EFFECTS OF LOUDNESS AND COMPLEX SPEECH ON SPATIAL AND TEMPORAL PRECISION IN PARKINSON'S DISEASE

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ABSTRACT

The paper presents preliminary results of a speech motor control study of hypokinetic dysarthria in Parkinson's disease (PD). By means of EPG, the tongue contacts of two speakers with PD and two control speakers during the production of target words containing initial /t/ stops were analysed in normal and loud condition as well as in complex sentences. The preliminary results showed no effects of increasing loudness on duration and on the number of tongue contacts in speakers with PD. Furthermore, frication of the stop /p/ to [f] was found for one speaker in the acoustic analysis.

Keywords: Parkinson's disease, EPG, speech motor control, articulatory precision

1. INTRODUCTION

The effects of increasing loudness (e.g. as part of the Lee Silverman Voice Treatment, LSVT) on sound pressure level, respiratory function, and intelligibility in PD are evidenced in acoustic studies as well as in kinematic studies of lip movements [3, 5]. Since articulatory imprecision in hypokinetic dysarthria is one of its characteristic features, the effects of increasing loudness on the quality of tongue movements are important as well, as the tongue is the most important articulator. According to the Quantal Theory of Stevens [10], articulatory changes do not necessarily have linear effects on the acoustic output, which means in return that if the intelligibility of sound production improves, the articulatory strategies cannot be predicted with any degree of certainty.

When increasing loudness results in an increased intelligibility in hypokinetic dysarthria, and when it does not affect the duration of articulatory movements as Kleinow et al. [5] and Dromey and Ramig [2] point out, changes of displacements and/or force and velocity can be expected. As McAuliffe et al. [6] conclude, reduced pressure on tongue contact can cause target undershoot in hypokinetic dysarthria. It is possible that the LSVT not only increases the sound pressure level but also the pressure of the lips and the tongue. Using a strain gauge system, Dromey [3] found increased displacements and velocities of lip movements for loud speech in comparison to normal speech in speakers with PD. For normal speakers Schulman [9] predicts shortening of stops in loud speech.

With our study we aimed to investigate by means of EPG what happens to the articulatory precision of lingual movements when comparing loud speech with normal speech production. Since coarticulation also affects precision of articulatory movements we examined speech motor control patterns in simple sentences as well in sentences more typical of connected speech. The results presented here are a first part of a larger study.

2. METHODS

2.1. Participants

The participants were two male speakers with hypokinetic dysarthria in PD (S1, S2; mean age = 80.0 years) and two male control speakers (C1, C2; mean age = 44.5 years). All speakers were English native speakers. During the recordings the participants with PD were "on" medication (S1: medication administered for 5 years, S2 for 9.2 years). Both speakers were classed by their neurologists as "akinetic-rigid", with a degree of tremor. The only speech therapy they participated in was the Lee Silverman Voice Treatment (LSVT) 15 months ago.

2.2. Speech material

The test corpus contained target words with a CVC structure where C = /t/ or /k/ and V = /ei/, for example: "take", "cake", "Tate". To investigate phonetic confusions according to Kent et al. [4], we also recorded the following three minimal pairs: /d/ and /t/ in initial position followed by /ɪ/ for voicing contrast comparison, bilabial stops followed by /iː / or /ɪ/ in “peach” and “pitch” for vowel duration contrast and analysis of final /tʃ/, and also initial /sk/ and /st/ for cluster analysis.

2.3. Experimental conditions

The WinEPG system was used to record EPG and acoustic data simultaneously. The artificial palates of the patients with PD were manufactured from duplicate dentures, so they did not need time for desensitising. The recording was divided into the following three tasks:

1. Simple sentences (normal (n) condition)
All 10 target words were included in the frame sentence “It’s a ___ again”. The speakers were instructed to read the test sentences from a monitor in a normal and habitual way. The target words were repeated 10 times in random order.

2. Complex sentences (s condition)
All target words were included in three sentences for example, “I decided to take the steak followed by cake with peach”. The speakers were asked to read the sentences in a normal and habitual way 10 times in a row.

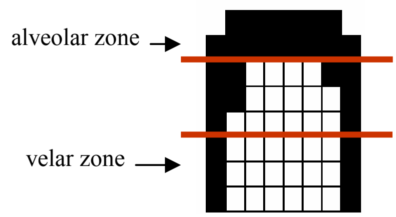
3. Simple sentences (loud (l) condition)
For this condition the speakers were instructed to read the test sentences in as task 1 in a loud and clear way. Therefore the speakers with PD were reminded to use the loud voice they had learned in speech therapy. The control speakers were asked to speak as loudly as they would do in a large room without a microphone.

