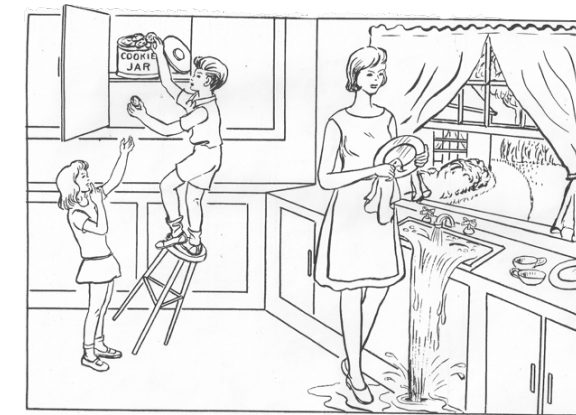


Introduction

- Amyotrophic Lateral Sclerosis (ALS) is a multi-system neurodegenerative disorder with motor and cognitive-linguistic deficits.
- Speech studies in ALS report slower speaking rate, longer pause durations, and more pause events compared to healthy speech. However, within-speaker longitudinal changes in speech are not well-characterized, and differences in motor versus cognitive effects on speech have rarely been examined in the same group of speakers.
- In this study, we analyze longitudinal changes of acoustic speech features from narrative speech samples using objective, reproducible, fully automated methods and assess their associations with clinical measures of bulbar motor, respiratory, and cognitive dysfunction.

Methods

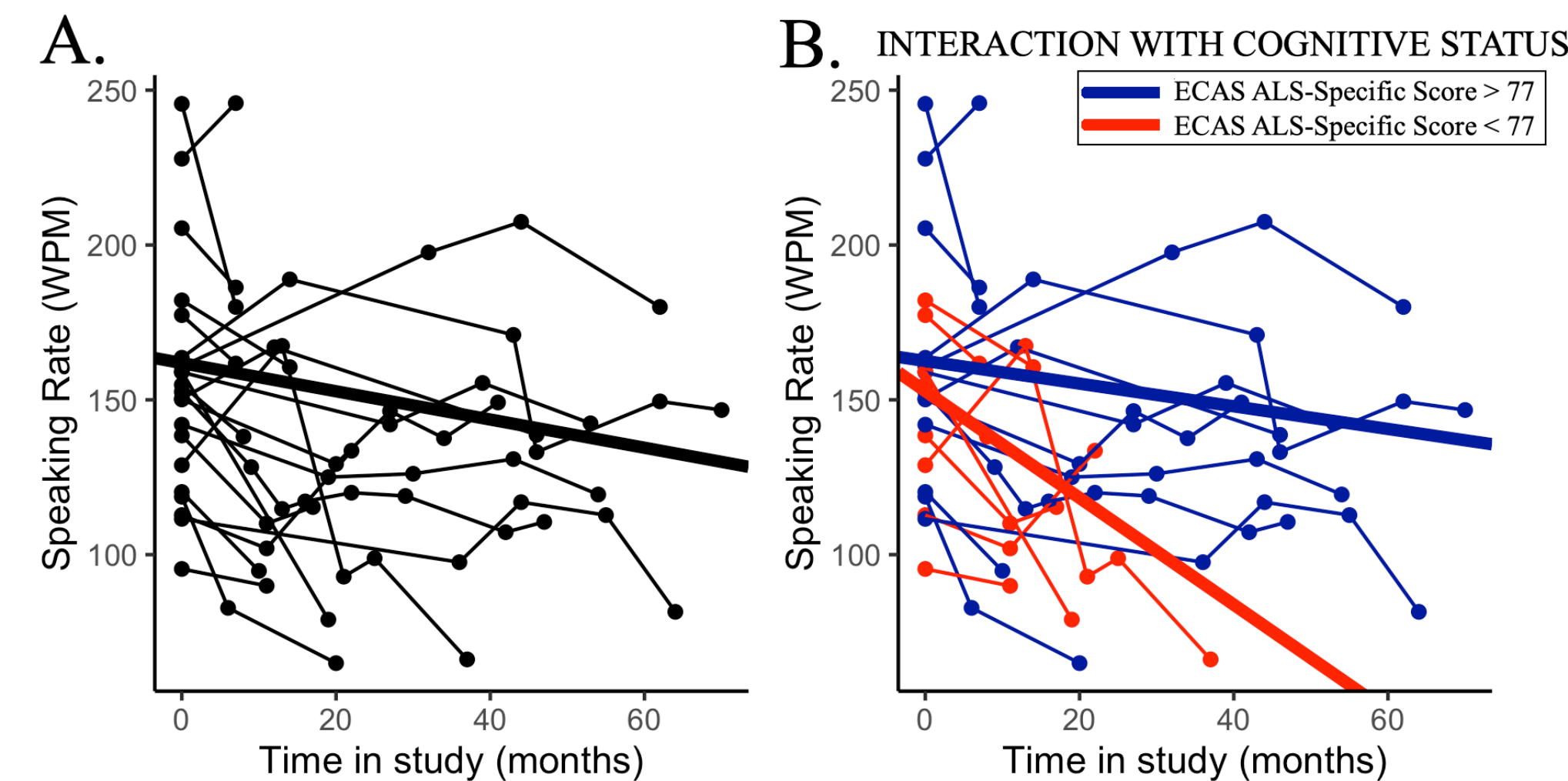
- 21 speakers with ALS (7 females, \bar{x} age at baseline: 62 y \pm 10.8; 1 bulbar-onset, 1 ALS-FTD onset, 18 spinal-onset, 1 unknown)
- ~1 min. picture descriptions in natural field conditions
- Up to 9 speech samples per speaker for up to 6 years (\bar{x} follow-up time = 30 months \pm 22; median inter-sample interval = 11 months; median samples/speaker = 3)
- We collected bulbar motor, respiratory, and cognitive-linguistic clinical metrics within 3 months of speech sample.



