GLOTTAL CHARACTERISTICS OF PEOPLE WHO STUTTER AND THE INTERACTION WITH SYLLABLE COMPLEXITY

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ABSTRACT

Stuttering is characterized by respiratory, laryngeal and articulatory peculiarities, especially when the to-be-produced speech is complex. This study examined the glottal behaviour in people who stutter (PWS) during production of simple bilabial (/p/, /b/, /m/) and complex (/pR/, /bR/) onsets. It was hypothesized that the glottal behavior of PWS presented idiosyncrasies, compared to people who do not stutter (PNS) and that these were modulated by the complexity of the onset. Producing semi-spontaneous speech with embedded target words, acoustic and EGG data were collected from 4 PWS and 4 PNS. From the perceptually fluent productions, duration of bilabial occlusion, intensity, open quotient (OQ), difference in intensity, pitch and laryngeal OQ between occlusion-phase and following vowel were measured.

No significant differences in glottal behavior were found between PWS and PNS. However, compared to PNS, PWS devoiced voiced consonants significantly more, which motivates a larger-scale investigation with more participants.

Keywords:
stuttering, EGG, voicing, articulatory complexity

1. INTRODUCTION

Stuttering is a movement disorder with deficiencies in sensorimotor processes [4], affecting, among others, speech movements [9,13]. These deficiencies in processing result in frequent repetition or prolongation of speech segments , and hesitations that disrupt the rhythmic flow of speech [12]. One of the factors that sets apart the speech of PWS is laryngeal behavior [1–3,6,10,18]. Compared to PNS, evidence shows that PWS demonstrate a steeper decrease in vocal fold contact, a less stable or prolonged open phase during dysfluent speech and a more gradual glottal onset after producing dysfluent speech [6]. In addition, studies reveal that PWS display higher activity of the laryngeal muscles during disfluent episodes compared to fluent episodes [10,21]. During fluent productions, however, glottal behavior appears to be similar in PWS and PNS [21].

In addition to these laryngeal idiosyncrasies, several studies have revealed that coordination between respiratory, laryngeal and articulatory gestures and its complexity affects speech production in PWS [6,9,10,11,14,17, 20]. Huinck et al. [11], for example, revealed that PWS showed longer reaction times when producing homorganic clusters, involving the same articulator, compared to heterorganic clusters, in which the consonant productions involved different articulators. Especially across word boundaries, higher reaction times were measured. The authors hypothesized that two consonants sharing the same place of articulation require more initiation time or planning than clusters involving different places of articulation. Byrd et al. [8], however, did not find an effect of phonetic complexity on response latency. These studies investigated possible differences in response latencies of the speech of PWS and PNS related to phonetic complexity. To the author's knowledge, not many studies examined how complexity of onset (clusters) affects physiological characteristics of the speech of PWS. Consequently, this exploratory study investigates the potential differences in laryngeal and articulatory behavior between PWS and PNS in relation to complexity of onsets further. Onset complexity in the present study is defined in terms of production differences of a singleton consonant onset (easier) versus production of an onset consonant cluster (more complex). Based on the hypothesis that PWS experience more difficulties in planning complex speech, it is expected that glottal and articulatory behavior of PWS demonstrate idiosyncrasies and that these differences are related to the complexity of onsets.

2. METHODS

2.1. Participants

The participants (age 20 to 46) consisted of 4 adult speakers who stuttered since childhood (PWS; 3 M, 1 F), and 4 typical (non-stuttering) speakers (PNS; 2 M, 2 F). The PWS were all diagnosed with developmental stuttering and had received some form of speech therapy in the past 3 to 5 years. The participants were all monolingual speakers of French. The study was approved by CERNI (Comité d'éthique pour les recherches non-intervention-nelles). No information about severity of stuttering or length and type of therapy was collected in a systematic manner.

2.2. Stimuli and data collection

The complexity of the onset was manipulated, using singleton consonant onsets and consonant clusters. In addition, a voiced / voiceless distinction of the onset consonant added an extra level of complexity. Target words consisted of CVCVCV or CCVCVCV syllables of which the first syllable started with /b/ (e.g., "baluchon"), /p/ (e.g., "panama"), /m/ (e.g., "minibus"), /bR/ (e.g., "brocanteur"), or /pR/ (e.g., "privation") followed by the vowel /o/, /a/, or /i/. All the words were male gender, resulting in a preceding /e/ for all the target onsets. The complete set of 30 CVCVCV/ CCVCVCV words with their frequency of occurrence [16] is listed in table 1.

