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Изворни научни рад

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VOICE ONSET TIME AND CLOSURE DURATION IN WORD-INITIAL /S/ + STOP CLUSTERS IN CLEAR AND CONVERSATIONAL SPEECH IN ENGLISH: THE EFFECT OF GENDER

The goal of this paper is twofold: (1) to analyze the voice onset time (VOT) and closure duration of stops in word-initial /s/ + stop clusters in clear and conversational speech and (2) to investigate the effect of gender on the production of these features. We analyzed read clear and conversational speech from the LUCID corpus, produced by 28 participants. Statistically significant results show shorter VOT values and longer closure durations in clear speech compared to conversational speech. Women produced shorter VOT values and longer closure durations than men, but these results are not statistically significant. A comparison between our results and the results of previous studies shows many similarities between stops in consonant clusters and word-initial voiced stops.

Key words: /s/ + stop clusters, clear speech, VOT, closure duration, gender.

Овај рад има два циља: (1) анализа времена наступа звучности и трајања оклузије плозива у почетним низовима /s/ + плозив у разговетном и конверзацијском говору и (2) испитивање утицаја пола на продукцију ових карактеристика. Анализирали смо читан разговетан и конверзацијски говор из корпуса *LUCID*, који је изговорило 28 учесника. Статистички значајни резултати показују мање вредности времена наступа звучности и дужа трајања оклузије у разговетном говору у поређењу са конверзацијским говором. У изговору жена краће је време наступа звучности, а трајање оклузије дуже, али ови резултати нису статистички значајни. Поређење наших резултата и резултата претходних студија показује многе сличности између плозива у консонантским низовима и звучних плозива на почетку речи.

Кључне речи: низови /s/ + плозив, разговетан говор, време наступа звучности, трајање оклузије, пол.

1. Introduction. Clear speech is a term which refers to a speaking style that speakers employ when they are aware of a perceptual difficulty on the part of the listener, e.g., a hearing impairment or a different mother tongue. Such awareness usually causes speakers to speak more slowly, more loudly, etc. As opposed to clear speech, the term that most authors use to denote the speaking style that does not include such hyperarticulation is conversational speech. Clear speech research is based on a comparison between these two speaking styles. As suggested by Uchanski (2005: 208), the comparison-based method is used since our current knowledge of speech acoustics and speech perception does not allow us to accurately classify any given speech sample as "clear" or to predict the level of intelligibility of a speech sample only based on its acoustic signal properties.

Some of the acoustic characteristics of clear speech based on the results obtained in previous studies are the following: slower speaking rate than that measured in conversational speech (Picheny et al. 1986; Smiljanić – Bradlow 2005), greater intensity (Picheny et al. 1986), more frequent and longer pauses (Picheny et al. 1986; Bradlow et al. 2003), an increase in F0 range (Bradlow et al.

2003; Smiljanić – Bradlow 2005), longer segments (Picheny et al. 1986; Ferguson – Kewley-Port 2002; Bradlow et al. 2003), vowel space expansion (Ferguson – Kewley-Port 2002; Smiljanić – Bradlow 2005), etc.

The goal of this study is twofold: (1) to analyze the voice onset time (VOT) and closure duration of voiceless stops in word-initial consonant clusters in which they are preceded by /s/ in clear and conversational speech in English and (2) to investigate the effect of gender on the production of these features. To the best of our knowledge, this is the first study that deals with VOT and closure duration in /s/ + stop clusters in clear and conversational speaking styles. The rest of the paper is organized in the following way: in Section 2, we discuss the differences between word-initial stops and stops preceded by /s/ at the beginning of a word in terms of VOT and closure duration. Factors influencing VOT are discussed in Section 3. The results of previous studies on clear and conversational speech relevant for the present study are reported in Section 4. In section 5, we present the research methodology. In Section 6, we report the results obtained in the research. The results are interpreted and compared with the results of other studies in Section 7. The final part of the paper contains conclusions and indicates the limitations of the study.

