

Automated Digital Verbal Fluency as a Marker of Cognitive Function in Amyotrophic Lateral Sclerosis

Leslie Ing^{1 2}, Bahman Mirheidari³, Emily Mayberry², Sharon Abrahams⁴, Lise Sproson⁵, Clare Bartlett⁶, Swapnil Gadgil⁶, Rebecca Bright⁶, Alys Wyn Griffiths¹, Esther Hobson¹, Heidi Christensen^{3*}, Christopher McDermott^{1 2*}, Daniel Blackburn^{1 2*}

¹ SiTraN, University of Sheffield · ² Sheffield Teaching Hospitals NHS Foundation Trust · ³ School of Computer Science, University of Sheffield · ⁴ Psychology & Language Sciences, University of Edinburgh · ⁵ NIHR HRC in Long Term Conditions (Devices for Dignity), STH NHS FT · ⁶ Therapy Box, London · ^{*}Joint senior authors



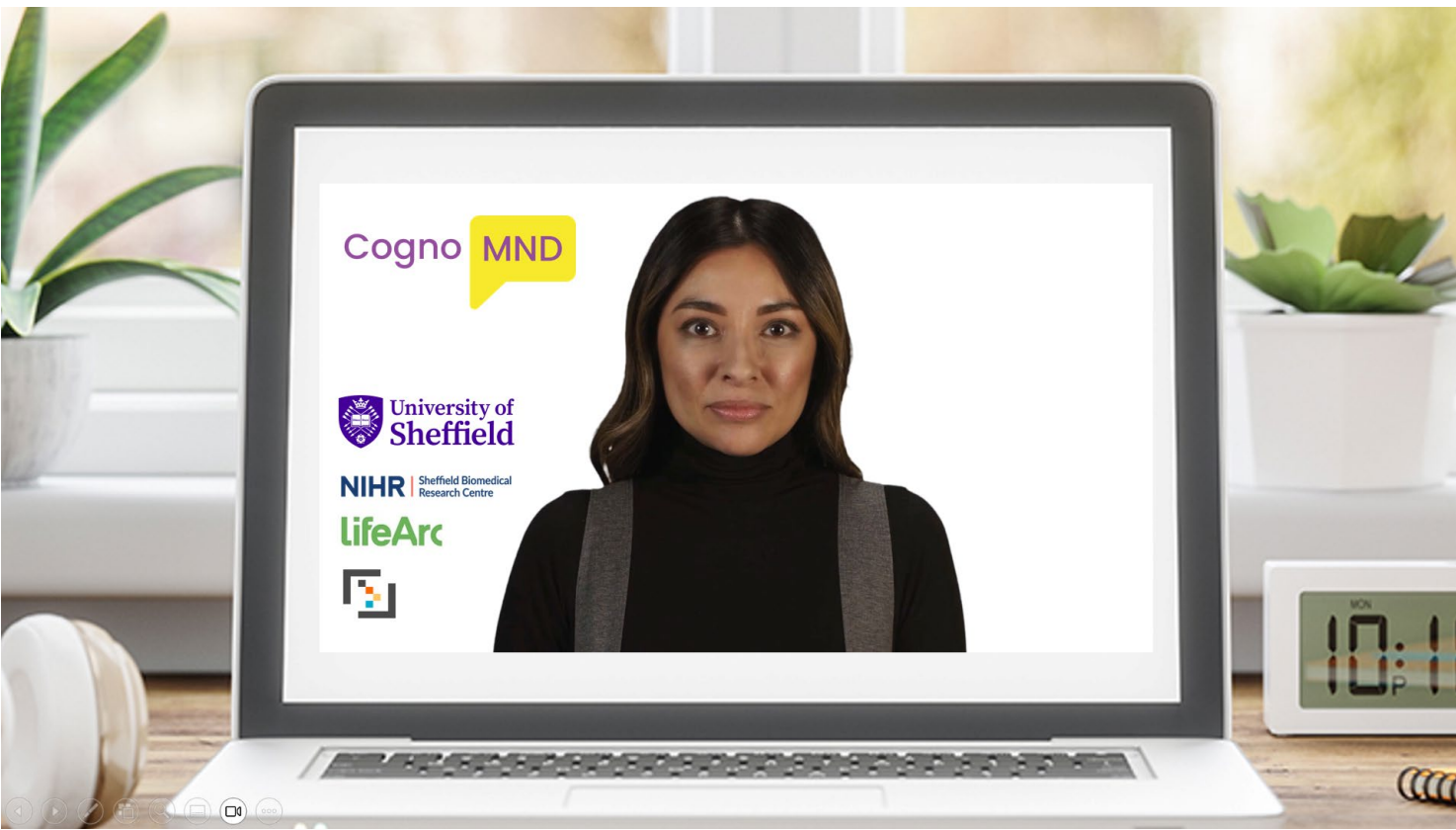
BACKGROUND

- Amyotrophic lateral sclerosis (ALS) is an aggressive, terminal neurodegenerative disease causing progressive muscle weakness.
- ALS lies on a clinicopathological continuum with frontotemporal dementia (FTD): up to 50% of people with ALS develop cognitive impairment, and 15% develop FTD.
- Phonemic verbal fluency is an early, sensitive marker of cognitive impairment in ALS, but conventional scoring is confounded by dysarthria which reduces word output independently of cognition.
- The Edinburgh Cognitive and Behavioural ALS Screen (ECAS) addresses this with its Verbal Fluency Index (VFI), which estimates thinking time per word independent of physical disability.
- However, the VFI requires an examiner-administered readback, limiting self-administration and scalability for remote cognitive screening.

AIM

To evaluate whether automated analysis of a digitally-administered verbal fluency task can measure cognitive function in ALS, independently of motor-speech impairment.

PLATFORM



- Self-administered at home through a virtual agent on the CognoMND™ remote-assessment platform.
- Short spoken tasks are recorded and analysed automatically; correct words and timing are identified without an examiner present.

STUDY COHORT

42 people with ALS; phonemic verbal fluency (P and S, 60 s); ECAS as ground truth. By ECAS, 30 cognitively normal (ALS-CN), 12 impaired (ALS-CI).

