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A Phonetic Study of Human Beatboxing Production : An Articulatory, Aerodynamic, and Acoustic Approach

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Title : A phonetic study of Human Beatboxing production : an articulatory, aerodynamic and acoustic approach

Abstract :
Before being a subject of scientific study, Human Beatboxing (HBB) is above all a musical practice. Beatboxers use their vocal tract to produce musical sounds : drum sounds, wind or string instruments, electronic music, and more. How is Beatboxing produced ? What are the capacities of the human vocal tract ? Is there a connection between Beatboxing and speech production ? This thesis attempts to provide elements for discussion on these questions. Based on articulatory, aerodynamic, and acoustic data, we present an analysis of Beatboxing production at different tempo (90, 120, 150 beats per minute). Our results show that subjects use similar production mechanisms to those found in linguistic systems. However, they combine a greater number of different mechanisms. Beatboxing possesses the properties of a discrete combinatorial system (Proctor et al., 2013). The results on tempo effects suggest that individual strategies for temporal reorganization of gestures are similar to the strategies proposed by Byrd et Tan (1996). Indeed, subjects modified the duration of gestures and the intervals between gestures. Coordination constraints between initiation and articulation gestures were observed for two subjects. Beatboxing offers a different perspective on phonetics, allowing for the update of its theoretical framework and a shift from a purely linguistic approach to an anthropophonic approach (Catford, 1977 ; Lindblom, 1990) of phonetic phenomena.

Keywords : Human Beatboxing, Phonetics, Articulation, Aerodynamics, Acoustics, Tempo

Introduction

Before being a subject of scientific study, Human Beatboxing (HBB) is, above all, a musical practice. Musicians use their vocal tract to produce musical sounds, that is, sounds without meaning. It is not the only technique that uses the vocal tract for musical purposes. One can think of the jazz singer Ella Fitzgerald, referred as the *"acrobat of scat"* on France Musique (Betillouloux, 2020). We can also mention the sound poetry of Henri Chopin, who produced sounds without meaning. The production of articulatory combinations without meaning is not exclusive to HBB.

HBB is a distinct discipline within Hip-Hop, which originated in the 1980s in Brooklyn, New York (Martino, 2009 ; Park et al., 2005). At that time, the use of *drum machines* or *beatboxes* became popular to accompany the MC (Master of Ceremonies). Beatboxes allows to play rhythmical and melodic baselines to accompany the rappers. Purchasing Beatboxes was costly for the artists ; in contrast, the vocal tract is free and available at any time. This is how these human beatboxes made of flesh and bones were born. According to an hypothesis by the Beatboxing community, the practice also developed in response to the confiscation of electronic beatboxes by the police.

The rise of the practice in the 2000s has not failed to attract the attention of researchers. Stowell et Plumbley (2008) provide some vocal characteristics of Human Beatboxing : non-syllabic patterns, the use of ingressive pulmonic sounds (*inhaled sounds*), various voice qualities, etc. Although their study is based on an *"impressionistic"* analysis of Beatboxing, the authors place Beatboxing among phonetic phenomena. Since then, two main approaches have been proposed to study Beatboxing : the *"paralinguistic"* approach (Proctor et al., 2013) and the phonological approach (Blaylock, 2022). We will revisit these approaches in Chapter 1.

Between music and phonetics, Human Beatboxing is a subject of scientific study that does not yet have a clear and defined theoretical framework. We know that it is a musical system in which musical notes are produced by the vocal tract. Therefore, it is both a vocal and musical practice. It is the atypical nature of this technique that has aroused the curiosity of phoneticians : how is Human Beatboxing produced ? What are the capacities of the human vocal tract ? Is there a connection between Beatboxing production and speech ? This thesis will attempt to provide some discussion points on these questions.

This thesis focuses on the production of Human Beatboxing using articulatory, aerodynamic, and acoustic data. In order to describe the production mechanisms of this vocal technique, we will start with the phonetic knowledge from speech production literature. We also want to understand how Beatboxing sounds vary. To do this, we will analyze isolated productions as well as productions of sounds within musical structures that we call *"Beat Patterns"*. A definition of *Beats Patterns* (BP) is given in the methodology (Chapter 2). These BPs are mainly composed of a sequence of stops and affricates. The interval between sounds is characterized by silence. In order to ensure the induction of variation, we will use a speeding up paradigm with 3 reference tempos : 90, 120, and 150 beats per minute (BPM).

