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F2 TRANSITION MEASUREMENT IN BULGARIAN ADULTS WHO STUTTER AND WHO DO NOT STUTTER

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Abstract. There is strong research evidence that F2 transitions may be used to differentiate the speech of persons who stutter from that of persons who do not stutter. However, what is known about F2 transitions in stuttering is based mostly on speakers of English. In this paper we present the first experiment on F2 transition in native Bulgarian speakers. Subjects included four Bulgarian adult males who stutter (mean age = 24 years) and four age-matched Bulgarian adult males who do not stutter. The software product Motor Speech Profile (MSP) as a part of the computerized speech laboratory (Kay Pentax) was used for the measurement of F2 transition. There was a notable difference in the magnitude of F2 variations, the rate of F2 variations and the regularity of F2 variations between participants who stutter and who do not stutter.

Keywords: F2 transition; stuttering; Bulgarian; adults who stutter; speech-language pathology

Introduction

Formant patterns are a very important acoustic cue for vowel perception. Changes in vocal-tract resonance serve as an acoustic signal of changes in vocal-tract configuration. These acoustic changes also share the approximate duration as the "underlying articulatory changes" (Kent & Read, 2002, p.154). The first two formants (F1 and F2) are adequate enough to identify vowels. Relating the formant frequency with vowel articulation F1 varies with tongue height and F2 varies with antero-posterior position of the tongue. However, according to the Dynamic Specification Model (Strange, 1987), vowels should not be conceptualized as a pair of steady-state formants, but rather as a "formant history" (Kent & Read, 2002). The formant transition itself includes enough information to correctly identify vowels. Nonetheless, measuring formant transitions is often difficult because of the variable durations, determining the initial and terminal points, and the rate of change.

The acoustic analysis of the speech of persons with communication disorders, of course, presents additional challenges. There have been numerous attempts to study

F2 transitions in the speech of persons who stutter (Stromsta, 1965; Klich & May, 1982; Zebrowski, Conture, & Cudahy, 1985; Howell & Vause, 1986; Kowalczyk & Yairy, 1995; Robb & Blomgren, 1997; Robb, Blomgren & Chen, 1998; Yaruss & Conture, 1993; Namita & Savithri, 2002; Chang, Ohde & Conture 2002; Subramanian, Yairi & Amir, 2003; Dokoza & Heđever, 2010; Dehqan, Yadegari, Blomgren & Scherer, 2016). Using different age groups, speech samples, and methods, two main hypotheses may be outlined. One concerns the importance of F2 transitions for the perceptual differentiation between the speech of adults who stutter (AWS) and adults who do not stutter (AWNS), whereas the other highlights the predictive value of F2 transitions for stuttering chronicity.

Studies dedicated to F2 transitions in stuttered speech usually are based on Van Riper`s classic definition that stuttering is a "temporal disruption of simultaneous and successive programming of muscular movements required to produce a speech sound or its link to the next sound" (Van Riper, 1982, p. 468) and on Wingate's (1964, 1969) assertion that a transition defect is central to stuttering behavior. Measuring F2 transitions allows researchers to extract information concerning vocal-tract geometry and the ability of PWS to make the appropriate articulatory movement transitioning from one sound to the next.

Robb and Blomgren (1997) provide evidence that the slope of F2 transitions of AWS differs from AWNS when producing perceptually fluent speech. They attributed this difference to abnormal lingual co-articulation of speech sounds. A year later, using refined methods of acoustic analysis, Robb, Blomgreen, and Chen (1998) reported that the fluent speech of AWS is more different than similar to that of normally fluent individuals. Results reported by Subramanian, Yairi, and Amir (2003) in their investigation of F2 transition as a differentiator of stuttered and nonstuttered children's speech are also a reminiscent of Van Riper`s (1971) and Wingates (1964, 1969) statements (Subramanian, Yairi & Amir, 2003). This assertion is also supported by the findings reported by Chang, Ohde and Conture (2002).

Although the the past studies vary in purpose and method, they confirm that individuals who stutter experience difficulty transitioning from one speech sound to the next and that the pattern of F2 transitions in stuttered and nonstutterered speech is different (Howell & Vause, 1986; Kowalczyk & Yairy, 1995; Robb & Blomgren, 1997; Yaruss & Conture, 1993; Namita & Savithri, 2002; Chang, Ohde & Conture, 2002).