2. VOT and closure duration in /sp, st, sk/ clusters. Ladefoged and Johnson (2011: 151–152) use the examples of CV words from Sindhi and Navajo to explain the differences between possible VOTs. During the articulation of a fully voiced stop, voicing is present throughout the closure, the release and the following vowel. The VOT value of this stop is -130 ms. In the production of a voiceless stop, there is no voicing during the stop closure. The voicing starts soon after the closure, with a VOT of less than 20 ms, which makes this sound an unaspirated stop. An aspirated stop has a VOT of around 50 ms. In Navajo, strongly aspirated stops have a VOT of around 150 ms.

In consonant sequences in which /p, t, k/ are preceded by /s/ word-initially, these sounds are not accompanied by the aspiration which generally occurs when /p, t, k/ are in initial position in English; for this reason, these sounds can be regarded as more similar to /b, d, g/ (Wingate 1982; Cruttenden 2014: 47). The measurements made by Klatt (1975) and Docherty (1992: 155) indicate that the stops in /s/ + stop clusters reduce their VOTs compared to voiceless stops occurring at the beginning of a word. These studies show that /p, t, k/ in s + stop clusters and word-initial /b, d, g/ followed by a vowel have similar VOT values. For instance, the mean VOT of /t/ before a vowel is 62.84 ms, the mean VOT of /d/ before a vowel is 25.56 ms and the mean VOT of /t/ when preceded by /s/ is 23.75 ms (Docherty 1992: 155). The acoustic similarities between these sounds influence their perception. Lotz et al. (1960) and Reeds and Wang (1961) performed experiments in which they removed /s/ from recordings of words beginning with consonant clusters. In both of the experiments, native speakers of English identified the stops following /s/ with voiced stops.

Schwartz (1964) measured closure duration in word-initial /sp, st, sk/ clusters in English. Mean durations were 87 milliseconds for /p/, 49 milliseconds for /t/ and 57 milliseconds for /k/. If we compare these values with those reported for intervocalic /p/ and /b/ (average durations 120 ms and 75 ms, respectively) (Lisker

1957: 43) and word-final voiced and voiceless stops (average durations 88 ms and 140 ms, respectively) (Chen 1970: 144), we can notice that the closure duration in /s/ + stop clusters is more similar to that of voiced stops.

3. Factors influencing VOT. Factors influencing VOT can be divided into speaker-related factors and non-speaker-related factors (Yao 2007: 183). The above-mentioned impact of /s/ on VOT can be classified as a factor of phonetic context, which belongs to non-speaker-related factors.[1] As regards speaker-related factors, the largest number of studies have dealt with gender, age, speaking rate, lung volume and individual talking style (Yao 2007: 183). The most important speaker-related factors for this paper are gender and speaking rate.

Robb et al. (2005) investigated the gender differences for VOT production in English in laboratory and non-laboratory settings. In both settings women produced voiceless stops with significantly longer VOT values (the authors did not find a significant difference concerning voiced stops). In some other studies women also produced longer VOT values for voiceless plosives than men (e.g., Ryalls et al. 1997; Whiteside – Irving 1998; Wadnerkar et al. 2006). In contrast, there are studies that did not discover any significant differences between men and women as regards VOT. For instance, Syrdal (1996) found no significant effects of gender on the production of VOT of /p/ and /b/ in spontaneous conversational telephone speech. Morris et al. (2008) measured the VOT of all plosives in isolated CV syllables and found no significant differences between males and females.

Miller et al. (1986) elicited /bi/ and /pi/ tokens from English speakers across a wide range of speaking rates. As speaking rate became slower, VOT values became slightly longer for /bi/ and considerably longer for /pi/. Kessinger and Blumstein (1997) analyzed the VOT of initial labial and alveolar stops in CV(C) words produced in isolation and in a carrier phrase at both slow and fast rates of speech (in Thai, French and English). The mean VOT value of the short lag category in English remained relatively stable across speaking rates (as well as in the other two languages), while VOT values for the long lag category became longer at the slow rate of speech, and shorter at the fast rate of speech (as well as in Thai). Volaitis and Miller (1992), who dealt with the VOT of both voiced and voiceless stops followed by the vowel /i/, concluded that VOT increased as speaking rate decreased (VOT values of voiceless stops were affected more than those of voiced stops).

