Speech and breathing in different conditions of limb movements and over time

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Speech, respiration and limb movements seem interconnected in different ways. For example, speech production increases the duration of breathing cycles while physical effort shortens it. Physical activity may also improve creativity and semantic memory in relation with breathing. In this paper, we analyze changes in breath groups and breathing cycles during narration of short stories recalled with different motions of the limbs (hands free, hands blocked, hands biking, legs biking), and their progress over two days. The analyses suggest a significant increase of the breath group duration on day 2 as compared with day 1. This effect seems especially clear in the hand-blocked and hands-biking conditions. It is interpreted as an evidence of larger interferences between limbs movements and speech in these two conditions.

INTRODUCTION

Speech relies on specific adaptation of breathing control in close link with cognitive activity [1,2]. For instance, it is well known that during speech production, inhalation phases are shorter and exhalation phases longer than during quiet breathing [3]. The cognitive and physiological demands of the speech task affect the breathing profile [4,5]. At the same time, the respiratory constraint may shape speech planning [6,7]. But adaptation of breathing control is also involved in limb movements. For example, breathing frequency increases with physical effort [8]. It also seems that breathing-speech vs. breathing-limb coordination could be changed with training: theater actors [9] and athletes [10] might show different speech / breathing coordinative profiles. Previous works suggest that limb movement as well as learning could be relevant paradigms to further question the speech-breathing link. In line with this idea, we analyzed this link over time in different conditions of limb movements.

METHOD

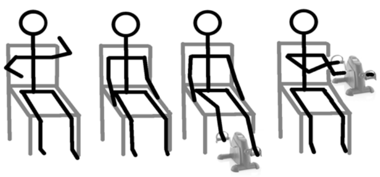

Figure 1: Experimental conditions, from left to right: Hands Free (HF), Hands Blocked (HBl), Legs Biking (LB), Hands Biking (HBi).

Eleven native speakers of German participated in this study. Their task was to watch short videos while sitting on a chair. They were then invited to retell the stories in different conditions: hands free (HF), hands blocked (HBl), hands biking on a mini-bike (HBi) vs. legs biking (LB) on the same mini-bike (Figure 1, left). Participants were recorded twice in the same conditions, on two different days. They also came back ten days later to retell the story in the HF condition only.

Speech and breathing were recorded synchronously using a microphone and the Inductance Plethysmograph system Respitrace®. Limb motion was also recorded using an Optitrack system but is not analyzed in the current paper. Interpausal units of speech (IPU) and breathing cycles were labeled automatically in Matlab and then checked and corrected when needed using Praat (Figure 2). The following measurements were considered to characterize the breathing cycles and the speech breath groups (in line with our previous work, cf. [11]):

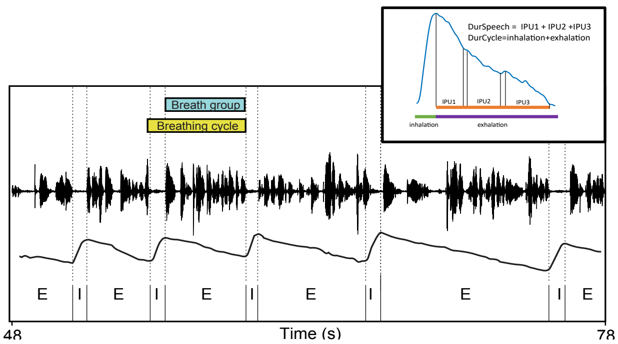

Figure 2: Identification of the breath group and the breathing cycle on the acoustic signal (top) and thorax trajectory (bottom)

- DurCycle: The duration of the breathing cycle (from the onset of the inhalation phase to the offset of the exhalation phase);

- SymCycle: The symmetry of the breathing cycle (duration of the inhalation phase divided by the total duration of the cycle);
- DurSpeech: The duration of the breath group (from the onset of the first interpausal unit to the offset of the last one produced on a same cycle);

We considered how these parameters changed according to the experimental condition and the day of recording.

