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ELECTROMYOGRAPHIC ANALYSIS OF LIP AND FACE MUSCLES IN BEATBOXING

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Abstract: Muscular activations of lip and face muscles have been studied while performing beatbox sounds in comparison to speech sounds. Five trained beatboxers were recorded for various tasks involving the production of beatboxed sounds (kick, hi-hat, and rimshot) and related spoken syllables ([pu] for kick, [ti] for hi-hat, and [ka] for rimshot). Activations of orbicularis-oris lip muscle and zygomaticus-major face muscles were recorded by surface electromyography (EMG) during the production of isolated and repeated sounds in both beatboxing and speaking condition. Sound pressure level was much greater in beatboxing than in speaking. As expected, bilabial sounds kick and [p] involved higher levels of orbicularis muscle activation than the other sounds studied. This activity was significantly higher for kick than for [p]. A difference in lip and face muscular activity between beatbox and speech was not found for hi-hat and rimshot, even though the boxemes were produced louder than the consonants at same place of articulation. These results underline the value of beatbox exercises for working on labial and facial praxis, and on speech intelligibility.

Keywords: beatbox, electromyography, speech, consonant, orofacial muscle activity

I. INTRODUCTION

Human Beatboxing is a recent and evolving musical practice, for which the beatboxer develops a particular motor skill in vocal instrumental playing [4, 5]. Recently, beatboxing exercises have been proposed in speech rehabilitation of articulation disorders in the case of young adults with congenital dysarthria and reduced speech intelligibility [1–3]. These studies have demonstrated that beatboxing could be an effective tool for improving articulatory deficiencies, speech production, and intelligibility. Yet, no study has ever assessed the orofacial muscular load in such sound production. The aim of the present study is to explore how muscular activity differs between producing kick/hi-hat/rimshot beatboxing effects, also called

boxemes [4], and three speech /p,t,k/ consonants with similar place of articulation uttered in syllabic consonant-vowel (CV) context.

II. METHODS

Subjects: Five trained French-speaking beatboxers were recorded for various tasks involving the production of beatboxed sounds (kick, hi-hat, and rimshot). The related spoken syllables were also recorded ([pu] for kick, [ti] for hi-hat, and [ka] for rimshot). For each task, the beatboxer performed a series of twelve repeated sounds or spoken syllables. For the subsequent analyses, nine occurrences in the middle of the series were retained.

Equipment and audio analysis: The recordings took place in a semi-anechoic laboratory room authorized for biomedical research. Audio and electroglottographic (EGG) signals were recorded synchronously and sampled at 20 kHz on 16 bits (dual-channel electroglottograph Glottal Enterprise EG2). Sound files were annotated by means of Praat software. Burst instants (release of occlusion and start of sound) and end of sound were manually detected on audio signal. For speech, end of consonant sound corresponded to start of voicing as assessed on audio and EGG signal. Sound pressure level (SPL) was computed on the annotated sound window (either boxeme or consonant part of the spoken syllable) with Matlab software.

Electromyographic analysis: Electrodes were placed on the lips in correspondence with the four sections of orbicularis oris (OO) muscle and bilaterally on the face in the region of zygomaticus major (ZYG) muscles (see Fig. 1). Activation of these lip and face muscles was recorded by surface electromyography (EMG) during the production of isolated and repeated sounds (MP150 BIOPAC, 20 kHz). For each task, EMG signals were bandpass filtered (5-450 Hz) and root-mean-squared (RMS) over a 25-ms sliding window to produce a linear envelope for each muscle activity pattern. Finally, RMS values were averaged over a time window including both the sound (boxeme/consonant) and the 100 ms preceding the burst instant (see Fig. 2).