4. VOT and closure duration in clear and conversational speech. Romeo et al. (2013) elicited /p/ and /b/ tokens via a picture-naming task – male and female participants named the pictures they saw on the computer screen using the sentence: "I can see a (noun)." The results obtained indicate that females produced longer /p/ VOTs in clear speech[2] than males (the difference was statistically significant), whereas VOT durations for /b/ were the same. Smiljanić and Bradlow

[1] According to Yao (2007: 183), the most established non-speaker-related factor is place of articulation; other non-speaker-related factors are phonetic context, word frequency and laboratory environmental setting.

[2] The authors indicate that they elicited "citation style speech, which would be closer to a clear than conversational speech style" (Romeo et al. 2013: 3783).

(2008) examined VOT and closure duration in clear and conversational speech in English and Croatian. They used semantically anomalous sentences containing word-initial /b, d, p, t/ and word-medial /b, g, p, k/ (in intervocalic positions). The VOT of word-initial voiceless stops in English clear speech was lengthened more than the VOT of word-initial voiced stops. The closure duration of stops was longer in clear speech than in conversational speech (especially for stops occurring at the beginning of a word).

5. Research methodology

5.1. Stimuli. The London UCL Clear Speech in Interaction Database (LUCID) (Hazan – Baker 2011) contains spontaneous and read speech in English in clear and conversational speaking styles. The corpus consists of five components: (1) *spontaneous conversational speech* – participants worked in pairs to complete the diapix task, which includes two versions of the same cartoon picture. The task of each pair of speakers was to locate the differences between the pictures by using words; (2) *spontaneous clear speech – VOC* – in this part, one participant heard the speech of the other participant processed through a three-channel noise vocoder. The vocoder made communication more difficult and the participant who was speaking had to use clear speech; (3) *spontaneous clear speech BABBLE and L2* – in the BABBLE condition, one of the participants heard the speech of the other in background noise, i.e., mixed with multi-talker babble. In the L2 condition, one native speaker of English did the diapix task with one non-native speaker of English; (4) *read conversational speech* and (5) *read clear speech* – in the picture naming task, participants named pictures using frame sentences, e.g. "I can see a (noun)." In the sentence reading task, participants read sentences which appeared on a computer screen. Even though the tasks for these two speaking styles were the same, the instructions were different (see 5.3). In this study we used read conversational speech and read clear speech elicited during the sentence reading task.

Participants read 144 sentences in total in one speaking style (they contained 36 keywords, each of which was employed in four different sentences; the position of the keyword was varied). We analyzed the words beginning with /s/ + stop clusters followed by a vowel (which do not represent keywords). Having in mind that the authors did not intend to investigate VOT in consonant clusters (the corpus includes a large number of minimal pairs beginning with /p/ or /b/), the number of words including /sp, st, sk/ is not equal in each group. The corpus contains nine words beginning with /st/, two words beginning with /sp/ and two words beginning with /sk/.

/st/
(1) The beach stall sold bats and balls.
(2) All the pets were stolen.
(3) The woman stopped to pay a bill.
(4) A push will start the Jeep.
(5) The woman bought a cake and pie stand.
(6) The surfers filled the shore with all their stuff.
(7) Many cells are studied in school.
(8) The socks had stars and spots.
(9) The shoot was still allowed.

/sp/
(10) All the sheets were spotted with the mud.
(11) The socks had stars and spots.

/sk/
(12) Many cells are studied in school.
(13) After school she knitted a sock.

5.2. Participants. The LUCID corpus comprises the speech of 40 native speakers of English (20 male, aged 18–29, mean: 20.8; 20 female, aged 20–28, mean: 23.5) and the speech of six non-native speakers of English. In this paper we analyzed stops produced by 10 male participants and 18 female participants, who were native speakers of Southern British English.[3] All of them were either students or staff from the University of London. Participants had normal hearing thresholds (20 dB HL or better for the range 250–8000 Hz) and did not have speech or language disorders in the past. They were not informed about the purpose of the recording and were paid for their participation.

