Weisel, 1985; Most and Aviner, 2009) as well as after CI (Wiefferink et al., 2013). Taken together, these results suggest there to be a strong impact of congenital hearing loss on the processing of facial emotional expressions, even after CI. Although this issue has not explicitly been addressed in post-lingually deaf adults, emotional sensitivity and social skills are reportedly worse in this population than NH individuals (Fusick, 2008; Hallam et al., 2006). On the other hand, progressive deafness requires adaptive cognitive processes to integrate verbal information based on visual cues. Partial restoration of audio-visual integration provided by spectrotemporal cues transmitted by the CI device requires further adaptation and additional “listening effort” to achieve speech comprehension (McGarrigle et al., 2014; Rudner, 2016). The increased attentional demand for the processing of verbal cues might be detrimental to nonverbal cues, and could thus result in difficulties recognizing non-verbal facial emotions. Whether adults with late-onset deafness assessed before and after CI are also impaired in the perception of facial expressions, and how dynamic face processing relates to speech-reading abilities, remain open questions. Given the importance of facial movements in speech reading and in sign language, we used dynamic instead of static facial expressions to examine visual emotional processing in adults with progressive deafness assessed before or after CI. We expected post-lingually deaf adults and CI users to show deficits in recognizing emotions in dynamic faces as compared to NH participants.

Moreover, we investigated whether emotions relying on visual cues from both the upper and lower part of the face, such as sadness, fear, and anger, are more difficult to process than those mainly expressed by the lower part of the face such as happiness (Ekman et al., 1983), from which speech cues are also extracted with lip-aperture relevant processing. According to the Russell circumplex model (Russell, 1980; Russell and Barrett, 1999), we measured dynamic facial emotion processing using a mixed task involving categorization of the four cardinal emotions (e.g., happiness, sadness, fear, and anger, Ekman and Friesen, 1978) and ratings of both emotional valence (from unpleasant-negative to pleasant-positive) and arousal (from calm to stimulating) in dynamic faces. We considered that emotional valence judgments would be preserved after acquired deafness, because this relies on associative and declarative forms of emotional memory that are not supposed to be affected by deafness (Adolphs et al., 1999); however, we expected to find an impaired arousal, as a side effect of deafness-related depressive states (Jones and White, 1990).

2. Methods

2.1. Participants

Twenty-three native French-speaking patients with severe to profound post-lingual progressive sensori-neural hearing loss were tested either before (Pre-CI, $n = 10$) or after CI (Post-CI, $n = 13$), with a mean post-CI duration of 35.2 [23–76] months. No patients had a history of neurological or psychiatric illness. All participants used oral communication with an average speech reading performance (dissyllabic word recognition) of 46% for the Pre-CI group and 50% for the Post-CI group. All but two Post-CI patients used a contralateral hearing aid ($n = 11$), which was turned on during the emotional facial test. All had good speech perception performances with a mean score of 84% ($SD = 12$) for dissyllabic word recognition, and 69% ($SD = 27$) for sentence comprehension in open-set lists with a signal to noise ratio of 10 dB after CI (Table 1). A group of 13 NH controls (9 female, 4 male; mean age = 57.0, $SD = 3.07$; mean number of years of education = 17.08, $SD = 3.01$) matched to the