

Automated Analysis of a Mobile-collected Motor Speech Task for Subtle-to-mild Cognitive Impairment in Alzheimer’s risk-enriched cohorts



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KEY FINDINGS

1. *TalkTracker* mobile app enables repeated, self-administered digital speech assessment at-home.
2. Subtle-to-mild impairment shows slower DDK syllable rate, suggesting articulatory movement slowing, complementary to the commonly recognized high-level slowing of word retrieval.
3. Higher intra-individual variability highlights the importance of repeated sampling in subtle decline.

WHY DDK?

- ✓ A widely used speech-motor task across 27 neurological and communication disorders, including cognitive impairments.
- ✓ Phonoarticulatory DDK (puh–tuh–kuh) uses speech sounds that are acquired early in typical development and highly prevalent across the world’s languages.
- ✓ Indexes core speech-motor control features (speed, rhythm, accuracy, coordination) relevant to lips, tongue, jaw, etc., but is understudied in early AD risk.
- ✓ Brief, low burden, easy to implement, and well suited for automated analysis and remote, self-administered mobile testing.

BACKGROUND

More than 55 million people worldwide currently live with Alzheimer’s disease (AD) and related dementias (ADRD), a number projected to reach 153 million by 2050. Current AD biomarkers, such as PET or CSF, remain invasive and costly. While blood-based biomarkers show promise, their utility for large-scale screening and monitoring, especially for cognitively unimpaired individuals at elevated AD risk, remains unestablished. *There is a critical need for tools that are accessible, low-burden, and applicable in community settings and support repeated deployment for long-term monitoring.*

To advance this direction, our lab developed *TalkTracker*, a tablet-based application that enables timely, at-home speech sampling to capture speech-derived digital biomarkers potentially sensitive to subtle cognitive–communicative changes associated with AD.

This study examined the sensitivity and feasibility of mobile diadochokinetic (DDK) tasks to detect subtle cognitive decline in AD risk-enriched cohorts.

REMOTELY ADMINISTERED PROCEDURES

Consent & Training:

- Informed consent obtained via in-person or virtual visits.
- iPads provided to ensure equitable access to the *TalkTracker* app.
- Guided training on iPad and *TalkTracker* app use.
- iPad available for both study and personal use throughout the 3-year study.
- Option to keep iPad upon study completion.

At-home Speech Collection:

- Speech recordings collected remotely via the *TalkTracker* app and uploaded to secure study servers.
- Weekly sessions (~20-30 min) for 8 consecutive weeks, repeated annually over 3 years.
- Usability questionnaire completed at the end of each 8-week cycle.
- Year-1 data collection nearing completion.

DDK TASK & AUTOMATIC ANALYSIS

Administration was fully self-guided, with on-screen verbal and audio instructions and embedded audio recordings via *TalkTracker*.

DDK Task:
trisyllabic “puh–tuh–kuh” repetition

Practice trial: produce sounds as quickly and clearly as possible

Press **Start Recording** and repeat puh–tuh–kuh for timed recording (7 sec)

Automatic Analysis via custom MATLAB:

- 1) Exclude the first and last 1 second of each recording;
- 2) Extract Hilbert Envelope;
- 3) Apply 20 ms- moving average for smoothing;
- 4) Normalize amplitude
- 5) “findpeaks” function: minimum peak height = 0.08; minimum peak prominence = 0.01; minimum peak distance = 117 ms.
- 6) Syllable duration was quantified as mean interval between successive syllable peaks.

OUTCOME MEASURES:

- **DDK Syllable Rate:** speech speed (syllable/sec).
- **DDK Rhythmicity:** within-recording variability (SD of syllable durations within each DDK recordings).
- **Intra-individual Variability:** across-session stability of syllable rate, indexed by
 - absolute SD of syllable rate across sessions per person
 - coefficient of variation (CV = SD/mean syllable rate).