5.3. Procedure. Participants were instructed to read sentences on a screen "casually as if talking to a friend" (conversational speech) and "clearly as if talking to someone who is hearing impaired" (clear speech). The sentences were presented in a pseudo-randomized order. They were recorded at a sample rate of 44,100 Hertz using an E-MU 0404 USB audio interface and Adobe Audition or DMDX (Forster, K. – Forster, J. 2003).

5.4. Measurements and data analysis. The measurements of VOT and closure duration were made in Praat (Boersma – Weenink 2021), based on inspection of waveforms and spectrograms and by listening to recordings. VOT was measured as the time between the onset of the stop burst and the onset of the periodic energy of the following vowel. Closure duration was measured as the time between the offset of the preceding /s/ and the onset of the stop burst. All values reported in this paper are expressed in milliseconds (ms).

The number of tokens we intended to analyze was 13 for each speaker in one speaking style,[4] which would result in 720 tokens in total. However, in some of the cases, it was not possible to make reliable measurements due to the noise during the closure phase, visible on the spectrograms, which is why these tokens were excluded from the analysis. Therefore, VOT was measured in 692 tokens (male participants: 166 /t/ tokens, 36 /p/ tokens and 38 /k/ tokens; female participants: 308 /t/ tokens, 72 /p/ tokens and 72 /k/ tokens). Closure duration was measured in 634 tokens (male participants: 150 /t/ tokens, 36 /p/ tokens and 40 /k/ tokens; female participants: 264 /t/ tokens, 72 /p/ tokens and 72 /k/ tokens).

[3] As indicated on SpeechBox, some utterances in the clear sentence reading task are slightly truncated and eight recordings of male participants in this task are not available. For this reason, it was not possible to analyze recordings of all 40 participants for the purpose of this study. The participants whose speech we analyzed were labeled by the authors as M11, M13, M14, M15, M16, M33, M35, M36, M41, M42 (male participants) and F4, F11, F12, F13, F14, F15, F21, F22, F25, F26, F31, F32, F37, F38, F41, F42, F47, F48 (female participants).

[4] The exceptions were speakers F4, F11 and F12. For F4, two sentences containing /st/ clusters were truncated and for F11 and F12, one sentence including this cluster was incomplete.

Statistical analysis was conducted using the Statistical Package for Social Sciences – SPSS 25. A two-way repeated measures ANOVA was completed with gender as a between-subject factor, speaking style as a within-subject factor and VOT and closure duration as dependent variables. Separate ANOVAs were conducted for each stop.

6. Results. In this section, we will present the results for VOT and closure duration in clear and conversational speech. Having in mind that the number of /t/ tokens is the highest in the corpus, the results for this group of tokens will be reported first.

6.1. Voice onset time. Table 1 contains mean VOT values produced by male and female participants in conversational and clear speaking styles.

Table 1: Mean VOT values and standard deviations (SD) for /t/, /p/ and /k/ in clear and conversational speech, produced by men and women.

Style	Gender	/t/		/p/		/k/	
		Mean	SD	Mean	SD	Mean	SD
Conv.	Male	22.67	5.35	15.39	2.51	27.22	9.65
	Female	21.67	3.49	13.53	4.73	26.97	7.53
Clear	Male	19.42	4.81	13.35	4.42	29.63	11.38
	Female	19.91	3.48	10.76	3.41	25.62	6.32

For the VOT of /t/, the main effect of speaking style was statistically significant [$F(1,26) = 15.184$, $p < .001$], indicating that speakers produced shorter VOTs in clear speech. The main effect of gender was not significant [$F(1,26) = 0.030$, $p = .865$], nor the gender × speaking style interaction [$F(1,26) = 1.353$, $p = .255$]. As regards /p/ VOTs, the results are identical. The main effect of speaking style was statistically significant [$F(1,26) = 7.909$, $p = .009$], while the main effect of gender [$F(1,26) = 2.903$, $p = .100$] and the gender × speaking style interaction [$F(1,26) = 0.182$, $p = .673$] were not. As regards VOT values in /sk/ clusters, the main effect of speaking style was not significant [$F(1,26) = 0.064$, $p = .802$]. The main effect of gender was not significant either [$F(1,26) = 0.697$, $p = .411$], nor the gender × speaking style interaction [$F(1,26) = 0.803$, $p = .378$].