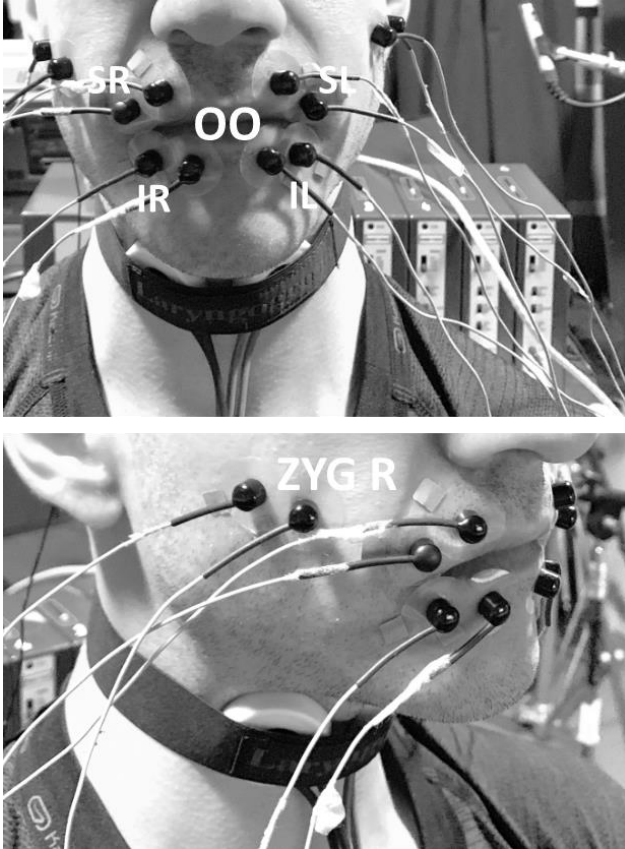


Fig. 1 : Placement of EMG surface electrodes. ZYG_L/ZYG_R: left and right zygomatic muscles. OO_SR/SL: right and left superior orbicularis oris, OO_IR/IL right and left inferior orbicularis oris.

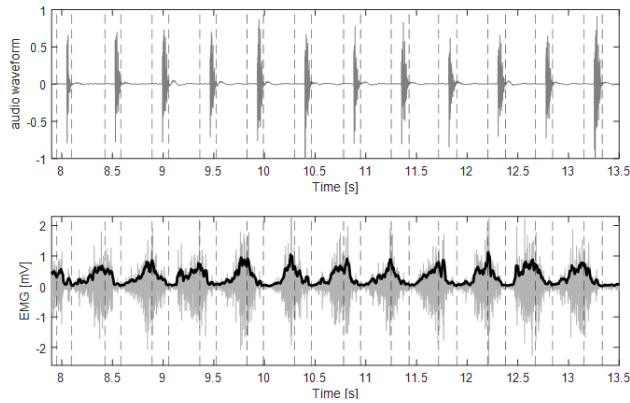


Fig. 2 : audio waveform (upper panel) and OO_SL muscle activity (lower panel) of one participant performing a series of kick sounds. Each vertical line represents the beginning and the end of the time window of interest. Lower panel: filtered EMG signal (in grey) and RMS envelope (black bold line).

Statistical analysis: Statistical models were implemented in R language, using a linear mixed modeling approach (function lme of package nlme).

They aimed to explore the impact of BOXEME factor (6 modalities, p, t, k, kick, hi-hat, rimshot), MUSCLE factor (OO and ZYG) and their interaction on variation in the response variable RMS in voltage. The hypothesis that labial and facial muscular activities measured by surface EMG would be higher in beatboxing than in speech was tested.

III. RESULTS

A. Sound pressure level in beatboxing and speaking.

As shown in Fig. **Fig. 3**, sound intensity was always found to be greater in beatboxing than in speaking, whatever the place of articulation.

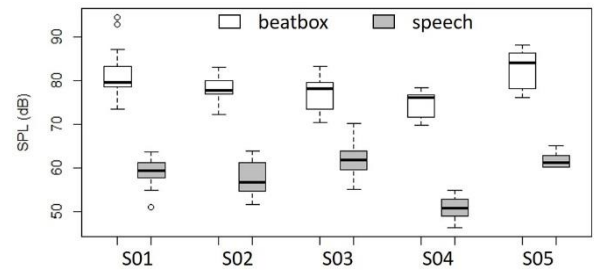


Fig. 3 : SPL values in dB for five beatboxers either beatboxing or speaking (consonant part).

