Aspirated Stop Productions in Ataxic Dysarthria: A Case Study

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Abstract

The timing relationship known as the Voice onset time (hereafter VOT) refers to the time difference between the release of the stop consonant closure and the beginning of the vocal cord vibration. VOT abnormalities, which are common in a variety of speech disorders, and individuals with dysarthria reveal errors only for voiceless stop consonants. This study examines the productions of English aspirated stops [p^h, t^h, k^h] in the production of a 37-year-old Traumatic Brain Injury patient with ataxic dysarthria resulting from a motor-vehicle accident. Data from sentence-readings and spontaneous productions are acoustically analyzed. Although productions show certain patterns that are also found in regular speech, H.D. reveals other tendencies that are typical of ataxic dysarthria, such as increased difference between /p/ and /k/ and quite large within speaker variability.

Key words: ataxic dysarthria, aspirated stops, VOT abnormalities, variability

1. Introduction

The timing relationship known as the Voice onset time (hereafter VOT) refers to the time difference between the release of the stop closure and the beginning of the glottal pulsing (vocal cord vibration). If the voicing starts before the release (i.e., during the closure period), then the situation is described as having “voice lead” and is given a negative VOT value in milliseconds (ms.), as in /b, d, g/ of Spanish. If, on the other hand, the voicing starts after the release of the stop closure, then it is said to have a “voice lag” and is described with a positive VOT value in ms. When the voicing starts shortly after the release (less than 30 ms.), as in [p, t, k] of English (‘spin’, ‘stick’, ‘skin’), it is called *short-lag VOT*, but when the voicing starts delayed long after the release burst, we get *long-lag VOT*, as in English aspirated stops [p^h, t^h, k^h] (e.g.,‘pin’, ‘tick’, ‘kin’). Lag amounts are described with positive VOT values in ms. (Lisker& Abramson 1964; Zampini & Green 2001). VOT abnormalities, which are common in a variety of speech disorders, are usually interpreted as a loss of timing control, but other variables such as the size of the glottal opening, the transglottal pressure, and the vocal cord tension can also affect the VOT values.There appears to be differing pattern of VOT errors between the aphasic and dysarthric subjects (Auzou, Ȍzsancak, Morris, Jan, Eustache, &Hannequin2000). While the aphasic subjects make timing errors when producing both voiced (/b, d, g/) and voiceless (/p, t, k/) stop consonants, the latter group reveal VOT errors only for voiceless stop consonants. The most widely accepted classification of dysarthria, which is advanced by Darley, Aronson & Brown (1975) is a perceptually based system. Accordingly, the four types of dysarthria, which are related to probable site of neurologic lesion, are *flaccid dysarthria* (related to lesions of lower motor neurons), *spastic dysarthria* (related to lesions of upper motor neurons), *ataxic dysarthria* (related to lesions of cerebellum), and *hypokinetic dysarthria* (related to lesions of the extrapyramidal system). Morris (1989)studied the production of the three voiceless stops in four types of dysarthria mentioned and reported that the patients with flaccid and ataxic dysarthria revealed significantly greater VOT variability than those with spastic and hypokinetic dysarthria. He also stated that speakers with ataxic dysarthria exhibited not only interspeaker but also intraspeaker VOT variability, which is also confirmed by other studies (Vigneux & Laframboise 1991; Ackerman & Hertrich, 1997; Kent, Kent, Thomas, Weismer & Stunlebeck, 2000). Hertrich & Ackerman (1993) examined data from four groups of dysarthrias due to either basal ganglia (Huntington’s disease, and Parkinson’s disease) or to cerebellar dysfunctions(Friedrich’s ataxia, and cerebellar ataxia) resulting in specific deviations of VOT. While all patient groups showed an increased intra-individual variability of VOT, only the patients from the latter group (ataxic) were characterized by increased inter-individual variability of VOT. Moreover, ataxic subjects showed increased VOT differences between /k/ and /p/.

2. The Study

This study examines the productions of English long lag (aspirated) stops [p^h, t^h, k^h] in a Traumatic Brain Injury (hereafter TBI) patient. The subject (H.D. initials) is a 37-year-old male with ataxic dysarthria resulting from a motor-vehicle accident.