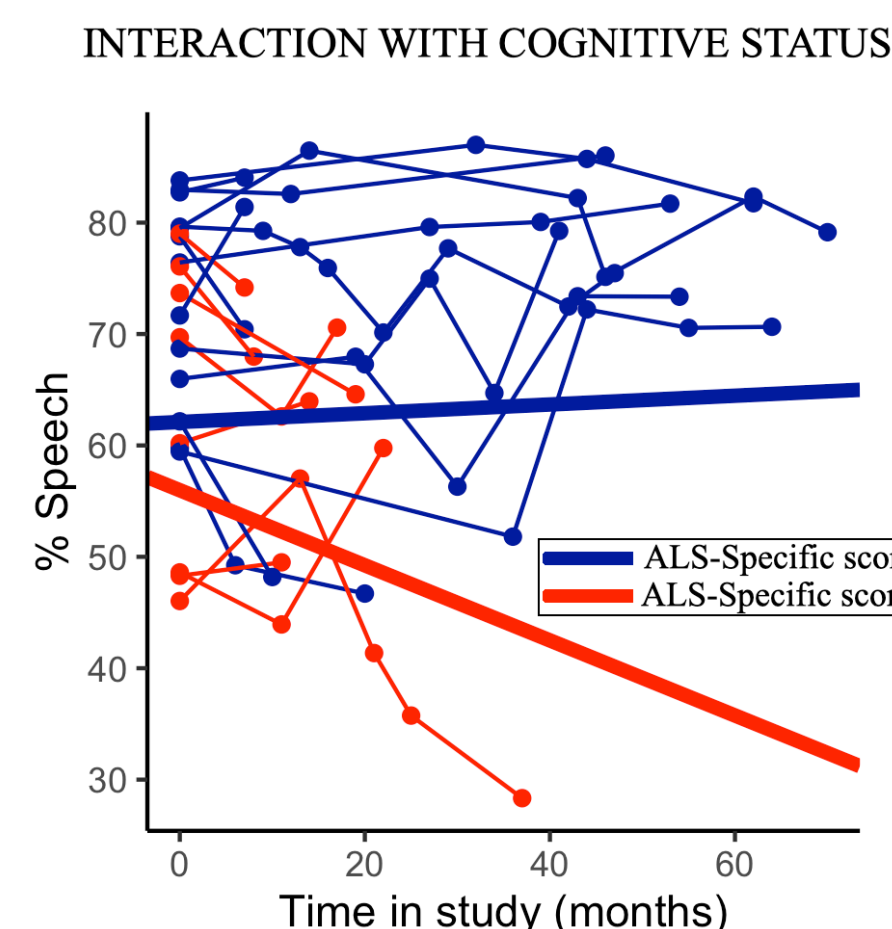
Clinical Measure	Baseline session	Last session	p-value
ECAS ALS-Specific score	83.889 (10.846)	86.438 (8.342)	0.06
Penn UMN Bulbar score	0.762 (1.136)	0.952 (1.161)	0.98
%FVC	87.526 (26.521)	78.190 (34.104)	0.042

- Speech samples were transcribed and automatically segmented into audible speech and silent pauses. Total spoken words were summed, and features including mean speech/pause segment durations, % time speaking, pause rate, and speaking rate were extracted.
- Longitudinal change of each feature of speech over time was analyzed using linear mixed-effect models (LMEs) with random intercept. Speakers were stratified into impaired or intact groups for each clinical metric based on established cut-points; LMEs tested interaction of time x clinical grouping. We covaried for disease duration at baseline.