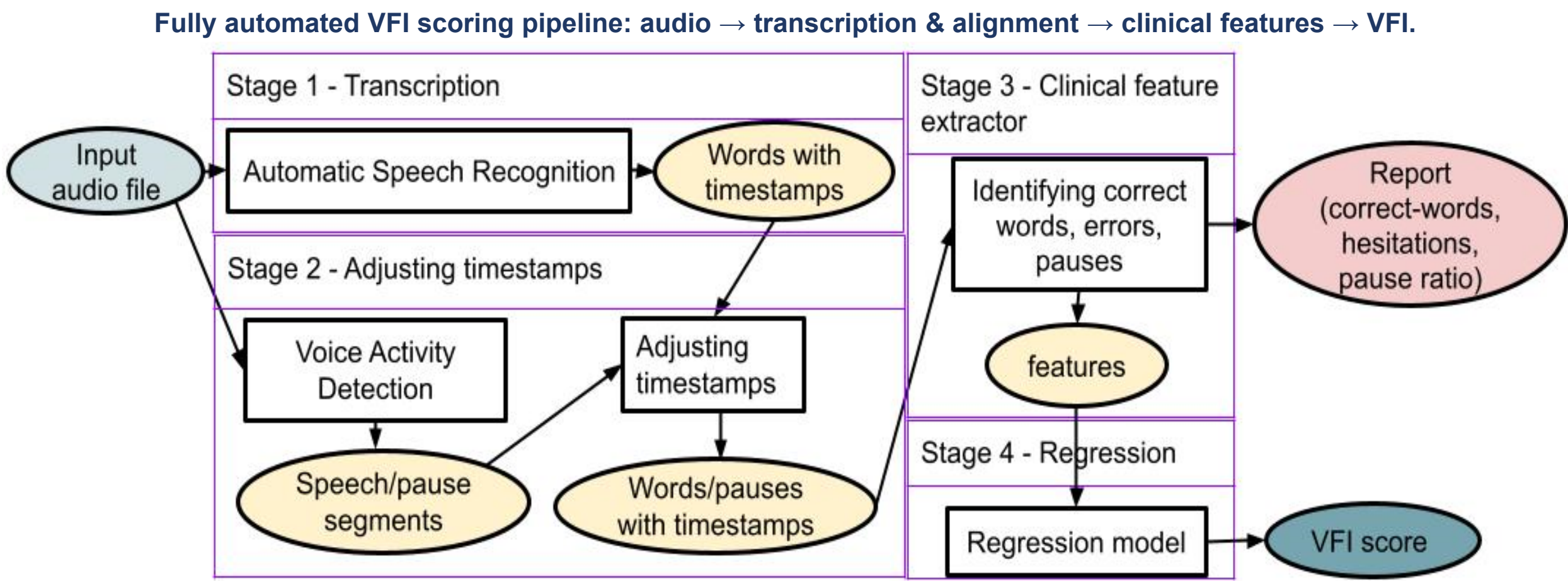
Characteristic	ALS-CN (30)	ALS-CI (12)	All (42)
Age, years	64.3 ± 14.3	63.6 ± 8.7	64.1 ± 13.0
Education, years	13.4 ± 3.1	11.8 ± 1.9	13.0 ± 2.9
Symptom duration, mo	43.2 (29–69)	23.5 (14–39)	34.3 (23–68)
ALSFRS-R speech	3.3 ± 0.9	3.2 ± 1.1	3.2 ± 1.0
Dysarthria, n (%)	15 (50%)	5 (42%)	20 (48%)
C9orf72	0	2	2
ECAS total	117.6 ± 6.8	92.2 ± 12.6	110.3 ± 14.5

