Bite Block Effects on Vowel Acoustic Contrast in Talkers with Amyotrophic Lateral Sclerosis and Parkinson's Disease

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INTRODUCTION

Talkers with dysarthria vary in their articulator-specific impairments. However, because the tongue and jaw are coupled and contribute as a compound movement to sound production, it can be difficult to identify each articulator's impact on the overall perceived speech decrements in talkers with dysarthria.

In talkers with ALS, tongue-specific articulatory impairment that result from degenerating tongue muscles may be in part obscured by compensatory jaw movements (Green et al., 2013; DePaul et al., 1988).

Minimal movements of the jaw, which can be frequently observed in talkers with Parkinson's disease (PD), may hinder adequate movements of the lip and tongue (Connor et al., 1989, Forrest et al., 1989).

Isolating the jaw and tongue by use of a bite block may provide important insights in single articulator capabilities in talkers with dysarthria (Netsell, 1975).

Although typical talkers are known to compensate fairly well for a fixed jaw, challenges to maintain similar speech acoustics have been noted for high vowels (Fowler & Turvey, 1980; Gay et al., 1981; Lane et al., 2005; Lindbloom et al., 1978). Thus, high vowels (i.e. /i/) may be particularly sensitive to detect articulator-specific impairments in dysarthria.

Hypothesized Bite Block Effects (see Figure 1)

Fig. 1

PD

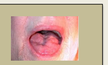
If the jaw is limiting the tongue, a lowered, fixed jaw will elicit

- ⬆ tongue displacements
- ⬆ acoustic contrast, F1 + F2 specification of /a/ + /i/, F2 slope

PD vs. Controls: Between-group differences expected to be more evident during jaw free speech than during jaw fixed speech.

Netsell, 1975

ALS



If the jaw is assisting the tongue, a lowered, fixed jaw will elicit

- ⬇ tongue displacements
- ⬇ acoustic contrast, F1 + F2 specification for /i/, F2 slope

ALS vs. Controls: Between-group differences expected to be more evident during jaw fixed speech than during jaw free speech.

DePaul & Brooks, 1993

In typical talkers only small differences may be evident between jaw free and jaw fixed speech driven by formant acoustics for /i/.

Fowler & Turvey, 1980

METHODS

Participants

ALS: n = 6, 2 females, 5 males, Mean age: 63 (52-68)
PD: n = 13, 5 females, 8 males, Mean age: 75 (57-88)
C: n = 21, 8 females, 13 males, Mean age: 69 (50-85)

Group	SIT Mean (%)	SIT Range (%)	Artic Rate Mean (syl/sec)	Artic Rate Range (syl/sec)
ALS	97.0%	96-100%	3.70	2.73-4.91
PD	95.6%	84-100%	4.20	2.46-5.47
Controls	99.0%	97-100%	4.37	3.49-5.61

Experimental Tasks

Five repetitions of the phrase "See a kite again" with an unconstrained jaw (free jaw) and while holding a 10 mm bite block (fixed jaw).

Speech Acoustic Analysis

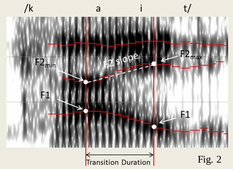


Fig. 2

Fig. 2: Onset and offset were determined by $F2_{min}$ and $F2_{max}$ of diphthong transition F1 and F2 values for each vowel of the diphthong were extracted using TF32.

Dependent Variables

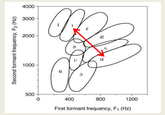


Fig. 4

Bite block effects on jaw position

Although kinematic data were not included as outcome measures in this study, the effect of the bite block on jaw position was examined for several talkers within each group. The extent to which the bite block impacted natural jaw position during /a/ and /i/ varied. In talkers with relatively small jaw movements (PD), the bite block perturbed the jaw position to a smaller extent than in talkers with relatively large jaw movements (ALS).

Fig. 3: Jaw movements during five repetitions of /ai/ during typical (black) and bite block speech (red) in a control talker.

