Articulatory Performance in Talkers with ALS: Comparisons of Clear and Slow Speech Effects

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INTRODUCTION

- Instructions to speak slower or as clearly as possible are widely used behavioral strategies to improve speech intelligibility during the early stages of ALS (e.g., Yorkston, Beukelman, & Ball, 2002).
- Clear speech → presumably targets reduced phonetic distinctiveness
  - In healthy talkers, clear speech elicits an increase in articulatory displacements, an increase in movement durations, and an increase in the relative contributions of the jaw to tongue and lip composite movements (Mefferd, in press; Tasko & Greilick 2010). Further, clear speech tends to decrease articulatory variability (Kuruvilla-Dugdale & Chuquilin, 2017).
- Slow speech → presumably targets articulatory speed constraints
  - In healthy talkers, slow speech is associated with an increase in articulatory displacement, increase in movement duration, an increase in the independent movements of tongue and lips from the jaw, and an increase in articulatory variability (e.g., Ackermann & Hertrich, 2000; Mefferd & Green, 2010; Mefferd, in press; Smith et al., 1995).
- Although slow speech has been investigated in talkers with ALS (e.g., Kuruvilla-Dugdale & Mefferd, 2017; Mefferd, Pattee, & Green, 2014; Turner, Tjaden, Weismer, 1994) direct comparisons of slow and clear speech effects on articulatory performance and motor control are lacking for this clinical population.
- It is unclear if and how clear and slow speech may affect articulatory performance and articulatory control differentially in talkers with ALS.
- Such insights may provide guidance in the selection of a speech treatment approach for talkers with ALS and may also provide a context to better understand the decline in speaking rate and articulatory changes during the early stages of speech deterioration.

STUDY AIM & HYPOTHESES

STUDY AIM: To determine the effects of clear and slow speech on articulatory performance and articulatory control in talkers with ALS and healthy controls.

- **HYPOTHESIS (TASK EFFECTS)**
  - PERFORMANCE: Movement durations will increase during clear and slow speech. Path length will show task-specific and articulator-specific changes. Inter-articulator coupling (jaw-tongue, jaw-lip) will increase during clear speech but decrease during slow speech for controls; however, no predictions were made for talkers with ALS.
  - MOTOR CONTROL: In controls, articulatory variability will decrease during clear speech but increase during slow speech. In talkers with ALS, articulatory variability will increase during slow speech; however, no specific predictions could be made for clear speech.
- **HYPOTHESIS (GROUP EFFECTS)**
  - PERFORMANCE: Groups will differ across all articulatory performance measures for habitual speech. No predictions were made for slow and clear speech.
  - MOTOR CONTROL: Talkers with ALS will have lower articulatory variability than controls during habitual speech; however, groups will not differ during slow speech. No specific predictions were made for clear speech.

METHODS

PARTICIPANTS

- 13 ALS participants (6M, 7F) with mild-moderate dysarthria
- 11 healthy controls (6M, 5F)

Group	Age (years)		Sentence Intelligibility (%)		Speaking Rate (WPM)	
	Mean	SD	Mean	SD	Mean	SD
ALS	62.7	7.9	91.3	8.7	133.8	39.8
Controls	64.5	11.3	98.8	1.10	182.8	24.3

DATA COLLECTION AND RECORDING

- 3D EMA (Wave, NDI Inc.; AG501, Carstens)
  - 3 tongue sensors
  - 1 lower lip & 2-3 jaw sensors
  - 1-3 head reference sensors
- Sampling rate = 400 Hz (Wave); 250 Hz (EMA)

Note: Tongue and lower lip movements were not decoupled from the jaw.

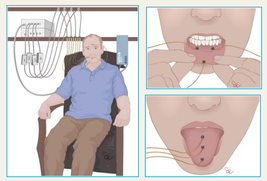


Figure 1. Experimental setup with Wave (NDI Inc.) and sensor placement

METHODS

EXPERIMENTAL TASKS

- Participants were asked to repeat the sentence 'Say that I owe you a yoyo today'
  - 10 X habitual rate and loudness
  - 10 X slow speech (i.e., half the habitual speaking rate)
  - 10 X clear speech (i.e., overenunciation)

ARTICULATORY PERFORMANCE

- **Articulatory path length –** the total distance a sensor moved from movement onset to offset.
- **Movement duration –** the time from movement onset to offset.
- **Inter-articulator decoupling –** ratio of average speed of the lower lip - jaw and tongue - jaw; a higher ratio indicates more decoupling between jaw and lip/tongue.