F2 transition measures may also have value as a predictor of stuttering chronicity (Stromsta, 1965; Yaruss & Conture, 1993; Subramanian, Yairi & Amir, 2003; Aziz & Safwat, 2005; Spray, Nitzkin, Chang & Berardi, 2016[1]). Although results do not yet provide clear evidence for studying F2 as a predictor of the developmental pattern of stuttering, there are reports that adults exhibiting chronic stuttering tend to reveal appreciable aberrations in this acoustic parameter (Roob & Blomgren, 1997; Dehqan, Yadegari, Blomgren & Scherer, 2016).

At present much of what is known about stuttering and speech motor control is based on speakers of the English language. Other languages may further contribute to our understanding of stuttering and speech perception, but the studies are few

(Dehqan, Yadegari, Blomgren & Scherer, 2016; Namita & Savithri, 2002; Aziz & Safwat, 2005). For Bulgaria, the present study represents the first research done in this area since a preliminary study by Padareva-Ilieva, Georgieva, and Simonska[2] was presented at the 2012 European Congress of the Comité Permanent de Liaison des Orthophonistes-Logopèdes (CPLOL) at The Hague, NL.

Aim of the study

The aim of the present investigation was to compare F2 transitions in AWS and AWNS to determine if the previous results (Howell & Vause, 1986; Roob & Blomgren, 1997; Dehqan, Yadegari, Blomgren & Scherer, 2016) are appropriate for the adults enrolled in the intensive non-avoidance group therapy offered at the South-West University Stuttering Research Center.

Method

To implement this study, the Motor Speech Profile (MSP) /Visi-Pitch IV, Model 3950; version 2.7.0/ was used. The MSP F2 transition protocol measures the ability of subjects to repeat vowel (V+V) combinations in a fast and rhythmic manner. This approach differs from what has been used previously in the professional literature[3]. The analysis assesses the subject`s ability to make F2 transitions in a fast, rhythmic manner without vowel neutralization, thereby assessing articulatory motility[4]. The analysis process generates four parameters – F2magn, F2rate, F2reg, F2aver.

F2magn – Magnitude of F2 variations /Hz/

F2rate – Rate of F2 variations /s/

F2reg – Regularity of F2 variations /%/

F2aver – Average of F2 value /Hz/.

Participants

The subjects included in the present study were 4 adult males who stutter (ages 22, 24, 25, and 27 years; mean age = 24 years and 5 months) and who were enrolled in intensive non-avoidance group therapy held by the second author, and 4 nonstuttering male controls of similar age, all of whom are native speakers of Bulgarian. All participants exhibited no hearing abnormalities, normal language use, speech articulation, and voice production, based on their medical history and interview with speech-language therapist with experience in stuttering assessment and treatment. Stuttering severity was determined using stuttering frequency and scores by application of the Stuttering Severity Instrument for Adults, Third Edition [SSI–3] (Riley, 1994). Two of the AWS were classified as moderate, one as severe and one as very severe degree. This is the initial severity measured before therapy but it is important to mention that all the PWS had experienced fluency shaping therapy prior to the intensive therapy.

Recording procedures

Audio recordings of 6-s duration were obtained for each subject for the production of vowel + vowel tokens. The tokens consisted of repeated consequences of front high vowel /i/ + high back rounded vowel /u/ – iu iu iu. These are two of the six vowels (i, ɛ, a, ɜ, ɔ, u) in the Bulgarian vowel system. These two vowels have very different articulatory positions and, as a result different F2 positions, require the subjects to change articulatory (tongue and lip) position.

The audio recordings were taken before the beginning of the intensive therapy program to avoid its possible impact on transitioning from one speech sound to the next.

Analysis

The small number of subjects and speech samples allows for a descriptive comparison between every AWS subject and his control (A) as well as between the two groups measuring the median value of the parameters (B).

MSP provides norm and STD for every parameter so this study is based on MSP statistics too.

Results. Analysis

A. Comparison between AWS and their controls concerning the four measured parameters

The first AWS (subject 1) had a low F2magn value (479.206 Hz), F2rate (2.151 /s) and F2aver (1443.127 Hz) compared with the results of control 1 (624.109 Hz – F2magn; 2.632 s – F2rate; 1561.755 Hz – F2aver). F2reg was higher (97.639%) compared with the control (90.892%). Subject 1 (S1) performed neutralization of the vowels, disability to change to the different position of the vowels as quickly as his control does, and his articulators are in an unusual position (see Table 1).

Subject 2 showed reduced F2magn (481.506 Hz) and F2aver (1393.356 Hz) compared with the results of control 2 (675.885 Hz – F2magn; 1541.284 Hz – F2aver), indicating reduced motility with the articulators in an unusual position. F2rate was higher (2.500 /s) than performed by the control (2.326). However, according to the STD provided by MSP statistics, both measures are close to the MSP norm. F2reg was higher (98.541%) compared with the control (92.462%) (see Table 1 and Table 2), suggesting that this AWS performed different regularity transitioning from one sound to the next compared with his control.