This thesis is composed of 5 chapters. Chapter 1 introduces the theoretical framework from which we will analyze the production of Human Beatboxing. Chapter 2 develops the adopted methodology. Chapter 3 provides a description of the production and combination of various production mechanisms. Chapter 4 presents the results of tempo effects on Human Beatboxing production. Finally, Chapter 5 proposes to expand the theoretical framework in phonetics.

Chapter 1 : Theoretical Framework

Chapter 1 first introduces the different subsystems that forms the vocal production system : the respiratory system, the laryngeal system and the "oral system" (which includes the muscular subsystems of the tongue, lips, and lower jaw). Language involves the use of a large number of muscles to produce sounds. The primary function of the muscle groups is to ensure vital functions of the human body, such as respiration or swallowing, for example. Acoustic communication in the human species leads to a reorganization of the physiological functioning of these multiple systems in order to ensure both vital functions and speech production. Similarly, during the production of HBB, another organization takes place to ensure (1) vital functions and (2) continuous vocal production, i.e., uninterrupted [1].

In Chapter 1, aerodynamic principles and initiation mechanisms are discussed as well as Beatboxing production mechanisms. During vocal production, whether it is speech or HBB, the activity of the sub-systems is reorganized to allow the production of sounds in the vocal tract. Vocal production is characterized by a muscular phase in which the contraction of respiratory, laryngeal, and oral muscles sets the production organs in motion to create variations in pressure and to generate an airflow on which articulation occurs to produce acoustic disturbances, i.e., sounds. A revision of Catford's model of initiation (Catford, 1977) is proposed. The revised model describes initiation in terms of gestures.

Finally, Chapter 1 discusses speed rate effects on speech production. Lindblom (1963) hypothesizes that phenomena such as reduction, assimilation, or elision are due to biomechanical limits of the production system. He explains that the production targets remain invariant, but the movement and the timing of articulators vary. Therefore, he raises the question of the spatial-temporal compromise in gesture realization as a function of speed rate. Speaking quickly means producing more syllables or words within a given time. Conversely, speaking slowly means producing fewer syllables or words within the same time slot. Variation of speed rate involves temporal reorganization of production gestures. Also biomechanical adjustments are made to ensure proper timing of production. Musical studies

1. Recall that during HBB battles or concerts, the person beatboxing must do it for several minutes without having to stop to catch their breath.

using the same paradigm are also mentioned.

Chapter 1 concludes with the presentation of the goals and the hypotheses. Our knowledge of the mechanisms of sound production in the vocal tract mostly comes from linguistic studies. The production of phonemes is subject to phonological constraints (finite phonemic inventory, phonotactic rules) and biomechanical constraints. Human Beatboxing is not a linguistic system but a musical one. Therefore, production mechanisms are not constrained in the same way. Because the production takes place in the vocal tract, biomechanical constraints are the same for HBB and speech. However, the structure and functioning of the system depend on musical constraints. These constraints come from the musical genres produced by beatboxers. If one produces a piece of *Jazz* or *Drum n Bass*, the choice of sounds and their combination in a metric structure will depend on the conventions and rules of the imitated genre. As a result, patterns of production, combinations, and coordination of units (whether gestures or features) in HBB will be different from what is observed in languages. How is production reorganized when beatboxing ? How does this reorganization vary as a function of tempo ? This thesis has two goals :

1. Following the proposal of Proctor et al. (2013), we will demonstrate that HBB is a discrete combinatorial system. We will attempt to show how HBB is a (articulatorily) more complex production system than speech.
2. Using a speeding up paradigm, we will analyze the effects of tempo on HBB production based on temporal, aerodynamic, and acoustic data.

We hypothesize that the primitives of HBB are the same as speech. However, the two systems differ in the combinatorial possibilities of the primitives structuring spoken or beatboxed units. We also hypothesize that increasing the speed rate will result in a reduction of the duration of production gestures and a decrease in the amplitude of the initiation gesture. In the absence of articulatory data at different tempos, we do not make any hypotheses regarding the amplitude of articulatory gestures.