CLINICAL SIGNIFICANCE

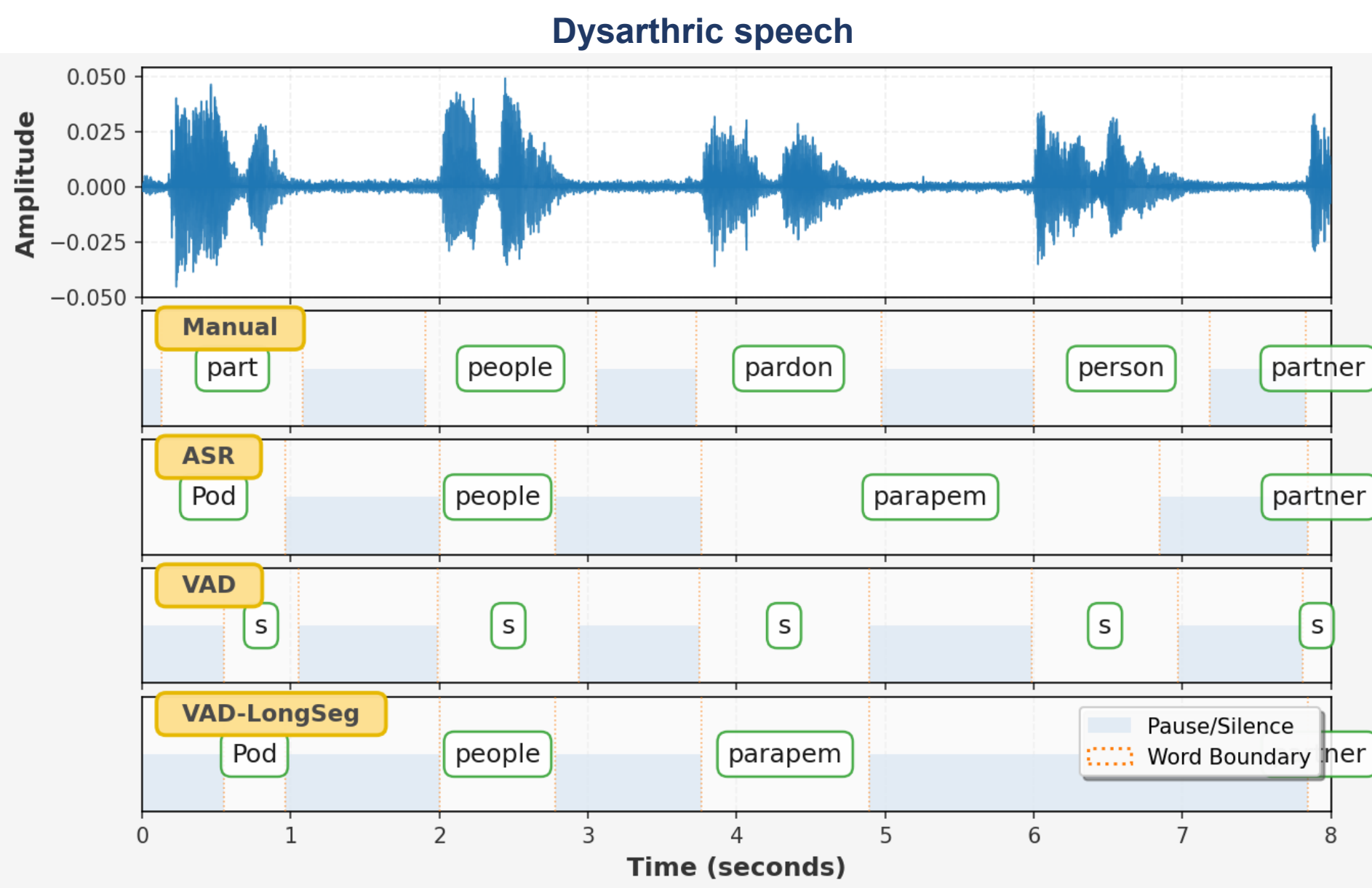
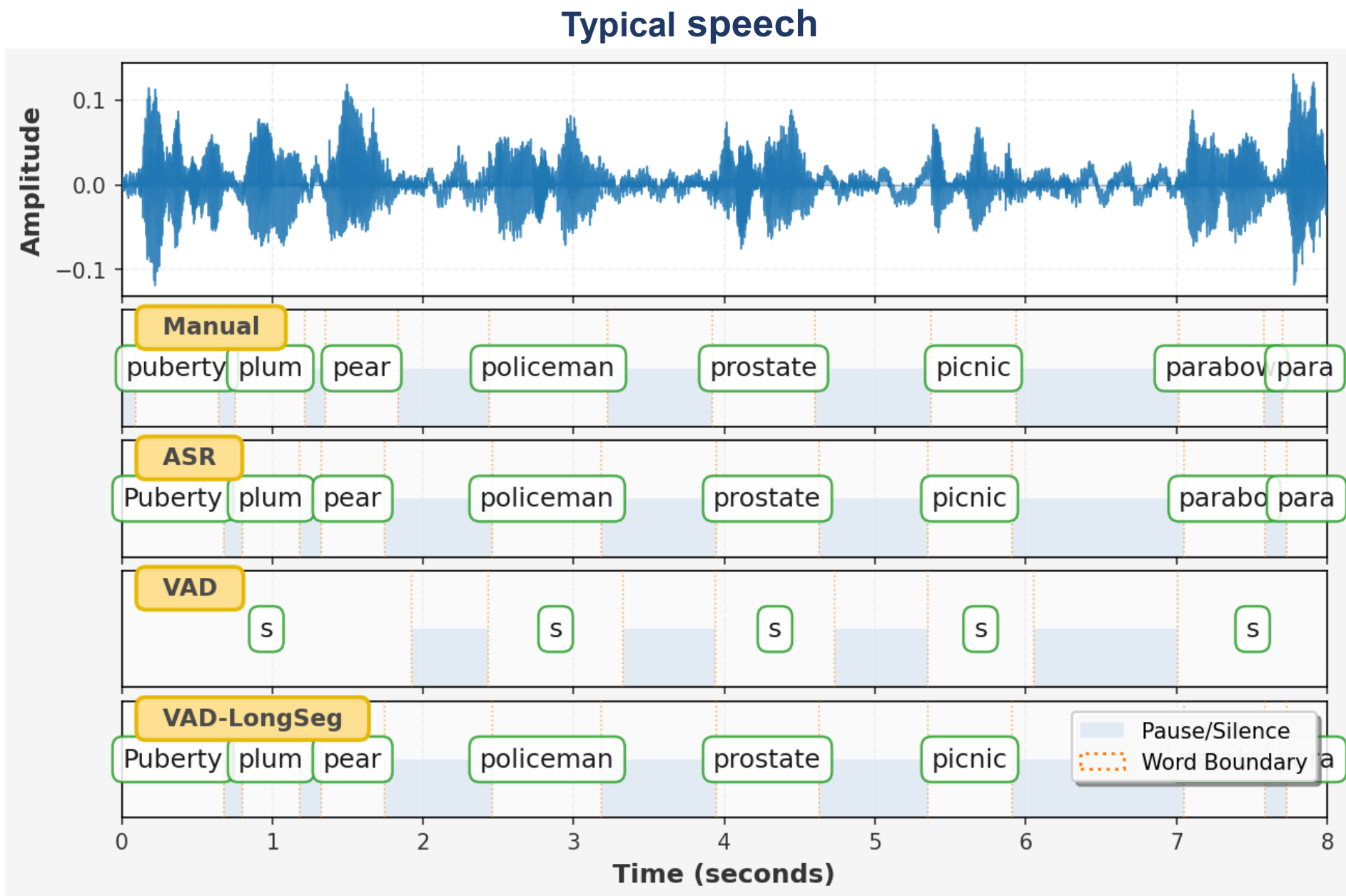
Automated, clinician-free verbal-fluency assessment could support scalable, remote cognitive screening in ALS.