ARTICULATORY VARIABILITY

- Tongue motor control was indexed using the spatiotemporal variability index (STI)
- **STI** – consistency of articulatory movement patterns are across ten repeated productions of the same utterance.

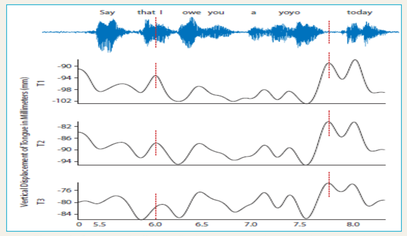


Figure 2. Onset and offset y-displacement markers used to parse the sentence 'I owe you a yoyo'

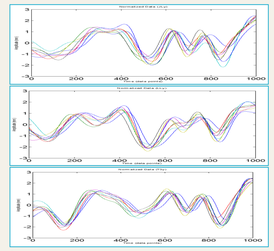
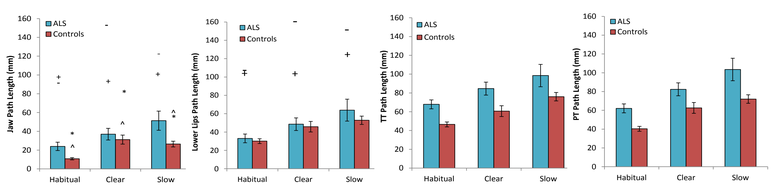


Figure 3. Amplitude and time-normalized vertical displacement trajectories of jaw, lower lip, and tongue back.

RESULTS

ARTICULATORY PERFORMANCE

1) Articulator Path Length



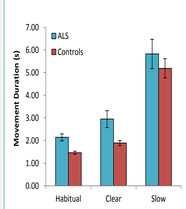
ALS Group n = 11; Control Group n = 7
Task Effect: $F(2, 32) = 9.16$ $p = .001$
Group Effect: non-sig.
Task x Group: $F(2, 32) = 1.66$ $p = .206$

ALS Group n = 11; Control Group n = 9
Task Effect: $F(2, 36) = 14.03$ $p = .001$
Group Effect: non-sig.
Task x Group Interaction: non-sig.

ALS Group n = 13; Control Group n = 9
Task Effect: $F(2, 40) = 9.70$ $p < .000$
Group Effect: $F(1, 20) = 1.82$ $p = .192$
Task x Group Interaction: non-sig.

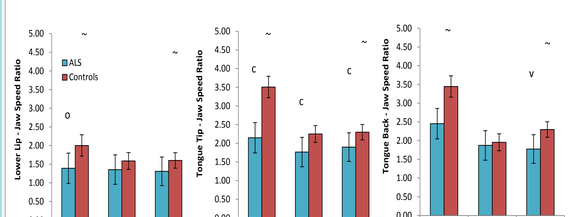
ALS Group n = 12; Control Group n = 9
Task Effect: $F(2, 38) = 19.49$ $p < .000$
Group Effect: $F(1, 19) = 2.91$ $p = .104$
Task x Group Interaction: non-sig.

2) Movement Duration



ALS: n = 13; Controls: n = 10
Task Effect: $F(2, 44) = 71.22$ $p < .000$
Group Effect: $F(1,22) = 4.17$ $p = .053$
Task x Group: non-sig.
Task: habitual < clear < slow
Group: Controls < ALS (habitual, clear)

3) Inter-Articulator Decoupling



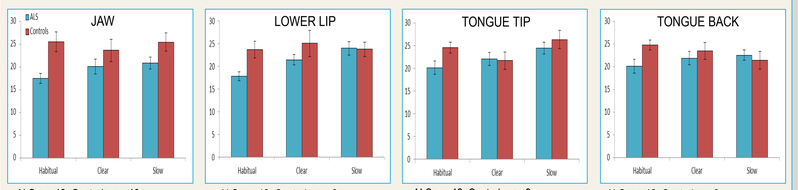
ALS: n = 12; Controls: n = 5
Task x Group: $F(2,30) = 4.99$ $p = .013$
Task: habitual > clear = slow (Controls)
Group: Controls > ALS (habitual)