Subject 3 had reduced F2magn (470.765 Hz) compared with control 3 (684.329 Hz) and both demonstrated relatively low values of F2aver (1419.763 Hz; 1403.451 Hz). Reduced articulator motility was observed for subject 3, with the articulators positioned unusually. The correlation in measures of F2rate for subject 3 and his control was almost the same as the measured in subject 2 and his control, both of which were close to the provided MSP norm. F2reg was similar to the control (see Table 1 and Table 2).

Subject 4 had a relatively low F2rate (2.041/ s) compared with control 4 (2.273 /s) and both subjects demonstrated low F2aver values (1490.595 Hz; 1410.801 Hz). Subject 4 was apparently not able to change to the different position of the vowels as quickly as his control, and the articulators were in an unusual position. Subject 4 had a reduced F2magn compared with his control, but the reduction was not as great when compared with the other subjects. Both measures were close to the MSP norm. Both Subject 4 and his control produced similar F2reg, which is in fact higher than the MSP norm (see Table 1 and Table 2).

Table 1. Measures of the four parameters for AWS and their controls

Subjects/ Parameters	F2magn, Hz	F2rate, /s	F2reg, %	F2aver, Hz
Subject 1	479.206	2.151	97.639	1443.127
Control 1	624.109	2.632	90.892	1561.755
Subject 2	481.506	2.500	98.541	1393.356
Control 2	675.885	2.326	92.462	1541.284
Subject 3	470.765	2.597	94.383	1419.763
Control 3	684.329	2.353	95.130	1403.451
Subject 4	564.166	2.041	96.647	1490.595
Control 4	597.187	2.273	97.632	1410.801

Table 2. Norm and standard deviation (STD) provided by Motor Speech Profile

Subjects/ Parameters	F2magn, Hz	F2rate, /s	F2reg, %	F2aver, Hz
Norm	548.26	2.445	93.233	1635.8
STD	60.626	0.276	2.484	106.17

A. Results and analysis concerning the four measured parameters in stuttering group.

All AWS except for Subject 4 demonstrated neutralization of the vowels, reflecting reduced motility (F2magn was reduced).

Subjects 1 and 4 had a reduced rate of F2 variation (2.041/s; 2.151/s), suggesting that they were not able to change to the different position of the vowels quickly.

The third parameter, F2reg, which assesses the degree in which a subject can maintain a regular periodic transition between the different positions of the vowels, was high for three of the subjects (S1, S2, and S3). Concerning the offered MSP protocol, these values were not too far from what could be considered admissible. Nonetheless, the present results call question as to whether these three subjects were able to maintain a regular periodic transitions. In any case, it was shown that there was a notable difference in the regularity of transitioning from one sound to the next between the two subject groups.

F2aver ranged from 1393.356 Hz to 1490.595 Hz. With reference to the MSP protocol, the values were too low for all subjects. However this parameter has the least clinical significance because it is not assessing motility. It may prove to have some value to show that the articulators are in an unusual position[5)].

B. Median value between the two groups

The four measured parameters varied between groups but to a different degree and these differences were less or more important when distinguishing AWS from AWNS (see Table 3).

F2magn differed the most. Except for Subject 4, the values of F2magn in the AWS group were consistently low compared with the high values of the control group.

Obviously different were the median values of F2reg such that we may draw attention to the fact that AWS and AWNS performed differently in maintaining regular periodic transitions.

F2rate and F2aver differed between two subjects and their controls (S1 – C1, S4 – C4 – F2rate and S1 – C1 and S2 – C2 – F2aver), but the median values in the two groups were not different (See Table 1 and Table 3).

Table 3. Median values of the four measured parameters in the two groups

Median F2 transition values in the two groups								
Parameter/ values Subjects	F2 MAGN		F2 RATE		F2 REGULARITY		F2 AVERAGE	
	MEDIAN	RANGE	MEDIAN	RANGE	MEDIAN	RANGE	MEDIAN	RANGE
AWS	480.356	470.765-564.166	2.326	2.041-2.597	97.143	94.383-98.541	1431.445	1393.356-1490.595
AWNS	649.997	597.187-684.329	2.340	2.273-2.632	93.796	90.892-97.632	1476.043	1403.451-1561.755

Conclusion

Most importantly, the F2 transition protocol assesses the degree of neutralization of the vowels. Therefore the magnitude of the F2 variations should directly correlate with articulatory motility and global intelligibility. Most of the AWS subjects in this research study demonstrated reduced F2magn as a result of neutralization of the vowels.