Chapter 2 : Methodology

Chapter 2 introduces the methodology of the thesis. It presents the principles of transcription, the corpus, subject recruitment and procedure, experimental techniques used, and data analysis principles. The protocol and the corpus were created in collaboration with Paul Vignes a professional beatboxer and the pilot subject.

This study does not aim to create a notation system. The developed system uses the International Phonetic Alphabet (International Phonetic Association, 1999) and its extensions for pathological speech (Ball et al., 2018). This system is not intended to become a notation system as it has been developed for the needs of this dissertation, and the dissertation is not representative of the richness and diversity of beatboxed sounds.

This study focuses on the production of beatboxed sounds in different contexts and at different tempos : in beatbox structures, isolated productions, and free productions ("freestyle"). Beatboxed structures are referred to as "Beat Patterns" (BPs). BPs (Beat Patterns) were created with the same metrical, rhythmical, and melodic structure in order to collect controlled and comparable data across subjects. The metric consists of 4 beats and 9 sounds. The rhythmic parameters of the Beat Patterns include alternating different pitch (high, low), different intensities (strong, weak), and different lengths (short, long). Finally, the melodic parameters refer to the different timbres specific to each instrument and each category of electronic sound. The metrical, rhythmical, and melodic structure is the same for each pattern, only the tempo changes (Figure 1). 11 BPs were created.

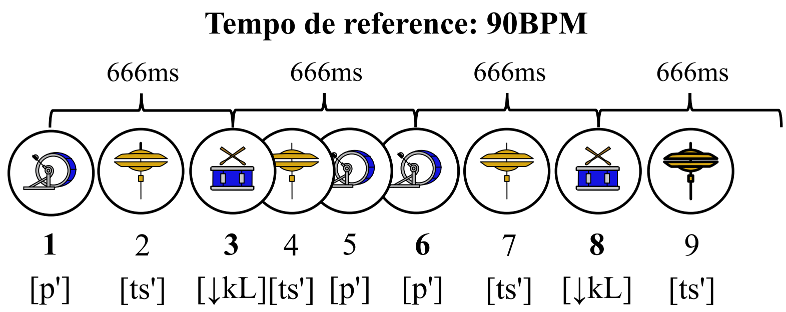

FIGURE 1 – Illustration of the metrical structure of a Beat Pattern with a reference tempo of 90 BPM.

The subjects of the study are professional male and female beatboxers recruited through the network of Subject 01. The number of selected subjects is 5 : one reference artist and 4 other artists (2 males, 2 females). To participate to this study, subjects must be 18 years of age or older and must not have any vocal or language disorders. Pregnant, parturient or breastfeeding women, as well as individuals deprived of their liberty, were not eligible to participate. The exclusion criterion was the discovery of a vocal pathology during the observation of the laryngeal structures during nasofibroscopy. The data from one participant was excluded because the pressure and airflow signals were confounded.

The first part of the experiment involved repeating the audio examples of the Beat Patterns (BPs) from the corpus. For each BP, each sound had to be repeated 8 times in isolation ; then, the subjects had to repeat the BP 4 times at 90, 120, and 150 beats per minute (BPM). In order to provide the same reference tempo for everyone, each subject was equipped with a vibrating metronome placed on the wrist like a watch. Each increase in the reference tempo was marked by a short pause to introduce the new reference. This first part of the protocol constituted a common base for all individuals participating in the study.

The second part of the protocol focuses on exploring the artists' repertoire regarding voice production. For this purpose, we asked the beatboxers to produce sounds inspired by electronic music, such as “scratches” or bass sounds. “scratches”, by analogy to scratching in *DJ-ing*, are sounds that imitate DJs spinning vinyl records on turntables to alter the sound and make it high or low pitch. “Vocal bass” sounds are imitations of synthetic sounds characterized by low frequencies ; their production relies on complex phonatory strategies. All subjects have different skills in terms of beatboxing style ; therefore, the exploratory corpus is not the same for each subject.