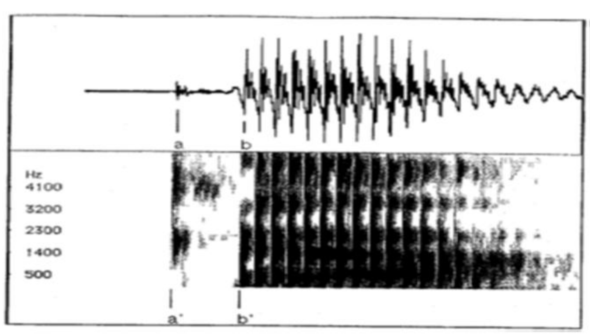
Ataxic dysarthria, which is caused by damage to the cerebellum or to the neural pathways that connect the cerebellum to other parts of the central nervous system. Among the causes of ataxic dysarthria are degenerative diseases, stroke, toxic conditions, traumatic head injury, and tumors can be given. In general, individuals with ataxic dysarthria give the impression that the movements of their speech mechanism are poorly coordinated. Patients with this condition seem to have problems controlling the timing and force of many muscular contractions that are needed to produce clearly articulated speech. Prosodic errors are prominent in ataxic dysarthria. Besides slow rate of speech and equal and excess stress, increased duration (lengthening) of segments including VOT is a fundamental property of ataxic dysarthria. H.D. had left-frontal hemorragic contusion and diffuse axonal injury. He had bilateral front parietal subarachnoid hemorrage and intraventricular hemorrages. Limb motor deficits are cited as right-side hemiparesis, and ataxia. Finally, memory problems and issues in problem-solving were registered as cognitive deficits.

2.1. Data

The data were collected five months after the accident when the patient was receiving outpatient speech therapy. Twelve sentences containing eight occurrences of each of the three long-lag stops [p^h, t^h, k^h] were collected with sentence reading. The frame used here was “Don’t say _____, say ______ instead”, whereby the second slot was occupied by the target word with a voiceless stop while the first slot had a non-target but semantically close word. For each long-lag target, 4 words had front vowels and 4 words had back vowels following the stop; they were all monosyllabics. In addition, eight target words of each of the three stops (some with multiple occurrences) were collected in conversational manner. In this mode, some target words came from H.D.’s narration of a ‘weekend account’ and the others from a ‘map task’ which involved giving directions to a place within their own locality. The target words that are elicited through the controlled sentence reading and through spontaneous conversational manner are given in appendices A and B, respectively. The data were collected in a quiet room and the productions were recorded using a head-mounted microphone (Shure SM10A) and a Marantz digital recorder at 44.1 kHz sampling rate.

2.2. VOT measurements

VOT values for the [p^h, t^h, k^h] targets were obtained from the waveforms and verified with the corresponding wide-band spectrograms as waveforms are resistant to temporal smearing, whereas spectrograms are not. In spectrograms, VOT corresponds to the interval between the onset of the energy “burst”, representing the release of an articulatory constriction, and the first of the regularly spaced vertical striations representing the vocal cord vibration (Özsancak, Auzou, Jan, &Hannequin, 2001). Lag time measurements were taken from the burst to the onset of the first formant of the following vowel. In the waveforms, positive VOT (or ‘lag’) exhibited a sharp spike (where the waveform becomes changes from quiescent to transient) denoting a release burst, and the onset of voicing was identified as the last extreme negative deviation from 0 in the waveform that preceded the onset of regular voiced pulsation where the waveform becomes periodic (i.e., jagged and “saw-tooth” waveforms, as shown in the figure below).



a=moment of release; b=start in voicing

Whenever the spectrogram and the waveform showed double bursts, we considered the first one to measure the VOT. 104 tokens (24 from sentence-reading and 80 from conversational) were examined. In some productions (fewer than 2%) VOT could not be measured and these were discarded. The non-measurables were due to the following three conditions: a) burst release was not evident (burst does not occur when a subject fails to achieve full closure in the production of stops), b)the vowel was weak and without observable glottal pulses, and c) continuous voicing throughout the voiceless stop closure. Measurement failure due to absence of burst was for [p^h] and [k^h]; the latter had the majority of problems (inadequate tongue elevation to achieve complete closure, and thus incomplete contact of the back of the tongue to the velum, resulting in a continual emission of air). The least frequently misarticulated target was the alveolar [t^h]. VOTs were remeasured three months after the original measurements and 92% of the second measurements were within 5 msecs of the original measurements and the remaining measurements were within 10 msecs of the originals. The data were reduced to reveal the mean and the standard deviation of VOT for [p^h, t^h, k^h].

2.3. Results

Table 1 shows the paired sample statistics of the three targets in sentence reading and spontaneous productions.

Table 1. Three targets, (/p, t, k), in Sentence reading and Spontaneous productions (Means, Standard Deviations, and Standard Error Means) 95% Confidence intervalof the difference

	Mean	N	SD	SEM (St. Er.Mean)
/p/ Sent. Reading	55	8	14.693	5.196
Spontaneous	52	8	14.570	5.151
/t/ Sent. Reading	63	8	16.544	5.849
Spontaneous	73	8	18.208	6.459
/k/ Sent. Reading	82	8	21.461	7.588
Spontaneous	88	8	23.875	8.441

Table 2 below shows the paired samples test revealing the paired differences of the three targets in sentence reading and spontaneous productions.