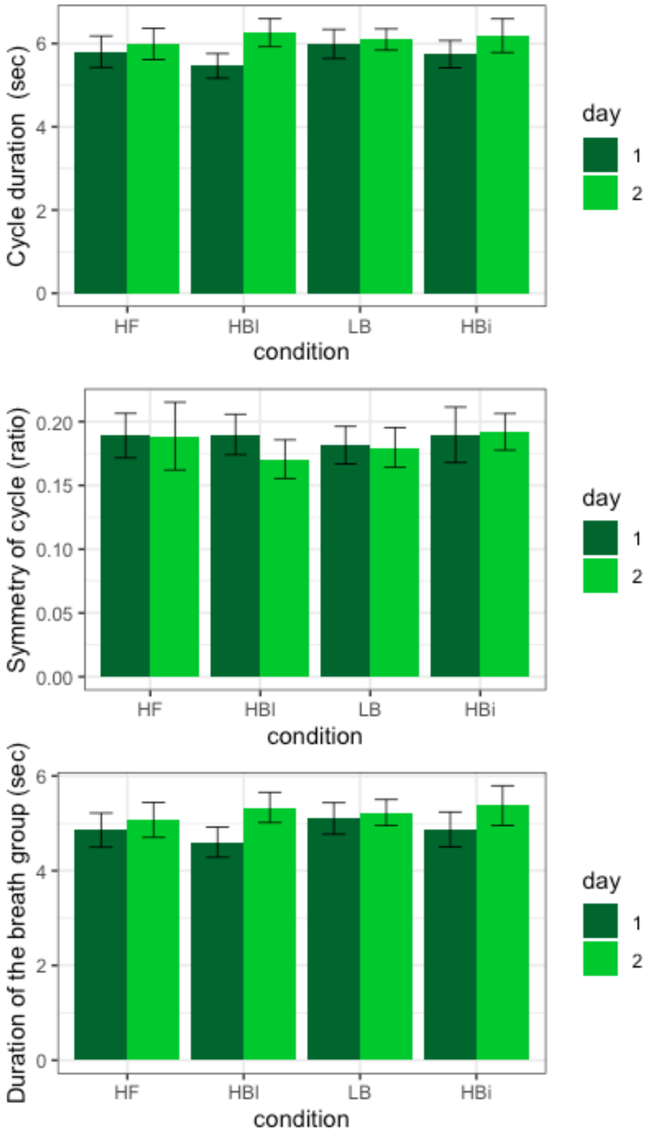

Figure 3: Measurements as a function of day (1 and 2) and experimental condition (HF, HBl, LB, HBi). Top: mean of the duration of the breathing cycles; Middle: mean of the *symmetry of the breathing cycles (inhalation duration/cycle duration); Bottom: mean of the duration of the breath groups*

RESULTS

The following linear mixed model (log(DurSpeech)~condition*day+(1|participant)) for DurSpeech measurements shows a significant effect of the day (z-value=2.271 p-value= 0.0232) but no effect of the condition. The amplitude of the effect was about +0.40 seconds from day 1 to day 2 in both cases. Neither the day, nor the condition significantly affected the asymmetry of the breathing cycle (Figure 3, middle).

Table 1: Means and standard deviations of DurCycle and DurSpeech as a function of day

Mean (± std)	Cycle duration (sec)	Breath group duration (sec)
day 1	5.75 (±1.10)	4.86 (±1.12)
day 2	6.13 (±1.12)	5.25 (±1.12)
Total	5.94 (±1.23)	5.05 (±1.13)

DISCUSSION

The increase in breathing cycle and breath group durations in these preliminary analyses might be related to a decrease of the cognitive load on day 2 as compared with day 1. Indeed, despite a non-significant effect of the condition, changes between day 1 and day 2 seem clearer for the unusual conditions of speech production (here, hands still and hands biking). These two conditions may induce a greater cognitive load than more usual conditions such as h ands free or biking with the legs. This could be evaluated by supplementary analyses of the linguistic content and the disfluencies. Further analyses of the correlation between the duration and amplitude of inhalation and the number of syllables per breath group should also help to understand to which extent these changes are related to changes in speech planning. Finally, analyses of the regularity of limb motion in the hand and leg biking conditions should help quantify the degree of familiarity to the task (e.g. in this case, smaller variability should be observed on day 2 with a different biking rate).

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