Laryngeal exploration was conducted using the Xion digital stroboscopic video recording system, which includes a light source for the flexible endoscope and an acoustic recorder with a microphone on the endoscope handle. The aerodynamic data was collected using the EVA 2 recording station, which allows for the automatic synchronization and calibration of aerodynamic and acoustic data. It comes with two channels for measuring airflow (oral through a silicone mask and nasal through nasal probes placed at the nostril entrance) as well as a probe for intra-oral pressure, inserted into the nose up to the oropharynx. Oral airflow was measured using a pneumotachograph (Ghio & Teston, 2004). The EVA2 station also has an integrated microphone located behind the pneumotachograph. To confirm the hypotheses formulated on the basis of VP’s aerodynamic and fiberoptic data, we decided to record 2D Real-Time MRI data. A simplified protocol was implemented for the acquisition of MRI data. The MRI recordings took place at the University Hospital of Nancy under the supervision of André Vuissoz, Research Engineer at the University of Lorraine.

Chapter 3 provides a phonetic description of Beatboxing (qualitative analysis), and Chapter 4 offers a description of the effects of tempo (quantitative analysis). The qualitative analysis follows the principles of a phonetic and physiological description. We prefer to describe the data produced in isolation, so that the phonetic context, i.e., adjacent sounds, cannot influence the realization of the analyzed sounds. In this description, we will describe productions from four aspects : initiation, articulation, phonation, and acoustics (timbre). The quantitative analysis focuses on measurements of duration, intra-oral pressure, constriction area, spectral moments, and their variation depending on the tempo of reference.

Chapter 3 : Human Beatboxing : a discrete combinatorial system

Chapter 3 aims to demonstrate that Human Beatboxing is a discrete combinatorial system, as proposed by Proctor et al. (2013). Additionally, we will attempt to demonstrate that HBB is (articulatorly) more complex compared to speech. Our hypothesis is that the primitives of Human Beatboxing are the same as in speech, because both systems manipulate the same production organs (respiratory, laryngeal, and oral systems). The difference between the two systems lies in the combinatorial possibilities of the primitives. To confirm or refute such hypothesis, we propose a phonetic description of the mechanisms of sound production in our corpus based on articulatory, aerodynamic, and acoustic data.

Chapter 3 consists of four parts. The first three parts discuss the sounds from the "Beats Patterns" corpus. We will analyze first the initiation mechanisms used by the subjects. Then, we will examine how beatboxers combine these mechanisms with articulatory mechanisms. Finally, we will demonstrate how these combinations result in discrete acoustic signatures. These three parts are essential for understanding the effects of tempo on beatbox sounds (Chapter 4). The last part focuses on the individual repertoires of the participants. We will present the physiological and acoustic characteristics of beatboxing voice, by exploring how beatboxers combine different phonatory mechanisms (egressive phonation, ingressive phonation). Additionally, we will discuss whistle mechanisms and how they can combine with other mechanisms.

Throughout this chapter, we have attempted to demonstrate that Human Beatboxing is a discrete and complex combinatorial system. We have seen that beatboxers use the same production mechanisms as in speech. However, the combinations of mechanisms in Human Beatboxing differ from those observed in the linguistic systems. For example, the *Throat Kick* [ɓ̚] is produced similarly to implosives in the world's languages, with the difference that in our case, the release is glottal, and the lips remain closed.

Our data has shown the use of all six possible initiation mechanisms. These mechanisms are not specific to Human Beatboxing as they are also found in speech. Initiation is then combined with various articulatory mechanisms, which are not specific to Human Beatboxing. Our data shows the use of five modes of articulation : stop, fricative, trill, nasal, and lateral. We have observed constrictions produced at 11 different places of the vocal tract : bilabial, labiodental, dental, alveolar, post-alveolar, velar, pharyngeal, epiglottal, aryepiglottal, ventricular, and glottal. All these combinations result in discrete acoustic signatures that distinguish categories (bass drums, snares) and sounds within a same category ("Inward K-Snare," "PF snare").

We have also shown that beatboxing voice rely on complex phonatory strategies combining regular and irregular periodic elements, aperiodic elements (frication), and out of phase periodic elements (double voice). These phonatory strategies are accompanied by tongue movements that affect intra-oral pressure, oral and nasal airflow, and acoustic signature. Finally, we have shown that the use of whistle mechanisms can overlap with other mechanisms (e.g., trills).

All these elements confirm that Human Beatboxing exhibits the characteristics of a discrete and complex combinatorial system. Our initial hypothesis is validated. The primitives do not appear to differ between speech and beatboxing. What differs is the greater possibility of combination in HBB compared to speech. Therefore, vocal production activity is organized differently. We will now explore how production varies depending on the reference tempo.