Table 2. Paired differences of the three targets in Sentence Reading and Spontaneous productions. 95% Confidence Interval of the difference

	Mean	SD	SEM	lower	upper	*t*	*df*	Sig. (2tailed)
Reading /p/-/t/	-8.000	7.010	2.478	-13.861	-2.139	-3.228	7	.014
Reading /p/-/k/	-27.000	17.509	6.190	-41.638	-12.362	-4.362	7	.003
Reading /t/-/k/	-19.000	19.719	6.972	-35.486	-2.514	-2.725	7	.030
Spontan. /p/-/t/	-21.000	20.149	7.124	-37.845	-4.155	-2.948	7	.021
Spontan. /p/-/k/	-36.000	15.175	5.365	-48.687	-23.313	-6.710	7	.000
Spontan. /t/-/k/	-15.000	33.768	11.939	-43.231	13.231	-1.256	7	.249

As can be observed, for the paired differences, all are significant except for the last comparison. In other words, H.D. has the targets phonemically separated quite well both in sentence reading and in spontaneous productions.[1] When we compare the same target in two modes of productions however, we see that his paired differences are not significant, as shown in table 3 below.

Table 3. Comparison of the same target in two modes of production.

	Mean	SD	SEM	lower	upper	*t*	*df*	Sig. (2 tailed)
/p/ R-S*	3.000	12.095	4.276	-7.112	13.112	.702	7	.506
/t/ R-S*	-10.000	22.155	7.833	-28.522	8.522	-1.277	7	.742
/k/ R-S*	-6.000	25.321	8.952	-27.169	15.169	-.679	7	.524

*R= Reading S= Spontaneous

3. Discussion and Conclusions

Looking at the data studied, we can make the following observations: H.D.'s productions are more in line with ataxic dysarthria as, compared to normal speakers, VOT durations are comparable or increased rather than decreased and within speaker variability is quite large. The productions are in agreement with those of normal speech (Klatt, 1975) since changing the place of articulation from front to back results in VOT increase. Also noteworthy is the increased difference between /p/ and /k/. Conceivably, articulatory slowness affects movements of the dorsum of the tongue more than those of the lips due to differences in muscular masses. Under these conditions a relatively slower release of the air stream during /k/ opening gestures than during the opening of the lips can be expected. H.D.'s data are also in agreement with normal tendencies in that VOTs are longer before sonorant consonants than before vowels (e.g.[p^h] of <u>play</u> 62 ms. vs <u>pass</u> 40 ms); they are also longer before high vowels than before mid and low vowels (e.g. [t^h] of <u>tick</u> 92 ms vs. <u>tack</u> 68 ms.). The rather notable characteristic of H.D's productions regarding the amount of variation for a given target. Comparison of H.D.'s sentence reading productions (means and the range)with 5 ataxic patients from Morris 1989 data (also from sentence reading), shown below may point to the severity his condition.

	H.D.	Morris (1989)
/p/	55 (30-74)	30 (18-45)
/t/	63 (36-92)	50 (26-75)
/k/	82 (42-118)	66 (28-105)

While the VOT values of H.D. are much higherthan those found in Morris' data, they are significantly lower than what was reported by Hertrich& Ackermann 1993 for 14 cerebellar ataxic dysarthria patients where the reported means were /p/ 80, /t/ 90, and /k/ 122. Since increasing severity of the dysarthria is marked by increased durations of all segments, including voice onset time, that are of normal duration in the speech of less severe dysarthrics (Kent, Netsell& Abbs, 1979), we can place H.D's values in between those of Morris and Hertrich& Ackermann.

NOTES

1- Although the difference between /t/ and /k/ in spontaneous data is not statistically significant, this is likelyto be due to the limited data. The rest of the data seem to be reassuring the phonemic separation of the three stops.

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APPENDICES

Appendix-A (target words in sentence reading)

pick	tick	kill
Pete	till	keep
pack	tack	cash
patch	tan	camp
pull	tour	cool
pool	tool	cook

pond	tart	call
punch	tall	car

Appendix-B (target words in spontaneous speech)*

promise	time(s) (11)	can
play	twelvekeen	
please (3)	twenty (8)	care(3)
p.m.	ten (11)	keep (2)
peapods	two (11)	car (6)
pass	take (2)	course (3)
put (3)	Taryn (3)	cook (2)
part (2)	toll	card

*Numbers in parentheses indicate the number of instances elicited for that target.

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