6.2. Closure duration. Table 2 contains mean closure durations for both genders in the two speaking styles.

Table 2: Mean closure durations and standard deviations for /t/, /p/ and /k/ in clear and conversational speech, produced by men and women.

Style	Gender	/t/		/p/		/k/	
		Mean	SD	Mean	SD	Mean	SD
Conv.	Male	33.27	5.24	67.68	13.24	42.32	12.80
	Female	40.12	8.09	73.86	7.11	54.31	9.43
Clear	Male	49.65	15.78	90.39	20.60	56.49	21.17
	Female	54.22	14.54	94.99	18.35	71.74	15.63

For the closure duration of /t/, the main effect of speaking style was statistically significant [$F(1,26) = 42.063$, $p < .001$], suggesting that participants produced longer closure durations in clear speech. The main effect of gender was not significant [$F(1,26) = 2.041$, $p = .165$], nor was the gender × speaking style interaction [$F(1,26) = 0.235$, $p = .632$]. The results are identical for the closure duration of /p/. The main effect of speaking style was statistically significant [$F(1,26) = 36.113$, $p = .001$]. On the other hand, the main effect of gender [$F(1,26) = 1.293$, $p = .266$] and the gender × speaking style interaction [$F(1,26) = 0.046$, $p = .831$] were not. For the closure duration of /k/, the main effect of speaking style was statistically significant [$F(1,26) = 22.077$, $p < .001$]. The main effect of gender was also significant [$F(1,26) = 8.387$, $p = .008$], indicating that for this stop women produced much longer closure durations than men (mean difference 27.24 ms) than was the case for /t/ and /p/ (11.42 ms and 10.78 ms, respectively). The gender × speaking style interaction was not significant [$F(1,26) = 0.235$, $p = .632$].

7. Discussion. The results presented in this paper show that both male and female speakers produced plosives preceded by /s/ with shorter VOTs and longer closure durations in clear speech than in conversational speech in English. The only exception is the VOT of /k/; for this plosive, male participants produced longer VOT values in clear speech compared to conversational speech. However, we believe that the lack of statistical significance in this result may have occurred due to the smaller number of tokens.

Even though the analysis shows a significant main effect of speaking style on /t/ and /p/ VOTs, the difference between VOT values in conversational and clear speech is small (-2.29 ms for /t/ and -2.51 ms for /p/). The results of previous studies indicate that the VOT of voiced stops is much less affected than the VOT of voiceless stops as the speaking rate becomes slower (Miller et al. 1986; Volaitis – Miller 1992; Kessinger – Blumstein 1997; Smiljanić – Bradlow 2008). According to the results of Smiljanić and Bradlow (2008), the difference between conversational and clear speech for English word-initial voiced stops equals -13 ms, while the difference for voiceless stops equals 29 ms. In this respect, we can say that mean VOT values of stops in consonant clusters that we analyzed are more similar to the mean VOT values of voiced stops at slower rates.

As regards closure duration, all three plosives were articulated with longer closure durations in clear speech than in conversational speech. Thus, our results are consistent with those of Smiljanić and Bradlow (2008), who found that the closures of both voiced and voiceless stops (in word-initial and word-medial positions) were lengthened more in clear speech.

