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► To cite this version:

Amélie Rochet-Capellan, Susanne Fuchs, Leonardo Lancia, Pascal Perrier. Breathing changes during listening and subsequent speech according to the speaker and the loudness level. ISICS 2012: International Symposium on Imitation and Convergence in Speech, Sep 2012, Aix-en-Provence, France. hal-00743785

HAL Id: hal-00743785

<https://hal.science/hal-00743785>

Submitted on 20 Oct 2012

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Breathing changes during listening and subsequent speech according to the speaker and the loudness level

Amélie Rochet-Capellan¹, Susanne Fuchs¹, Leonardo Lancia² and Pascal Perrier³
¹ZAS, Berlin, Germany, ²MPI, Leipzig, Germany, ³GIPSA-lab/DPC Grenoble, France

Introduction

In the context of the interactive alignment model for multi-level adaptations in dialogue situations (Pickering and Garrod, 2004), our work focuses on the adaptation of listener's breathing to a speaker's breathing. Our general goal is to understand if, and how, listeners adapt their breathing to speakers' breathing: what are the information that the listener's breathing system is "catching" from the speakers' behavior to eventually change accordingly? Previous works showed that, in dialogue situation, listeners and speakers tend to synchronize their breathing at the time of turn-taking (Guaïtella, 1993; McFarland, 2001). Moreover, perception studies found that when breathing noise (e.g. when speakers inhale) is added to speech synthesis, the listeners' recall performance increases (Whalen et al., 1995). From the acoustical signal, listeners are also able to discriminate between speech produced starting at high lung volume versus speech started at a low lung volume level (Milstein et al., 2004). Breathing profiles during listening are also different than during breathing at rest, and could be an indicator of the perceptual process. In this context, Brown (1962) hypothesised that poor listeners may be less capable to adapt their breathing to the speaker's breathing when compared to better listeners. Recently, Stephens et al. (2010) pre-recorded speakers' acoustical productions and the co-occurring brain activity. Then, they monitored listeners' brain activity during the audio playback of the speakers' productions. They found some speaker-listener neural coupling, even if the speaker was not present. Using a situation analogous to Stephens et al. (2010), the present study investigates if listeners' breathing changes according to the speaker they listen to (male vs. female) and to the loudness level (normal vs. loud) of the speaker's voice. We also evaluate if breathing during speech produced right after listening differs according to the speaker and to the loudness level of the signal heard during the listening task.

Methods

Our protocol was comparable to the one developed by Stephens et al. (2010). We pre-recorded acoustic and breathing movements produced by two *readers*, one male (23 yrs, 1.86m, 65kg) and one female (35 yrs, 1.70m, 58kg), while they were reading short texts (fables) with a normal and then a loud volume level. We played back these audio recordings to *listeners* (26 females, average age 25±3 (std) and average Body Mass Index 21.5±2). The listeners heard either the male or the female reader, and 5 texts in normal speech first and in loud speech second, or in the reverse order. Listeners were instructed to listen attentively to the story and to briefly summarize it afterwards. Readers and listeners were all native speakers of German. Acoustical and breathing signals were recorded for readers and listeners in the same conditions. Breathing movements were recorded for the thorax and the abdomen using Resptrace. We expected different breathing profiles for the two readers, due to their different morphologies, and variations in breathing profiles according to the level of loudness (Binazzi et al., 2006; Huber et al., 2005). These differences between readers should have some echo in listeners' breaths during the listening and the summary task. The effects of readers, loudness and condition order on the amplitude and duration of the breathing cycle were tested using Linear Mixed Model.

Results and conclusion

As expected, the two readers differ in the two conditions of loudness, particularly with respect to breathing frequency (female: normal < loud, male: normal > loud) and with respect to duration of exhalation (longer for loud vs. normal for the male, no diff. for the female). Both readers were generally similar with respect to amplitude of inhalation: loud speech goes hand in hand with deeper inhalation than normal speech. During listening, listeners tended to inhale more frequently and shorter when listening to loud speech as compared to normal speech. This tendency was observed for 18/26 listeners and did neither depend on the reader, nor on the condition order. However, a three level interaction showed that the decrease of cycle duration, when listening to loud speech as compared to normal speech, could be greater when loud speech

was heard before normal speech, especially for the male speaker. The amplitude of the breathing cycle was globally larger in listening to normal as compared to listening to loud speech. The effect of loudness on amplitude was dependent on the reader. It was more prominent for the listeners to the male reader (11/13 subjects) than for the listeners to the female reader (4/13 subjects) who even tended to show the reverse pattern. The effect of the loudness condition on the amplitude of inhalation during listening also showed an effect of condition order and was mainly observed when subjects listened to the loud condition first. This difference in amplitude due to the condition order was observed only for the listeners to the female reader. When listeners spoke to summarize the texts right after the listening task, the asymmetry between inhalation and exhalation strokes of the breathing cycle increased as compared to the shape of inhalation and exhalation during listening. These changes in breathing pattern between listening to speech and speech production are similar to previous observations (McFarland, 2001). However, we did not find any significant effect of the reader, nor of the loudness level on the shape of the listeners' breathing cycle during the summary task. This could be due the fact that a large variability was observed between subjects in the way they achieve the summary task (e.g. number of breathing cycles).

These preliminary results show that listeners' breathing is sensitive to the reader and to the loudness of the reader's speech. This sensitivity could be a physiological reaction, as breathing is closely linked with heartbeats and emotional state. It could also be linked with the fact that the cognitive load could be greater for louder speech as compared to normal speech. Finally, changes in listeners' breathing could result from an adaptation to specific characteristics of the reader's voice and/or rhythms or to a speaker-listener's coupling, as it has been observed for body movements in dialogue or for brain activity during listening (Schmidt et al., 2011, Shockley et al., 2003; Stephens et al., 2010). We are now using spectral methods to evaluate if some synchronization between listener's and reader's breathing could be observed.

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