Table 1: CVCVCV target words (between brackets, the frequency of the word (<5 very rare; <10 rare; >20 frequent; > very frequent) is reported. the first number is the frequency obtained from movies; the second value indicates frequency based on books (frequency of occurrence per million)). Bold words indicate high frequency words.

	/a/	/i/	/o/
/p/	**Paradis (33.23/28.04)**	Pissenlit (0.68/1.28)	Potager (1.93/3.04)
	Panama (0.15/1.22)	Piranha (0.26/0)	Policier (5.43/2.97)
/pR/	Praticien (0.3/1.35)	Prisonnier (16.97/11.69)	Promoteur (1.12/0.81)
	Praline (0.41/0.47)	**Professeur (90.02/49.53)**	Privation (0.7/1.49)
/b/	Bananier (0.18/0.61)	Bikini (2.34/1.49)	Bolero (0:0)
	Baluchon (0.87/1.96)	Bijouterier (0/0)	Bolognaise (0.08/0.14)
/bR/	Brasero (0.02/1.15)	Bricoleur (0.52/0.27)	Brocanteur (0.28/3.58)
	Braconnier (0.48/2.03)	Britannique (0.25/0.88)	Brocoli (0.69/0)
/m/	Macaron (0.12/0.61)	Mirabelle (0/0.74)	Mocassin (0.06/0.07)
	Maquillage (11.36/11.08)	Minibus (1.99/0.54)	Mobilier (0.66/5.27)

Speech productions were collected in a semi spontaneous speech task. The target words were written on flashcards and shuffled. 3 piles were constructed and from these, 3 cards were shown by the experimenter. The participant was instructed to formulate a sentence as quickly as possible, using these three target words. Each combination of words was offered 5 times.

2.3. Data collection and analysis

Vocal fold vibration was recorded with a two-channel Electro-Glottograph (EG2 Glottal Enterprise), which measures the degree of contact between vocal folds [7]. Electrodes were placed on two sides of the thyroid cartilage. The signal was high pass filtered with a cut-off frequency of 40 Hz, digitized with a sampling rate of 44.1 Khz. The audio signal was recorded simultaneously using a pressure microphone (Bruel and Kjær 4944-A), placed 30 cm from the lips. The sound intensity level was calibrated using a measuring amplifier (Nexus, Bruel & Kjaer).

The acoustic data were manually annotated with PRAAT [5]. Observing the spectrogram, the start and end of the target words, the onset syllables (CV and CCV) and the occlusion phases of the bilabial stops were annotated. Using scripts developed under Matlab, the following information was extracted from the audio and EGG signals:

For voiced and voiceless onsets:
1. duration of occlusion phase.

The following values were calculated only for the voiced bilabial stops:
1. Mean sound intensity level during the occlusion phase.
2. Mean glottal Open Quotient (OQ), measured from the closing and opening peaks of the derivative EGG signal [7], during the occlusion phase.
3. Mean difference in pitch, expressed in semitones to eliminate gender differences between the groups (see equation (1)), during occlusion phase and the following vowel.

$$(1)\ 12 * \log 2\left(\frac{F0vowel}{F0bilabial}\right)$$

4. Mean difference in Open Quotient between the occlusion phase and the vowel.
5. Mean difference in intensity between the occlusion phase and the following vowel.

Only the perceptually fluent productions were selected for analysis. Because the vowel condition was not of interest for the current study, data are collapsed across vowel. Table 1 shows that only 2 words in the voiceless onset category were high frequency words; the voiced onset words were all low frequent. Consequently, because 5 of the 6 variables involved the voiced category, this factor is not discussed any further.

The independent variable, relevant for the current study, was "type of onset", consisting of 5 levels: /p/, /b/, /m/, /pR/, /bR/. 6 Repeated measures ANOVA's, with the measures listed above as dependent variables, Group (PWS and PNS) as "between subjects", and "type of onset" (/p/, /b/, /m/, /bR/, /pR/) as "within subject" variables were run with the statistical package NCSS [15]. The Tukey-Kramer Multiple-Comparison Test was used for PostHoc analyses.