METHODS: AUTOMATED PIPELINE

Phonemic fluency recordings (P- and S-words) are transcribed by ASR, time-aligned with voice-activity detection and segment adjustment, and reduced to interpretable timing and pause features. A regularised model (LASSO) then estimates the Verbal Fluency Index.



Manual alignment vs ASR, raw VAD and adjustment strategies: typical speech (above) and dysarthric speech (below) Longest-segment selection recovers word/pause timing close to manual reference, even in dysarthric speech.



ASR word error (%)

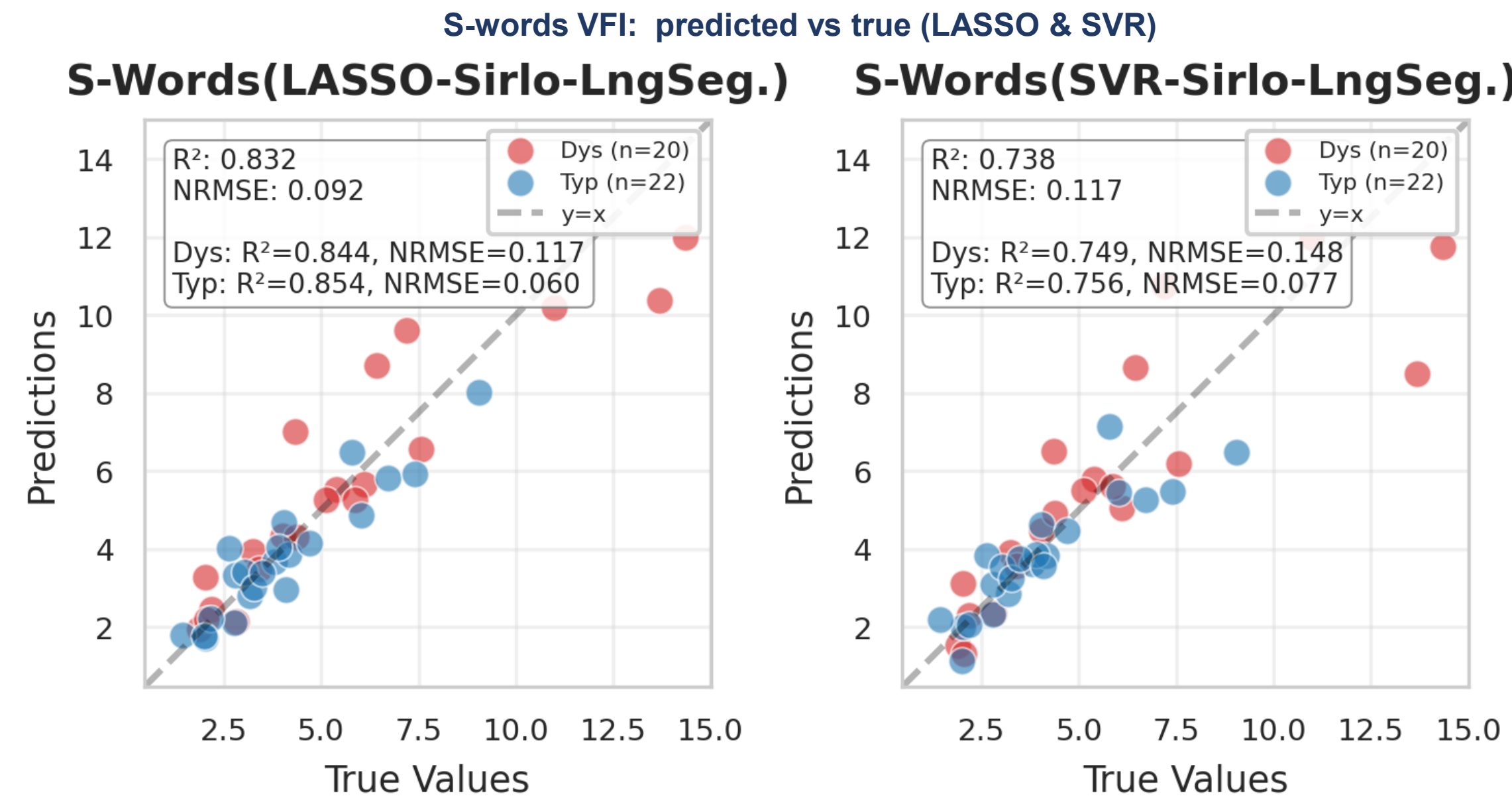
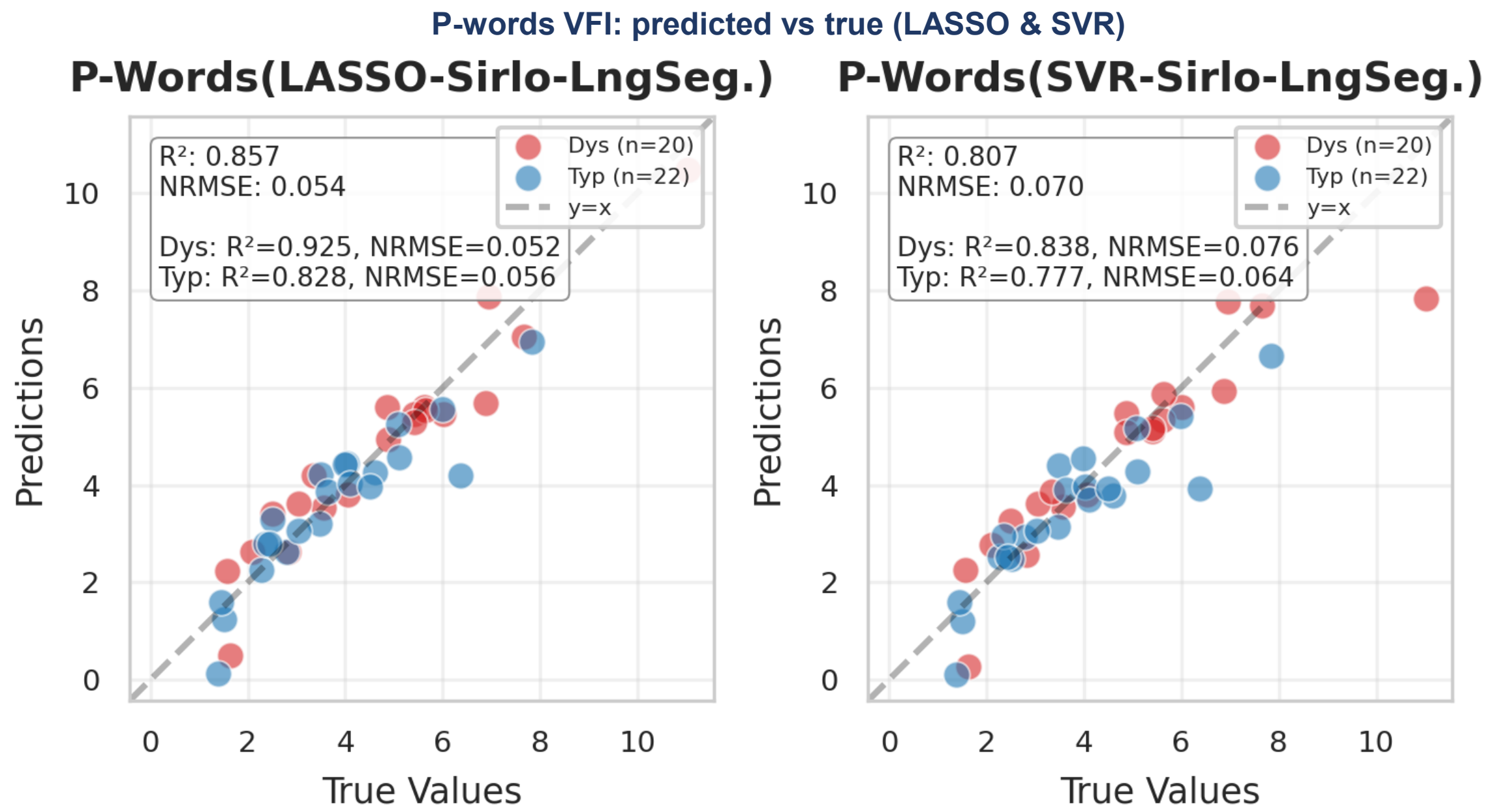
Task	Dys	Typ	All
P-words	28.8	17.1	21.5
P – no fill.	22.2	8.1	14.0
S-words	37.1	12.8	23.0
S – no fill.	24.0	15.0	18.7