2.4. Data analysis

Articulate Assistant software (version 1.15) was used to analyse the EPG data. This software provides a measure of the degree of closure across the palate and this measure was applied to the first two rows (=14 contacts, see Figure 1) in order to automatically determine the onset and offset times of alveolar closure for the initial stop /t/.

Using this measure it was possible to identify onset and offset times even when closure was incomplete by lowering the threshold of acceptance. In each case, these labeled time-points were compared against a spectrogram of the acoustic signal to confirm their validity (onset of closure= end of /a/, offset of closure = burst of /t/).

Figure 1: Phonetic zones of the EPG palate



Measurements
Mean durations of the alveolar closure of the initial /t/ were calculated for each of the 10 repetitions of “take” and “Tate”. In order to address the question whether loud or complex sentence condition affects the number of tongue contacts, the mean contacts in the alveolar zone across the number of repetitions were compared.

In some cases dysfluencies occurred in speakers with PD in terms of prolonged closure phases. They were also excluded from statistical analysis since these values would distort the mean values.

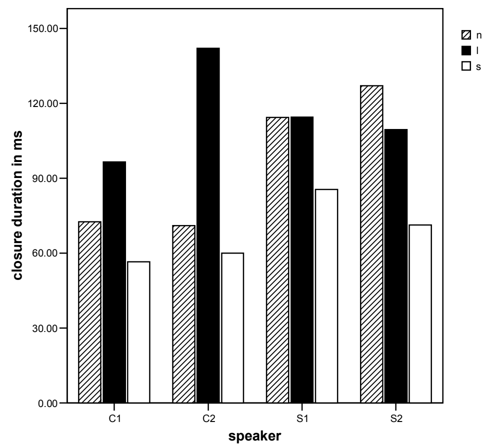
3. RESULTS

3.1. Closure duration

The first results of the study focused on the initial stop /t/ in the target words “take” and “Tate”.

Speaker comparison
By means of a univariate ANOVA (dependent variable = duration, fixed factor = speaker) significant temporal differences were found for the normal condition between the speakers of each group ($p<.05^*$). The post-hoc-test Scheffé revealed significant longer durations for the speakers with PD (S1 and S2) in this condition (see hatched bars in Figure 2 and column 3 in Table 1, $p<.05^*$).

Figure 2: Mean durations of the closure duration of /t/ for normal (n), loud (l) and sentence (s) condition



Comparison of conditions

A univariate ANOVA (dependent variable = duration, fixed factor = condition) showed significant temporal differences between all conditions for all speakers ($p<.05^*$)

For the controls C1 and C2 post-hoc analysis revealed longer durations for the loud condition compared to the normal condition. The speakers with PD (S1, S2) did not show an increase of closure duration during loud speech. As can be seen in Table 1, S2 even showed shorter durations in loud speech (109.5ms) than in normal speech (127ms).

Table 1: Post-hoc-test Scheffé for the closure duration of /t/, specified are the means (in ms) for loud (l), normal (n) and sentence (s) condition, p = .05

	mean		p	mean	p
speaker	l	n	l-n	s	n-s
C1	96.5	72.5	.000*	56.5	.000*
C2	142.0	71.0	.000*	60.0	.127
S1	114.5	114.4	1.000	85.5	.000*
S2	109.5	127.0	.160*	71.3	.000*

Significantly shorter closure durations were produced in the complex sentences compared to the normal condition in the simple sentences of all speakers, except C2 (see Table 1).

3.2. Number of Contacts

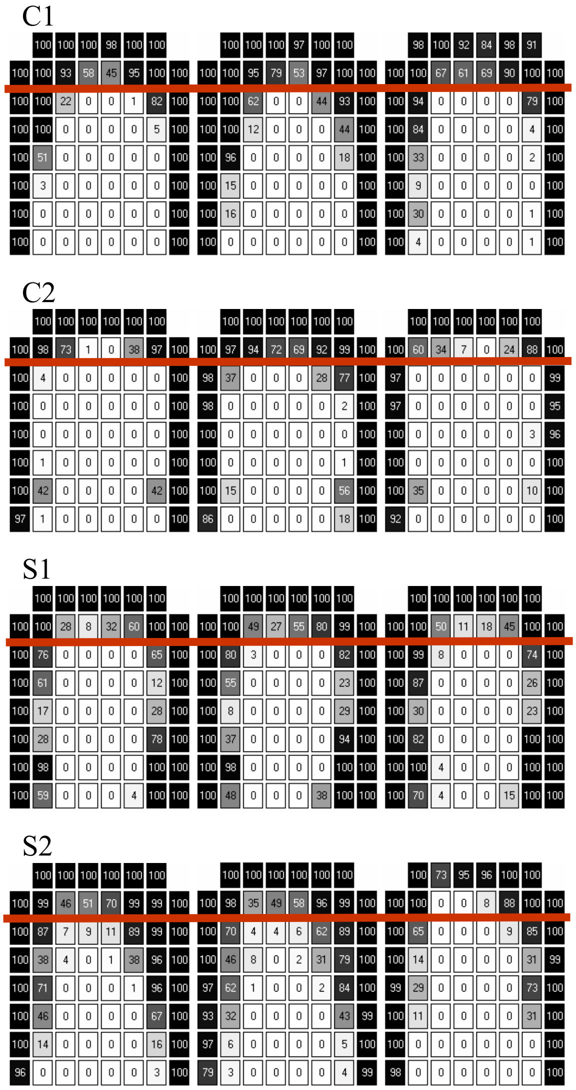
Figure 3 illustrates the mean percent alveolar contacts across 20 repetitions of initial /t/ ("take", "Tate"). Control C2 was the only speaker who produced loud speech with significantly more alveolar contacts (the Scheffé-test revealed 2.2 more contacts out of 14 contacts in the alveolar zone; $p<.05^*$). For the other speakers no significant effects of loud speech on the number of alveolar contacts were found by post-hoc analysis ($p>.05$).