Chapter 4 : From sounds to *Beat Patterns* : speed rate effects on Beatboxing

The objective of Chapter 4 is to describe, analyze, and explain the effects of tempo (90, 120, 150 BPM) on the production of Human Beatboxing (HBB). We hypothesized that increasing the speed rate would lead to a decrease in the duration of production gestures and a decrease in the amplitude of the initiation gesture. In the absence of articulatory data at different tempos, we did not make any hypotheses regarding the amplitude of articulatory gestures [2]. The production of HBB is analyzed through various phonetic measurements. Temporal measurements aim to analyze the duration of beatboxed structures, Beat Patterns, as well as the duration of sounds. Aerodynamic measurements will be used to study the effects of tempo on pressure and the relative constriction area. Finally, spectral moment measurements will be used to study their variation with respect to tempo. The sounds in this chapter have already been analyzed in Chapter 3.

Through temporal, aerodynamic, and acoustic analyses, we will attempt to identify how factors such as the intrinsic characteristics of sounds and external factors (metrical position, BP type) influence the effects of tempo. Our corpus presents a significant diversity of sounds with systematically different phonetic characteristics. The major challenge of this chapter is to analyze tempo effects on sounds in a system that is still poorly studied and understood. The challenge of this work is to disentangle the factors that influence the variability of sound production.

This chapter consists of 4 parts. The first part will present an analysis of the production task by giving general results regarding subjects' actual tempo and production error rate. The second part will present the results of the effects of tempo on the duration. The third part will analyze the variation of aerodynamic parameters according to the reference tempo. The fourth part will focus on the acoustic analysis of the effects of tempo on HBB production.

Our initial hypothesis is partially confirmed. We have shown a tendency for sounds and intergestural intervals to decrease. In the acoustic analysis of the *closed hi-hat* [t͡s'], we have shown contextual variation phenomena triggered by temporal overlap of gestures. Thus, tempo has an effect on the temporal organization of gestures in the patterns. However, the variations of the amplitude of initiation gestures did not exhibit a similar pattern to duration reduction. Regarding pressure, we have observed that it does not necessarily decrease as the tempo increases. We suggested that pressure regulation depends on individual strategies for regulating acoustic intensity.

Our data also showed the influence of factors other than tempo on sound realization. Firstly, we demonstrated differences in sound duration and gestural coordination between

2. Note that the amplitude of a gesture refers to its trajectory, which can be longer or shorter (Ostry & Munhall, 1985)

initiation mechanisms. The analysis of the subset of closed hi-hats [t͡sʼ] revealed, for 2 subjects at least, interactions between initiation gestures and between initiation and articulation gestures. Pressure tends to weaken when these mechanisms interact. However, it is possible to overcome this constraint, as shown by the data from subject GA. We also observed a systematic effect of position 4 on the degree of duration and pressure reduction in hi-hats.

Every analysis aimed to highlight individual variation. The strategy to speed up is reflected in the temporal reduction of sounds and intergestural intervals to different extents. However, in the acoustic analysis, it was noted that for VP, primarily, and for CJ, to a lesser extent, the temporal reduction of sounds was not sufficient to limit temporal overlap between gestures. In the case of subject AI, fewer acoustic cues of temporal overlap were observed. It was also noted that the reduction in sound duration and intergestural intervals was more variable. This means that the degree of gesture overlap is more variable. This could explain why subject AI exhibits more variability regarding speed rate. GA appears to have a lot of agility in his production strategy. He is the subject whose speed rate is closest to the reference tempo. He reduces the duration of sounds and intergestural intervals, but we did not observe any indications of temporal overlap for this subject. Therefore, he manage to limit temporal overlap of gestures while speeding up.

Chapter 5 : General Discussion

Chapter 5 concludes the dissertation by discussing the theoretical implications of our results. The two previous chapters have shown how the production system reorganizes its activity based on new combinatorial patterns and new patterns of articulatory coordination (Chapter 3). We have also demonstrated how the Beat Patterns vary according to different speed rates (Chapter 4). However, describing HBB within the current framework presents a challenge. The limitations of the current framework arise from the fact that the accumulated knowledge in phonetics comes from research in linguistics. However, if we want phonetics to explain all phenomena of human vocal production, we need to broaden the framework to include non-linguistic productions. We propose to put phonetics within an "anthropophonic" framework, as suggested by (Catford, 1977) and (Lindblom, 1990). Similarly, we put Human Beatboxing within the anthropophonic framework. A phonological framework, as proposed by Reed (Blaylock, 2022), would imply that musical systems have a phonology and that Human Beatboxing is affected by constraints specific to phonological systems.