The main effect of gender on VOT values was not statistically significant. Therefore, our findings are similar to those reported in Syrdal (1996), Robb et al. (2005; for voiced stops) and Morris et al. (2008). Nevertheless, most of the studies which did discover significant differences between the two genders in terms of VOT found the differences for voiceless plosives. It is interesting to note that Romeo et al. (2013), who analyzed the speech of the same participants as we did (using different materials), found statistically significant differences between men and women for /p/ VOTs (men: 64 ms, women: 74 ms), but not for /b/ VOTs (11 ms for both genders). In addition, in five of six cases in our analysis, women produced

slightly shorter VOT values than men, which was also the case for voiced stops in the study by Robb et al. (2005); for voiceless stops, women produced significantly longer VOT values. A comparison between these results points up the similarity between stops in consonant clusters and voiced stops.

For closure duration, the effect of gender was statistically significant only for /k/ (which may also be due to the smaller number of tokens); nevertheless, the results suggest that the closure duration for all voiceless plosives in both speaking styles was longer in female participants' productions.

8. Conclusions. The results obtained in this study indicate shorter VOTs and longer closure durations in the production of stops preceded by /s/ in clear speech compared to conversational speech. Women produced shorter VOT values and longer closure durations than men. Nevertheless, the differences between the two speaking styles and gender differences were not large. Thus, the results showed that stops in consonant clusters and word-initial voiced stops were similar when spoken at slower speaking rates as well. The study dealt with /s/ + stop clusters in English; however, since Kessinger and Blumstein (1997) showed that the mean VOT values of the short lag categories did not change across speaking rates in three languages which have different categories of voicing, we believe that the analysis of unaspirated stops in clear and conversational speech in some other languages could yield similar results to those reported in this paper.

The limitation of the present study refers to the number of tokens, which was relatively small for /p/ and /k/. Even though the VOT values and closure durations for these two stops showed similar patterns as those for /t/, we believe that a more reliable acoustic analysis should include a larger number of tokens. The smaller number of tokens influences other factors relevant for the analysis as well. For example, /p/ and /k/ were followed by the same vowels, while the number of vowels following /t/ was larger. Production experiments, which would take into account all factors that can affect VOT and closure duration, could provide a fuller picture of /s/ + stop clusters in clear and conversational speech.

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ВРЕМЕ НАСТУПА ЗВУЧНОСТИ И ТРАЈАЊЕ ОКЛУЗИЈЕ У НИЗОВИМА /S/ + ПЛОЗИВ НА ПОЧЕТКУ РЕЧИ У РАЗГОВЕТНОМ И КОНВЕРЗАЦИЈСКОМ ГОВОРУ У ЕНГЛЕСКОМ: УТИЦАЈ ПОЛА

Р е з и м е

Први циљ овог рада била је анализа времена наступа звучности и трајања оклузије плозива у почетним низовима /s/ + плозив у разговетном и конверзацијском говору. Други циљ било је испитивање утицаја пола на продукцију ових карактеристика. Колико знамо, ово је прва студија која се бави анализом времена наступа звучности и трајања оклузије у низовима /s/ + плозив у разговетном и конверзацијском говору. Анализирали смо читан разговетан и конверзацијски говор из корпуса *LUCID* (Hazan – Baker 2011). Имајући у виду да ауторке корпуса нису намеравале да анализирају време наступа звучности плозива у консонантским низовима, број стимулуса коришћених за анализу није једнак за све гласове. Корпус садржи девет речи које почињу низом /st/ и по две речи које садрже низове /sp/ и /sk/. У истраживању је анализиран говор 28 учесника. Испитаници су добили инструкције да прочитају реченице „опуштено, као да разговарају са пријатељем" (конверзацијски говор) и „разговетно, као да разговарају са неким ко има оштећење слуха" (разговетан говор). Време трајања наступа звучности мерено је у 692 стимулуса, а трајање оклузије у 634 стимулуса. Статистички значајни резултати показали су мање вредности времена наступа звучности и дужа трајања оклузије у разговетном говору у поређењу са конверзацијским говором. У изговору жена време наступа звучности је било краће, а трајање оклузије дуже, али ови резултати нису били статистички значајни. Поређење са резултатима претходних студија показало је многе сличности између плозива у консонантским низовима и звучних плозива на почетку речи. Недостатак истраживања представља релативно мали број примера коришћен за анализу плозива /p/ и /b/.

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