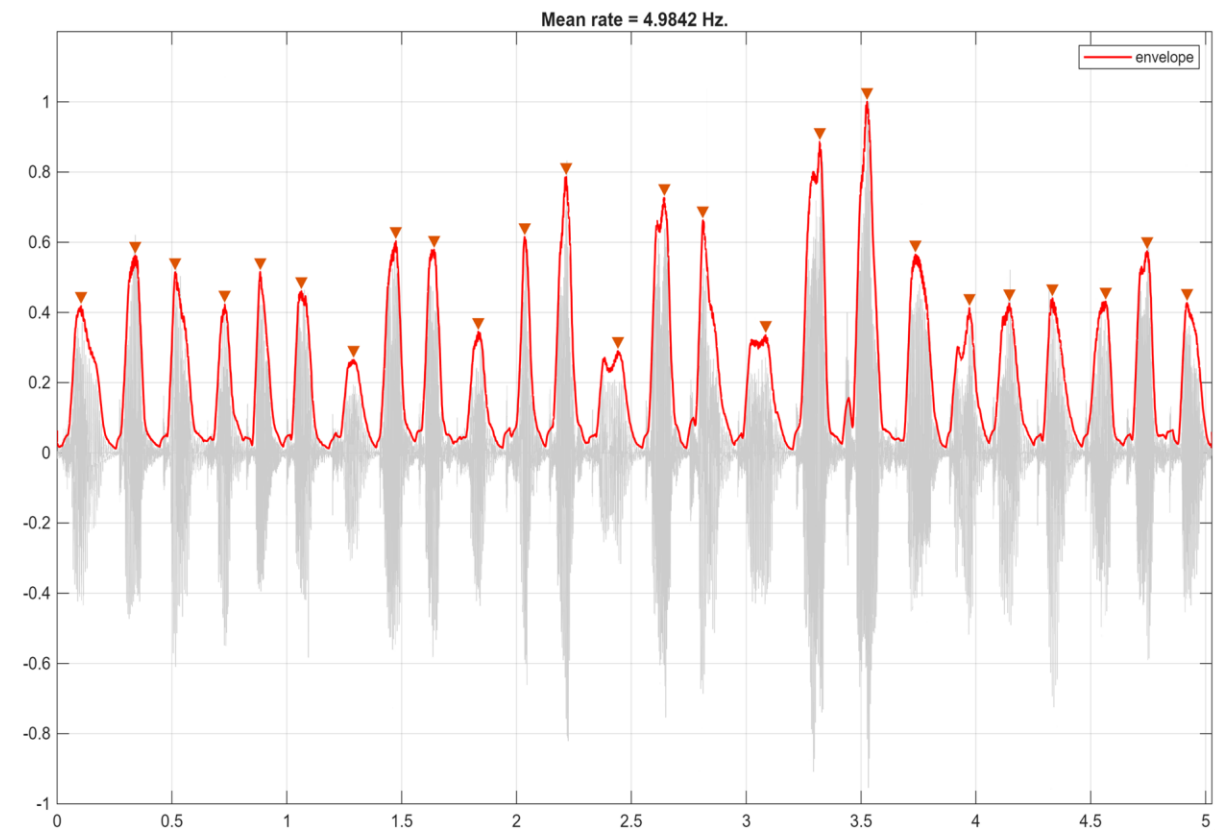


Figure 1. Example of automated syllable-peak detection from a DDK recording. This illustrates that the automated procedure accurately identifies individual DDK syllable and highlights the pseudo-rhythmic structure of alternating syllables during rapid DDK. The raw audio signal from a participant’s puh–tuh–kuh production is shown in gray, overlaid with the smoothed amplitude envelope in red. Orange ▽ indicates detected syllable peaks.