Post-hoc analysis showed for C2 and S2 significantly fewer alveolar contacts in the complex sentences (C2= 1 and S2= 1.9 fewer contacts, $p<.05^*$) than in normal speech. As can be seen in the palate frames in Figure 3, C2 reduced the number of contacts in the second row of the alveolar zone while the speaker with PD (S2) produced some incomplete closures in the first row.

3.3. Phonetic confusions

In S1 the acoustic analysis frequently showed frication of the bilabial stop /p/ to [f] (see Table 2).

Figure 3: Mean percent contacts of the initial alveolar closure of /t/ across the 10 repetitions of take and Tate, from left to right: normal, loud, and sentence condition for all speakers



While frication of the stop in "pitch" was observed both in normal and loud condition in the simple sentences, it never occurred in the normal condition of the word "peach".

Interestingly, in the complex sentence production, in which the target words appeared at the end of the sentences, in no cases was the stop fricated.

Table 2: Absolute and relative frequency of frication of the stop /p/ of speaker S1

	condition		
word	normal	loud	sentence
peach	0	9 (90%)	0
pitch	10 (100%)	9 (90%)	0

4. DISCUSSION

The preliminary results of the study revealed for the PD speakers: 1. significantly longer closure durations of /t/ in the normal condition compared to the controls, 2. no significant temporal differences of the closure in the normal and loud condition (controls showed an increased duration), 3. no significant increase of alveolar tongue contacts in the loud condition.

Contrary to the findings of McAuliffe et al. [7] closure durations for /t/ were significantly longer in speakers with PD compared to the controls in the normal speech condition.

Temporal results confirm the findings of Kleinow et al. [5] who pointed out that loud voice does not effect temporal aspects in hypokinetic dysarthria. With regard to the control speakers our findings are contrary to those of Schulmann [9]. They increased the closure duration significantly compared to normal speech.

However, since speakers with PD neither modified the duration nor the number of tongue contacts in their loud speech, the question which parameter leads to the general listeners perception of an increasing intelligibility when PD speakers use loud speech is still unclear. Changes of tongue pressure are possible. We agree with McAuliffe et al. [6] that pressure-sensing palatographs (PPG) could be a suitable method in order to investigate tongue pressure for example in loud speech as well as other modifications of speech performance.

The fact that in our study the bilabial stop /p/ was frequently fricated in the loud condition can be discussed 1. as target undershoot as a result of shorter durations according to the hypothesis of Schulman [9], and 2. as a result of a lower jaw position. Mooshammer et al. [8] discuss different reasons for the motivation for lowering the jaw: one could be the increase of vocal effort. The absence of the frication in the more connected speech task can be seen as evidence that lowering the jaw only seems to be used in cases where increased vocal effort is required as in the LSVT.

Furthermore, following the hypothesis that the ability of the basal ganglia for self-initiated movements is impaired in Parkinson's disease [1], insufficient initiation of the coordination of the lips is also possible. In order to explore these questions further, jaw and lip movements and their effects on the other articulators should also be examined in further studies (e.g. by means of EMA or 3D motion analysis).

Further planned studies will include more speakers and will focus on the effects of places of articulation (tongue tip versus tongue back movements), on voicing and vowel lengths contrast and timing in clusters. Furthermore, intelligibility ratings will be used in order to determine how changes in speech style in hypokinetic dysarthria is perceived by independent listeners.

5. CONCLUSION

In order to address the question whether labial, and lingual-palatal articulatory movements are controlled in a different way in hypokinetic dysarthria, the phonetic investigation of different motor subsystems is necessary.

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