B. Muscular activation in beatboxing and speaking

Fig. 4 presents the EMG activation amount for lip and face muscles in human beatboxing and in speech. Kick and [p] are bilabial sounds, i.e. sounds that are produced via complete occlusion and subsequent release of the vocal tract at the lips. In both cases, the occlusion is achieved by recruiting the orbicularis oris muscle. Yet, muscular activities were significantly higher for kick than for [p] ($p < 0.001$) for all the studied muscles. Rimshot compared to [k] did not significantly increased the muscle activities, except for OO_SR ($p = 0.024$), even though the vocal-tract occlusion to produce these two sounds is situated far from the lips, in the back region of the oral cavity. Finally, hi-hat sound did not lead to higher level of muscle activity compared to [t], except for ZYG_R ($p = 0.010$). In such sounds, occlusion is achieved by the action of tongue pushing against upper teeth.

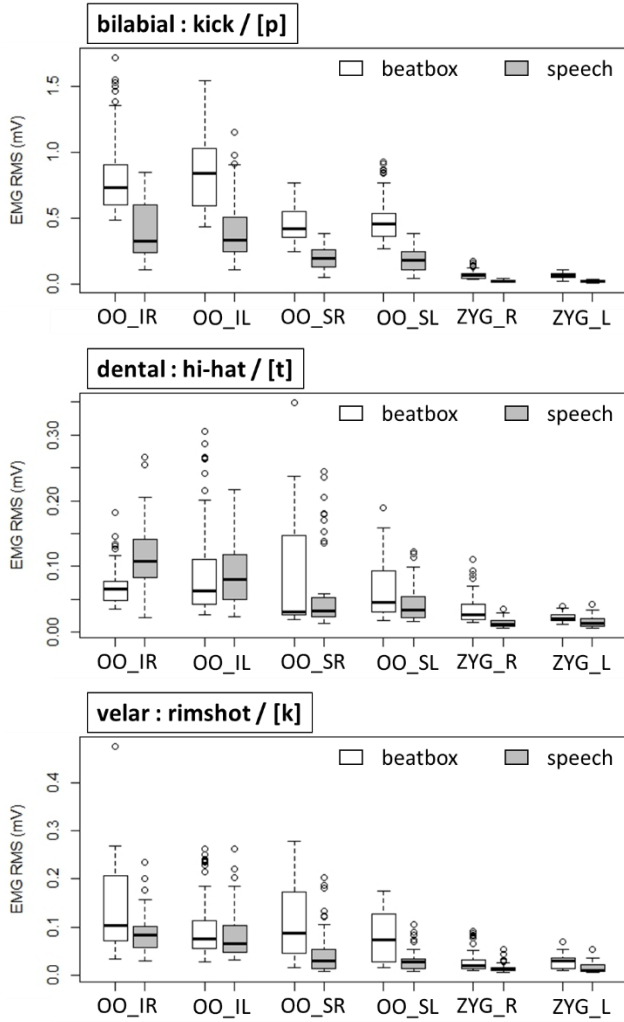


Fig. 4 : Amount of EMG RMS signal for beatboxing and speaking, depending on the place of articulation (bilabial, dental, velar). For muscles abbreviations, see Fig. 1.

IV. DISCUSSION AND CONCLUSION

An underlying question in this study was whether beatboxing exercises would be suitable for rehabilitation in the case of dysarthria and orofacial myofunctional disorders. Enhanced lip and facial muscular activities have been evidenced in beatboxing sounds as compared to speaking CV syllables with similar place of articulation for consonants. This has been verified for kick boxemes essentially. It has not been found for rimshot and hi-hat boxemes articulated

respectively in the velar and dental region. These sounds did not activate the lip and face muscles more than speech ones, even though they resulted in louder sounds.

An enhanced muscular contraction can be beneficial for working on labial and facial praxis in the context of dysarthria. It could contribute to muscle strengthening in the case of orofacial myofunctional disorders. However, the speech therapist who would use such beatboxing exercises should take great care in avoiding muscular overload or fatigue that may be induced. In this respect, hi-hat and rimshot boxemes are of much interest as they can be produced loud with a muscular effort comparable to speaking consonants.

Lip and face muscles were explored here. Another major articulator in beatboxing is the tongue. In a further study, it would be worth exploring whether beatboxing may require enhanced tongue muscular activation.

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