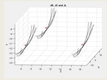


Fig. 3

- Acoustic contrast between /a/and /i/ in "kite" (Euclidean distance in F1-F2 planar vowel space)
- Vowel acoustic specification (F1 and F2 for /a/ and /i/ in /ai/)
- F2 transition duration (from $F2_{min}$ of /a/ to $F2_{max}$ of /i/)
- F2 slope (F2 transition extent over F2 transition duration)

RESULTS

Changes in Acoustic Contrast for /ai/ in "kite"

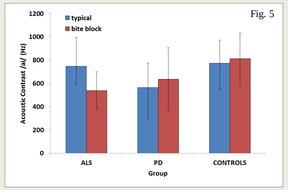


Fig. 5

Within-Group comparisons
Jaw free > jaw fixed in ALS (p = .046)
Trend: jaw free < jaw fixed in PD (p = .064)

Between-Group comparisons
Mann-Whitney *U* Test:
PD vs. C: jaw free (p = .010)
ALS vs. C: jaw fixed (p = .010)

Individual Responses to Fixed Jaw: Increase/Decrease in Acoustic Contrast (Fig. 6)

ALS: 83% of talkers decreased acoustic contrast by 100Hz or more
PD: 46% of talkers increased acoustic contrast by 100Hz or more
C: 33% of talkers increased and 19% decreased acoustic contrast by 100 Hz or more

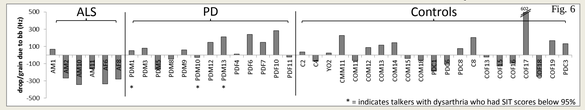


Fig. 6

Other Significant Findings

Relative to Controls, talkers with ALS demonstrated
- Higher F1 for /i/ during jaw fixed (p = .033)
- Lower F2 for /i/ during jaw fixed (p = .023)
- Shallower F2 slopes during jaw fixed (p = .031)

Relative to Controls, talkers with PD demonstrated
- Lower F2 for /i/ during jaw free (p = .024)
- Shallower F2 slope during jaw free (p = .019)
- A tendency of shallower F2 slope during jaw fixed (p = .079)
- A tendency of lower F2 for /i/ during jaw fixed (p = .053)

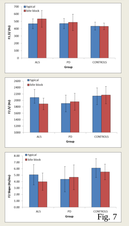


Fig. 7

Measure	ALS		PD		Controls	
	free	fixed	free	fixed	free	fixed
Duration (ms)	137.00	131.47	119.94	126.24	115.61	128.80
F1 /a/ (Hz)	773	733	713	742	773	801
F2 /a/(Hz)	1413	1397	1412	1378	1452	1455
F1 /i/ (Hz)	468	534	470	487	435	432
F2 /i/ (Hz)	2089	1891	1907	1956	2136	2165
F2 slope (Hz/ms)	5.06	3.98	4.36	4.66	6.09	5.49

DISCUSSION

Within-Group Comparisions

In **talkers with ALS** bite block effects support the hypothesis that the jaw is assisting the weakened tongue during speech production, particularly during high vowels, such as /i/. These findings are congruent with previous kinematic reports of increased jaw activity with disease progression (Green et al., 2013; Shellikeri et al., 2016). Findings also support anecdotal reports of speech function decline under a fixed jaw condition in talkers with ALS (DePaul et al., 1988). Interestingly, however, transition durations from $F2_{min}$ to $F2_{max}$ did not change and significant F2 slope changes were mainly driven by F2 changes of /i/ in this group.

In **talkers with PD** bite block effects did not reach significance; however, trends of increased acoustic contrast during bite block speech moved in the predicted direction. Formant values of /a/ and /i/ tended to change. The bite block size may have been insufficient to elicit significant increases in acoustic contrast. Findings support the notion that the jaw may be, at least in part, hindering the tongue's range of motion in talkers with PD. Alternatively, the bite block may serve as a cue to increase articulatory effort in talkers with PD.

Although bite block effects were non-significant for **controls**, speaker-specific responses varied a lot. Extremely large differences in acoustic contrast were likely due to changes in speech style (casual speech vs. clear speech). Further, in congruence with previous studies, incomplete compensation was observed in some talkers (e.g. Fowler & Turvey, 1980; Lindblom et al., 1978). In contrast to the ALS group, F2 slope changes were driven by increased F2 transition duration and not by formant values.

Between-Group Comparisons

As predicted, acoustic contrast was only significantly reduced during jaw free speech in PD and during jaw fixed speech in ALS relative to controls. Although the underlying mechanisms of bite block effects cannot be fully delineated in this study, findings of this study yield important clinical implications for the assessment and treatment of talkers with dysarthria.

Acknowledgements
This study was supported in part by NIH Grant RDC015075A and start-up funds from Wichita State University and Vanderbilt University Medical Center. We would like to thank all volunteers who participated in this study. Special thanks also to all members of the Speech Kinematics and Acoustics Lab, particularly Erin Corder, Sarah Reilly, Emma Cerre, Sean Hess, Jaclyn Fitzsimmons, Sophie Mouros, and Brett Myers for their assistance.