In the introduction of "Fundamental problems in phonetics," Catford writes that the title of his book should have been "Anthropophonics : the phonetic categorization of human sounds." He mentions to have been "dissuaded" from choosing an "eccentric" title that could discourage some readers. Catford borrowed the term "anthropophonics" from the linguist Jean Baudouin de Courtenay. It is a term that refers to the study of the human potential for vocal production. This approach does not only deal with the sounds and phonemes of a language but with all sounds that can be produced with the human vocal tract. Lindblom (Lindblom, 1990) revisits this approach in his article “On the notion of possible speech sounds.” Whether a sound is possible beatboxing sound or spoken sound, the selection of units in the anthropophonic space must be done in the same way (Figure 2). The selection of units in the anthropophonic space (*anthropophonic alphabet*) is subject to systemic constraints defined by the needs of sound systems to establish lexical contrasts (in the case of speech) or acoustic contrasts (in the case of HBB).

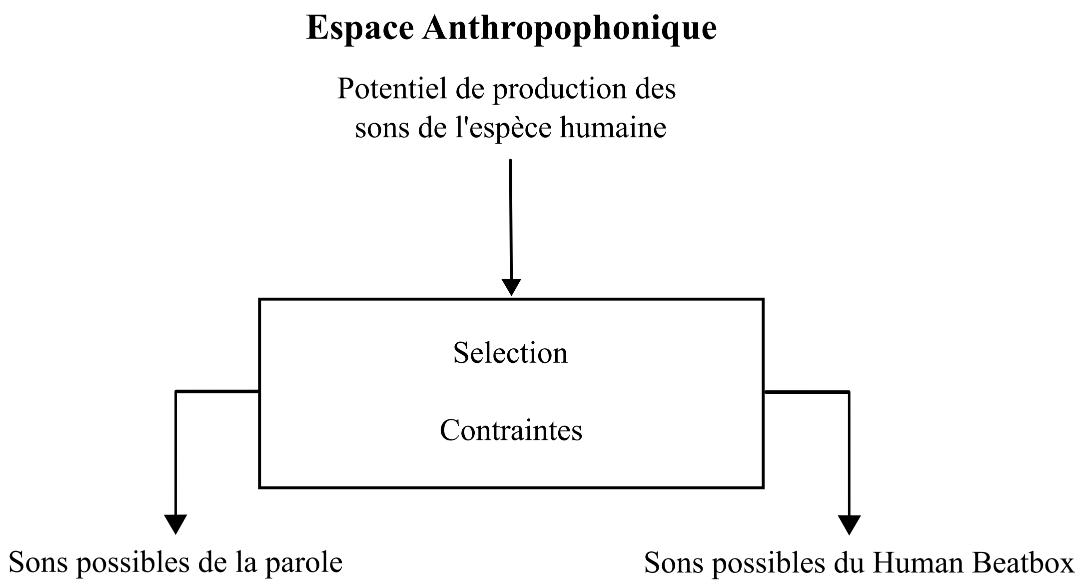

FIGURE 2 – Anthropophonic approach to Human Beatboxing

Lindblom (1990) postulated a *power constraint* on possible speech sounds [3]. The *power constraint* aims to avoid extreme articulatory movements (*synergy constraint*) and extreme speed rates (*rate constraint*). It means that effort constrains the complexity and articulatory coordination of speech units. It is possible to overcome such constraints when beatboxing. Just like a musician would work to improve their musical performance, beatboxers must train to fully exploit the capacities of the human vocal tract. Overcoming the power constraint requires time and practice (time that our species does not have to learn to

3. Power refers to energy cost as a function of time. In other words it refers to the physical efforts

speak). For this reason, we believe that beatboxing sounds would be poor candidates for linguistic systems. Linguistic systems prefer simple articulations that sufficiently contrast with each other (*sufficient perceptual contrast* rather than *maximal perceptual contrast*; see Lindblom (1990)). In HBB, beatboxers select sounds based on musical and aesthetic needs. Sound selection is based on the artistic choices of beatboxers : to produce drum or percussion sounds, one would select stops, fricatives, and affricates; to produce trumpet or saxophone sounds, sounds with harmonic structure would be selected, and so on. This suggests that the selection of relevant units in speech or Beatboxing is motivated by production goals.