The results in the present experiment provide strong evidence that F2 regularity may be regarded as an indicator of the different way in which AWS and AWNS maintain regular periodic transitions.

F2rate, which shows the ability of the AWS to change to the next articulatory position quickly enough, can also be considered as a differentiator between groups although a difference was observed between two AWS and AWNS.

It is interesting to draw attention to the fact that the control group (all controls except the fourth one) had high values of F2magn and almost similar F2aver values in comparison with two of the AWS subjects. It is important to note that such an articulation (high front + high back vowel in sequence) is unusual for native Bulgarian speakers. This is the likely reason for the deviation in the values performed by AWNS. Regardless, the aim of the present study was to investigate whether the measurement of F2 transition is a useful acoustic parameter for differentiating AWS and AWNS and to observe whether AWS and AWNS subjects could be differentiated on their ability to maintain a periodic, constant level of V+V vocalization with very different second formant target positions, when repeated at a fast rate.

A common method of acoustically examining vowel formant transitions is within a consonant + vowel (CV) or consonant + vowel + consonant (CVC) syllable context. As it was mentioned already MSP uses another method that makes the procedure more practical to implement. Using this new method, the present study confirmed previous results (Roob & Blomgren, 1997; Dehqan, Yadegari, Blomgren & Scherer, 2016), showing that F2 transition differs for AWS and AWNS.

The present results should be viewed with caution because the number of subjects and tokens were small. Further, the results may not be representative for the stuttering population but just for the AWS enrolled in the intensive non-avoidance group therapy offered at the South-West University's Stuttering Research Center. As the first Bulgarian study of this type, it is hoped that it may inspire additional research studies involving a greater number of subjects and employing different research methods.

NOTES

1. Spray, G., Nitzkin, J., Chang, Soo-Eun, Berardi, M. (2016). Second formant transitions in stuttering persistence & recovery. (poster) At Philadelphia, PA, Conference: American Speech-Language-Hearing Association, 2016. Available at: <https://www.researchgate.net/publication/315462090_Second_Formant_Transitions_in_Stuttering_Persistence_Recovery> [Accessed on 20.09.2017]
2. Padareva-Ilieva, Georgieva, D., Simonska, M. F2 Transition measurement in Bulgarian stutterers and nonstutterers. (poster) CPLOL, The Hague, 2012. Available at: <http://www.logopedie.nl/bestanden/cplol/proceedings_poster/2.pdf>.
3. Only one experiment using MSP was found but measuring children`s speech. See Dokoza, K. P. and Heđever, Ml. (2010). Motoričke govorne vještine djece koja mucaju. Hrvatska revija za rehabilitacijska istraživanja, Vol.46, No.1, 69 – 79.
4. Visi-Pitch IV, Model 3950, version 2.7.0., Motor Speech Profile (MSP), model 5105. 2006. Kay Pentax software instruction manual, January.
5. Visi-Pitch IV, Model 3950, version 2.7.0., Motor Speech Profile (MSP), model 5105. 2006. Kay Pentax software instruction manual, January.

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ИЗМЕРВАНЕ НА F2 ФОРМАНТНИ ПРЕХОДИ ПРИ ВЪЗРАСТНИ СЪС ЗАЕКВАНЕ И БЕЗ ЗАЕКВАНЕ

Резюме. Формантните преходи на втория формант представляват огромен интерес за изследователите, изучаващи природата на заекването. Има доказателства за това, че в речта на заекващите формантните преходи се различават от тези, измерени в речта на лица без плавностни нарушения. Досегашните твърдения се базират почти изцяло на изследвания с лица, носители на английски език. В тази статия представяме първия по рода си експеримент с възрастни лица със заекване, носители на българския език. В изследването е използван MSP (Motor Speech Profile – софтуерен продукт, част от компютризирана речева лаборатория Kay Pentax), метод, различен от описаните в известната ни научна литература, засягаща възрастни лица със заекване. Този продукт измерва способността на лицата да артикулират бързо и коректно гласни с различно артикулационно място, като измерва четири параметъра – магнитуд, регулярност, скорост и средна стойност, на формантния преход на втория формант. На базата на сравнение между плавна реч, продуцирана от възрастни лица със заекване, и контролна група лица без нарушение на същата възраст установяваме, че са налични отчетливи разлики във формантните преходи по отношение на три (магнитуд, регулярност и скорост) от изследваните четири параметъра на формантния преход на втория формант.

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