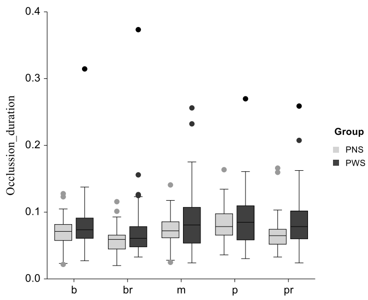
3. RESULTS

Before reporting the physiological data, the data were scanned for cases in which no F0 and OQ during occlusion of voiced stop consonants could be determined, meaning that the speaker devoiced these onset consonants. It was observed that PWS devoiced voiced onsets (30 cases (7%); 9 /b/, 19 /bR/, 2 /m/) more often than PNS (5 syllable onsets (1 %); 3 /bR/, 2 /m/).

3.1. Duration of occlusion phase

Inspecting figure 1, it can be observed that the durational values for PWS showed larger outliers and thus displays more excessive variation in duration. In addition, all the durational values for PNS (/p/: M = 0.08, /pR/: M = 0.07, /b/: M = 0.07, /bR/: M = 0.06, /m/: M = 0.08) are slightly smaller than the values for PWS (/p/: M = 0.09; /pR/: M = 0.08; /b/: M = 0.08; /bR/: M = 0.07; /m/: M = 0.09). However, the repeated measures ANOVA did not confirm this observation as statistically significant. The duration during occlusion phase differed significantly, however, depending on "type of onset" (F(4,24) = 3.03, p = 0.04). Posthoc analyses revealed that /p/ (M= 0.08, SD = 0.03) was significantly longer than /bR/ (M = 0.06, SD = 0.03).

Figure 1: vertical axis: duration of occlusion phase (in seconds); horizontal axis: different types of onsets for PWS (light) and PNS (dark grey).

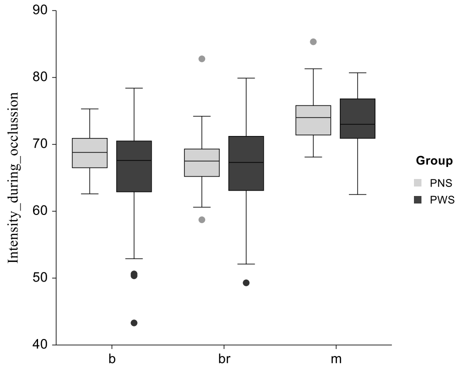


3.2. Sound intensity during bilabial occlusion

PWS did not differ from PNS regarding intensity of the voiced occlusion phase.

The "type of onset" was highly significant (F(2, 12) = 72.23, p = 0.00). The intensity during /m/ (M= 73.62, SD = 3.65) differed significantly from /b/ (M=67.54, SD = 5.26) and /bR/ (M = 67.16, SD = 5.26). This is consistent with the fact that some sound likely is radiated at the nostrils during the occlusion.

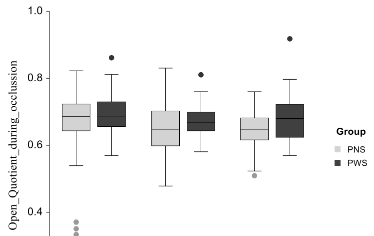
Figure 2: vertical axis: Voice intensity during the occlusion phase (in dB); horizontal axis: different types of onsets for PWS (light) and PNS (dark grey).



3.3. OQ during occlusion

Again, inspecting the plots in figure 3, all the OQ values during occlusion phase for PWS (/b/: M = 0.69; /bR/: M = 0.67; /mr/: M = 0.68) were slightly higher than the values for PNS (/b/: M = 0.68; /br/: M = 0.64; /mr/: M = 0.65), especially for /bR/ and /m/. This observed difference in OQ between PWS and PNS, however, did not show up as statistically significant. In addition, "type of onset" did not show any differences in OQ.

Figure 3: vertical axis: Open Quotient during the occlusion phase; horizontal axis: different types of onsets for PWS (light) and PNS (dark grey).

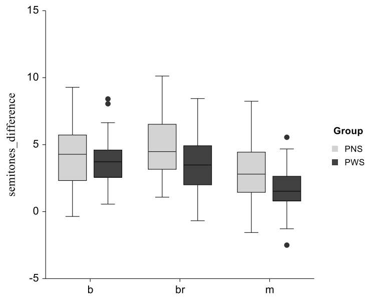


3.4. Inter-segmental difference in pitch

Inspecting figure 4, it can be inferred that the mean pitch difference from the occlusion phase to the following vowel is smaller for PWS (/b/: M =3.62; /br/: M = 3.55; /m/: M =1.65) than the values for PNS (/b/: M =4.25; /br/: M =4.93; /m/: M = 3.17). This trend did not reach significance.