Conclusion

Taken together, the results show that subjects use production mechanisms similar to those found in the world's languages, but beatboxers use a greater number of different mechanical combinations ([↓k͡ʟː ʡ̬͡ʃː ↓ʙ̥ˡː]). The results regarding the effects of tempo suggest that individual strategies for temporal reorganization of gestures are similar to those proposed by Byrd et Tan (1996). Indeed, subjects manipulated the duration of gestures and the intervals between gestures. Future studies are needed to understand the strategies for regulating pressure and acoustic intensity as tempo increases. This thesis paves the way for future studies on the effects of tempo on Human Beatboxing production. It would be interesting, for example, to revisit the MRI data to analyze patterns of gestural coordination.

How may Human Beatboxing contribute to phonetic science? It is quite clear that beatboxers exploit a larger part of the human vocal tract's capacities. Human Beatboxing raises questions about the vocal potential of our species and prompts us to question the under-use of the vocal tract by phonetic systems of the world's languages. Why do languages structure themselves the way they do and not otherwise? If we want to understand why languages underexploit the vocal capacities of our species, we would first need to attempt to define the extent of the vocal tract's capacities. Defining the extent of these capacities requires a shift from a *microscopic* approach (linguistic phonetics) to a *macroscopic* approach (anthropophonics). The macroscopic approach cannot be achieved without expanding the phonetic framework. Human Beatboxing invites us to look at phonetics from a different perspective. It also encourages to update the theoretical framework of phonetics, transitioning from a purely linguistic approach to an anthropophonic approach (Catford, 1977; Lindblom, 1990) of phonetic phenomena. Such approach would not only be beneficial for studies on Human Beatboxing but also for studies on language acquisition and language disorders.

BIBLIOGRAPHY

Association, I. P. (1999). *Handbook of the International Phonetic Association : A guide to the use of the International Phonetic Alphabet*. Cambridge University Press.

Ball, M. J., Howard, S. J. & Miller, K. (2018). Revisions to the extIPA chart. *Journal of the International Phonetic Association*, *48*(2), 155-164.

Betillouloux, A. (2020). Ella Fitzgerald, pionnière du jazz. https://www.francemusique.fr/jazz/video-ella-fitzgerald-pionniere-du-jazz-84980

Blaylock, R. (2022). *Beatboxing Phonology* (thèse de doct.). University of Southern California.

Byrd, D. & Tan, C. C. (1996). Saying consonant clusters quickly. *Journal of Phonetics*, *24*(2), 263-282.

Catford, J. C. (1977). *Fundamental problems in phonetics*. Indiana University Press.

Ghio, A. & Teston, B. (2004). Evaluation of the acoustic and aerodynamic constraints of a pneumotachograph for speech and voice studies. *International Conference on Voice Physiology and Biomechanics*, 55-58.

Lindblom, B. (1963). Spectrographic study of vowel reduction. *The journal of the Acoustical society of America*, *35*(11), 1773-1781.

Lindblom, B. (1990). On the notion of “possible speech sound”. *Journal of phonetics*, *18*(2), 135-152.

Martino, R. (2009). *Le Human Beatbox et ses participants*. Université Pierre-Mendès-France. Grenoble, France.

Ostry, D. J. & Munhall, K. G. (1985). Control of rate and duration of speech movements. *The Journal of the Acoustical Society of America*, *77*(2), 640-648.

Park, J., TyTe & Noise, W. (2005). History of Beatbox : Old School. https://www.humanbeatbox.com/articles/history-of-beatboxing-part-2/

Proctor, M., Bresch, E., Byrd, D., Nayak, K. & Narayanan, S. (2013). Paralinguistic mechanisms of production in human “beatboxing” : A real-time magnetic resonance imaging study. *The Journal of the Acoustical Society of America*, *133*(2), 1043-1054.

Stowell, D. & Plumbley, M. D. (2008). Characteristics of the beatboxing vocal style. *Dept. of Electronic Engineering, Queen Mary, University of London, Technical Report, Centre for Digital Music C4DMTR-08-01*.