ALS: n = 12; Controls: n = 6
Task x Group: $F(2,32) = 2.86$ $p = .072$
Task: habitual > clear = slow (Controls)
Group: Controls > ALS (habitual)

ALS: n = 11; Controls: n = 6
Task x Group: $F(2,30) = 4.11$ $p = .027$
Task: habitual > clear = slow (Controls)
Group: Controls > ALS (habitual)

RESULTS

ARTICULATORY CONTROL



ALS n = 13; Controls n = 10
Task Effect: non-sig.
Group Effect: $F(1, 21) = 6.9$ $p = .016$
Task x Group: $F(2, 42) = 1.65$ $p = .21$
Habitual < Slow = Clear (ALS)
ALS < Controls (habitual, slow)

ALS n = 13; Controls n = 9
Task Effect: non-sig.
Group Effect: non-sig.
Task x Group: $F(2, 40) = 2.46$ $p = .10$
Habitual < Slow = Clear (ALS)
ALS < Controls (habitual)

ALS n = 13; Controls n = 9
Task Effect: $F(2, 40) = 4.58$ $p = .016$
Group Effect: non-sig.
Task x Group: $F(2,40) = 1.48$ $p = .17$
Habitual < Slow = Clear (ALS)
Clear < Habitual = Slow (Controls)
ALS < Controls (habitual)

ALS n = 12; Control n = 9
Task Effect: non-sig.
Group Effect: non-sig.
Task x Group: $F(2, 38) = 3.17$ $p = .05$
Habitual > slow (Controls)
ALS < Controls (habitual)

DISCUSSION & CONCLUSIONS

ARTICULATORY PERFORMANCE

- As predicted, movement durations increased for both groups. Compared to controls, talkers with ALS had longer durations for habitual and clear speech, but not for slow speech.
- Trends of task x group interactions can be observed for jaw path length suggesting that talkers with ALS tend to move the jaw more than controls during habitual speech and slow speech; however, not during clear speech.
  - This is congruent with other reports of abnormally large jaw movements in talkers with ALS (Shellikeri et al., 2016; Rong et al., 2016; Yunusova et al., 2013). However, it remains unclear if these exaggerated jaw movements indicate a compensatory strategy (i.e. clear speech) or a pathology.
- Findings suggest that larger jaw movements in talkers with ALS result in greater inter-articulatory coupling (jaw-lip, jaw-tongue) during habitual speech. Trends of larger tongue composite movement during habitual, clear, and loud speech in talkers with ALS relative to controls are also likely jaw-driven.
  - May explain small vowel space areas during habitual and slow speech in talkers with ALS in the presence of large tongue composite movements (Mefferd, 2016, Turner, Tjaden & Weismer, 1995).

ARTICULATORY CONTROL

- Significantly lower articulatory variability in talkers with ALS compared to controls during habitual speech replicate previous findings for jaw and lips (Mefferd et al., 2014).
  - Large jaw movements during habitual speech in talkers with ALS may indicate that the jaw is used as an active articulator (vs. stabilizing role) with more goal-directed movements compared to controls, which may explain low jaw variability during habitual speech in ALS.
  - Increased jaw-lip and jaw-tongue coupling in talkers with ALS may explain the lower variability of lower lip and tongue in talkers with ALS for habitual speech.
- Jaw variability increased from habitual to clear and slow speech in talkers with ALS. Increasing the already large jaw movements may tax the speech motor system for talkers with ALS. In addition, durational changes may contribute to increased jaw variability (e.g., Mefferd et al., 2014; Smith et al., 1995).

CLINICAL IMPLICATIONS

- Because of the high degree of inter-articulator coupling (jaw-lip, jaw-tongue) that were observed in talkers with ALS, treatments may need to focus on more independent tongue and lip movement to improve phonetic distinctiveness and ultimately intelligibility in these talkers. Based on findings of this study, neither slow or clear speech appear to achieve this.
- Talkers with ALS may already implement an articulatory strategy that balances articulatory performance and control while also managing fatigue.

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