Segmentation error (%)

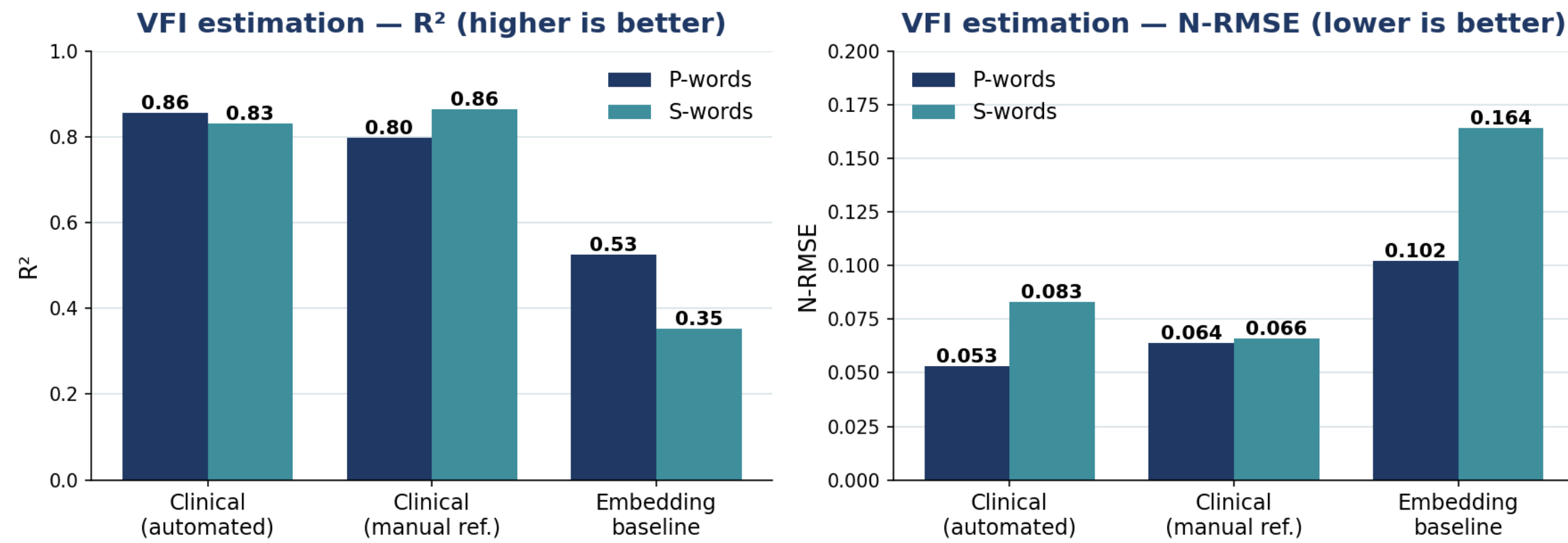
VAD method	P	S
Silero (sel.)	6.9	11.8
CNN-BILSTM	11.0	13.5
FSMN	15.6	20.7

RESULTS

Automated VFI predictions closely match clinician scored VFI: P-words R^2 0.86 · N-RMSE 0.05 S-words R^2 0.83 · N-RMSE 0.08



VFI accuracy by feature extraction approach - R^2 and N-RMSE by task



All models and feature sets (5-fold CV, mean ± SD)

Task	Best model / feature set	R^2 (±SD)	N-RMSE
P	Clinical - automated (LASSO)	0.86 ± 0.11	0.05 ± 0.02
P	Clinical - manual ref. (LASSO)	0.80 ± 0.13	0.06 ± 0.02
P	Embedding baseline (HuBERT)	0.53 ± 0.19	0.10 ± 0.01
S	Clinical - automated (LASSO)	0.83 ± 0.04	0.08 ± 0.04
S	Clinical - manual ref. (LASSO)	0.87 ± 0.11	0.07 ± 0.03
S	Embedding baseline (HuBERT)	0.35 ± 0.34	0.16 ± 0.01

Generalisation across dysarthria

Estimation errors are broadly similar for dysarthric and typical speakers. The clearest penalty is in S-words:

S-word N-RMSE	Typical	Dysarthric
lower = better	0.060	0.117

Attributed to higher ASR word error and segmentation inaccuracy in dysarthric S-words; P-word errors were similar across groups. Bounded by this cohort's dysarthria range (20/42).

CONCLUSIONS

- In this feasibility cohort (n = 42), a digital verbal-fluency task scored by a fully automated pipeline, with no clinician input, was able to reproduce the clinician-derived Verbal Fluency Index, an established ECAS cognitive index (R^2 0.86, N-RMSE 0.05).
- Together these findings support remote, self-administered verbal-fluency assessment in ALS, and point toward scalable, at-home cognitive screening more broadly.
- Next: larger dysarthria-enriched cohorts, validation against the clinical scoring bands, and additional speech tasks.

CognoMND

Acknowledgements: Funded by LifeArc and supported by the NIHR Sheffield BRC and NIHR Devices for Dignity. Views are the authors' and not necessarily those of the NIHR, LifeArc, or the Department of Health and Social Care.