Compensation for visual deprivation in speech perception is only partial: Evidence from perception of coarticulated speech

Véronique Delvaux[1,2], Kathy Huet[1], Myriam Piccaluga[1], Bernard Harmegnies[1]
[1]Institut de Recherche en Sciences et Technologies du Langage, UMONS, Belgium
[2]Fonds National de la Recherche Scientifique, Belgium
Veronique.Delvaux@umons.ac.be

This study investigates the time course of speech perception by French-speaking blind listeners. Previous work has provided strong evidence that blind listeners perform either equally well or better than sighted controls at a wide range of auditory tasks including speech comprehension (Chen *et al*., 2014; Dietrich *et al*., 2013; Hugdahl *et al*., 2004; Niemeyer & Starlinger, 1981; Teng *et al*., 2012; Wan *et al*., 2010). However, to date there is little phonetic literature on the perception of segmental contrasts by blind listeners (such as Ménard *et al.*, 2009), and none on the time course of speech perception.

In this study, we compared the perception of anticipatory coarticulation between blind and sighted listeners using gated stimuli. Our first aim was to study how the perception of the /i-y/ contrast by French-speaking blind listeners unfolds over time. Our second aim was to position the performances of the blind listeners with respect to the full range of performances exhibited by sighted controls when stimuli were presented auditorily, visually and audiovisually, whether in acoustically non degraded or noisy conditions. The goal was to determine the extent to which the potential advantage in auditory acuity compensated for visual deprivation in blind listeners, and how such compensatory effects might be mediated by the addition of noise to the coarticulated stimuli. Indeed, previous work on audiovisual speech perception has shown that visual information most enhances speech intelligibility in noise (Grant & Seitz, 2000; Ross *et al*., 2007; Schwartz *et al*., 2004;), while it is in acoustic noise that blind listeners particularly outperform sighted listeners (Chen *et al*., 2014; Muchnik *et al*., 1991; Niemeyer & Starlinger, 1981; Smeds, 2015).

Sixteen participants (8 congenitally blind, 8 sighted) completed two tasks on pairs of stimuli gated from original [agi] and [agy]: a two-alternative forced choice identification task and an AX discrimination task. Both tasks were performed on stimuli which were presented in quiet vs. (acoustically-)noisy conditions, combined with three sensory modalities: audio-only (for blind and sighted listeners), audio-visual and visual-only (for sighted listeners only). Performances were assessed using metrics based on proportion of correct answers (to pairs of different stimuli) as a function of gate.

First, data collected in the audio-only condition revealed that blind listeners performed slightly but significantly better than sighted controls, in both discrimination and identification. Noise affected all participants, but was more detrimental to sighted listeners. Thus, blind listeners exploited better and earlier than sighted controls the acoustic information present in the speech signal as a result of anticipatory coarticulation, especially in noise.

Second, performances of sighted listeners were compared as a function of modality of presentation of the stimuli. As expected given the role of visual information in the perception of rounding contrasts (Robert-Ribes *et al*., 1998; Roy, 2012; Troille *et al*., 2010), large and systematic differences in performances were found between the audio-only and audiovisual conditions, signalling strong visual enhancement (Peele & Sommers, 2015). In most instances, visual enhancement was strong enough to compensate for the presence of acoustic noise. In fact, the comparison between perceptual scores on one hand, and acoustic and visual articulatory measures (i.e., horizontal and vertical lip openings) on the other hand, confirmed that visual and auditory information were not temporally aligned in our stimuli, and that sighted listeners exploited relevant

visual information as soon as it was available, i.e. ahead of acoustic information (Jesse & Massaro, 2010).

Third, performances of the two groups of listeners were compared when they were given access to the richest available information to them in speech processing, i.e. auditory information for blind participants vs. audiovisual information for sighted participants. The results were non equivocal. As soon as some visual information was provided to sighted listeners, they largely outperformed blind listeners in all tasks.

Altogether, these results provide evidence in favour of *partial* compensation for visual deprivation in speech perception. The superiority exhibited by blind participants in processing auditorily-presented gated stimuli allowed them to compensate only partially for their inability to exploit visual information in order to process coarticulated speech as quickly and efficiently as sighted controls.

References

Chen, M.-S., Liu, J.-S., & Chen, W.-R. (2014). Different performance on auditory discrimination between sighted and blind individuals. *Proc. 5th IEMI*, 133-137.

Dietrich, S., Hertrich, I., & Ackermann, H. (2013). Training of ultra-fast speech comprehension induces functional reorganization of the central-visual system in late-blind humans. *Front Hum Neuro,* 7, 701.

Grant, K.W., & Seitz, P.F. (2000). The use of visible speech cues for improving auditory detection of spoken sentences. *J Acoust Soc Am,* 108, 1197-1208.

Hugdahl, K., Ek, M., Takio, F., Rintee, T., Tuomainen, J., *et al*. (2004). Blind individuals show enhanced perceptual and attentional sensitivity for identification of speech sounds. *Cognitive Brain Research,* 19, 28–32.

Jesse, A., & Massaro, D.W. (2010). The temporal distribution of information in audiovisual spoken-word identification. *Atten Percept Psychophys*, 72, 209-25.

Ménard, L., Dupont, S., Baum, S.R., & Aubin, J. (2009). Production and perception of French vowels by congenitally blind adults and sighted adults. *J Acoust Soc Am*, 126, 1406-1414.

Muchnik, C., Efrati, M., Nemeth, E., Malin, M., & Hildesheimer, M. (1991). Central auditory skills in blind and sighted subjects. *Scand Audiol,* 20, 19–23.

Niemeyer, W. & Starlinger, I. (1981). Do the blind hear better? Investigations on audi- tory processing in congenital or early acquired blindness. II. Central functions. *Audiology*, 20, 510–515.

Peelle, J.E. & Sommers, M.S. (2015). Prediction and constraint in audiovisual speech perception. *Cortex* 68, 169-81.

Robert-Ribes, J., Schwartz, J.L., Lallouache, T., & Escudier, P. (1998). Complementarity and synergy in bimodal speech: Auditory, visual, and audio-visual identification of French oral vowels in noise. *J Acoust Soc Am,* 103, 3677-3689.

Ross, L.A., Saint-Amour, D., Leavitt, V.M., Javitt, D.C., & Foxe, J.J. (2007). Do you see what I am saying? Exploring visual enhancement of speech comprehension in noisy environments. *Cerebral Cortex,* 17, 1147-1153.

Roy, J.-P. (2012). Anticipation labiale et perception visuelle. *Can J Ling*, 57, 109–132.

Schwartz, J.L., Berthommier, F., & Savariaux, C. (2004). Seeing to hear better: evidence for early audio-visual interactions in speech identification. *Cognition*, 93, B69-78.

Smeds, H. (2015). Blindness and Second Language Acquisition. Studies of Cognitive Advantages in Blind L1 and L2 Speakers. *Unpublished doctoral dissertation,* Stockholms Universitet.

Teng, S., Puri, A., & Whitney, D. (2012). Ultrafine spatial acuity of blind expert human echolocators. *Experimental Brain Research,* 216, 483–488.

Troille, E., Cathiard, M.-A., & Abry, C. (2010). Speech face perception is locked to anticipation in speech production. *Speech Commun*, 52, 513–524.

Wan, C.Y., Wood, A.G., Reutens, D.C., & Wilson, S.J. (2010). Early but not late-blindness leads to enhanced auditory perception. *Neuropsychologia* 48, 344–348.