Results

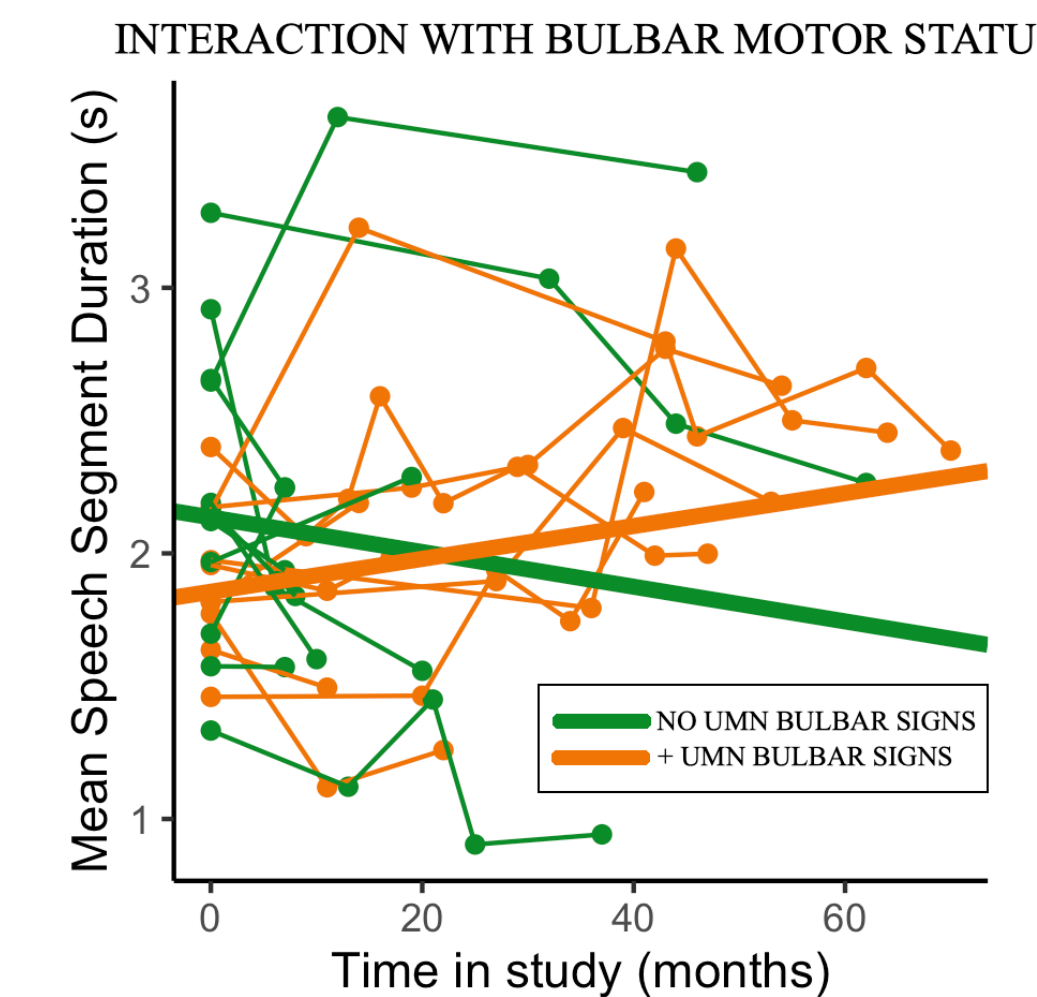


- **A.** Speaking rate declined on average by 5.5 WPM per year ($p = .0019$).
- **B.** Rates declined differentially based on cognitive status: speakers that scored below cut-point during disease course declined significantly faster than cognitively intact speakers (21 vs. 4.4 WPM per year, $p = .001$, $p = .028$). Bulbar scores did not differ between the two groups.
- Speaking rate over time did not interact with bulbar or FVC status.



- Percentage of time spent speaking (not pausing) changed differentially over time based on cognitive status ($p = .03$): speakers below cut-point during disease course decreased proportion of speech time by 4% per year ($p = .03$), while those with intact cognition maintained % speech over time ($p = .43$).
- Longitudinal change in %speech interacted with bulbar status (not shown): neither group slopes over time were statistically significant.
- %speech did not interact with FVC status.

Results cont.



- Mean speech segment durations changed differentially depending on bulbar status ($p = .03$): speakers with UMN signs during disease course lengthened speech segments by ~74 ms per year ($p = .06$), while those without any UMN bulbar signs maintained speech durations over time ($p = .19$). FVC or ECAS scores did not differ between the two groups.
- Change in speech durations interacted with FVC status (not shown): neither group slopes were significant.
- Speech durations did not interact with cognitive status.

Conclusions

- Measures of speech timing and duration are differentially impacted by bulbar motor, respiratory, and cognitive dysfunction over disease course in ALS.
- Cognitive impairments result in a faster decline in speaking rate explained by a greater proportion of time spent pausing.
- Bulbar UMN disease results in longer mean speech segment durations over time; reduced FVC results in shorter speech segments.
- These findings support the role of automated acoustic analysis in characterizing speech longitudinally in ALS.

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