For both groups, the difference in semitones is smaller (F(2,12) =45.67, P = 0.00) during /m/ (M = 2.44, SD= 2.06) than during /b/ (M =3.96, SD = 1.96) and /bR/ (M=4.32, SD = 2.34).

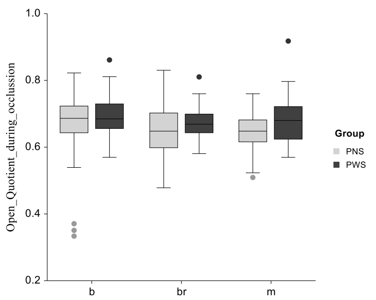
Figure 4: vertical axis: difference in pitch during vowel and occlusion phase (in semitones); horizontal axis: different types of onsets for PWS (light) and PNS (dark grey).



3.5. Intersegmental difference in OQ

PWS and PNS behaved similarly regarding the difference in OQ measure. In addition, no significant differences were revealed for "type of onset" (see figure 5).

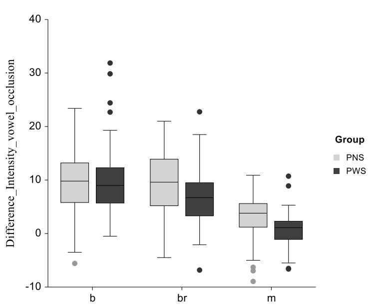
Figure 5: vertical axis: difference in OQ during vowel and occlusion phase; horizontal axis: different types of onsets for PWS (light) and PNS (dark grey).



3.6. Inter-segmental difference in sound intensity

PWS and PNS displayed similar values regarding the difference in intensity during vowel and occlusion phase (see figure 6).

Figure 6: vertical axis: difference in voice Intensity (in dB) during vowel and occlusion phase; horizontal axis: different types of onsets for PWS (light) and PNS (dark grey).



However, a main effect of "type of onset" was revealed ($F(2, 12) = 96.80$, $p = 0.00$). The intensity difference when the onset consisted of /b/ ($M = 9.42$, $SD = 5.70$) or /bR/ ($M = 8.12$, $SD = 5.56$) was significantly smaller than when the syllable onset was /m/ ($M = 1.83$, $SD = 3.60$). In addition, a significant interaction was revealed ($F(2,12) = 4.28$, $p =0.04$): when the first syllable started with /bR/, PNS ($M=9.53$, $SD = 5.67$) showed larger differences in intensity than PWS ($M= 6.70$, $SD = 5.10$).

4. DISCUSSION

The current study hypothesized that complexity of onsets affected glottal behavior in PWS. Compared to the voiced productions of PNS, the study revealed that frequently no F0 and OQ could be detected during /b/, /m/ and /bR/ productions of PWS. This finding potentially indicates a difficulty realizing VOT efficiently. Especially during the complex onset /bR/ no voicing was detected frequently, suggesting that the articulatory complexity of onsets affects glottal behavior in PWS [11,14]. However, the glottal measures in terms of OQ, did not show idiosyncrasies in behavior of PWS.

One explanation for the lack of an effect is the small number of speakers in our study. Consequently, more data need to be collected to substantiate the observations. Another possibility is that effects of phonetic complexity that difficulties reveal themselves when temporal factors are considered. Weiner [21] mentioned that PWS showed deficiencies in *the transitions* towards glottal events, which suggests that not the discrete events are important markers when describing speech of PWS. Consequently, future studies should include measurements that take temporal factors into account.

The only significant effect found in the current study concerned the difference in intensity between occlusion phase and the following vowel. This difference was smaller for PWS than for PNS when the onset was /bR/. If we assume that a decrease in intensity is potentially the result of smaller articulatory movements [19], it can be speculated that PWS reduce the range of their articulatory movements in words with complex onsets. Because all PWS had received some form of therapy, it is possible that strategies to prevent stuttering episodes underlie the findings; these strategies likely affect complex onsets more, as they are more challenging for PWS.

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