RESULTS

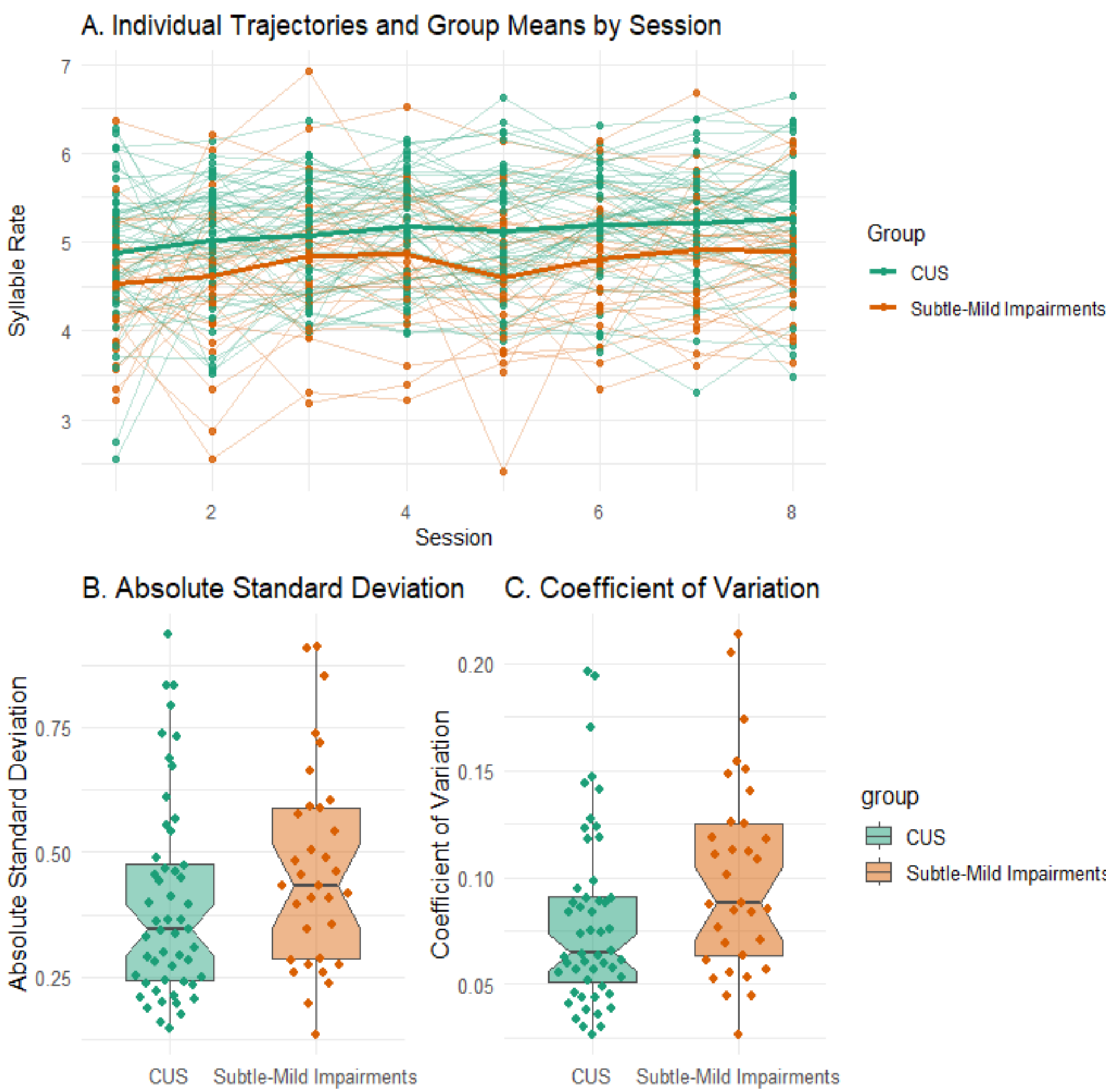


Figure 2. Cognitive group differences in home-collected DDK performance over 7-8 consecutive weeks. Individuals with subtle-to-mild cognitive impairment produced slower and more variable syllable rates than CUS adults.

- a. Linear mixed-effects models showed a significant main effect of cognitive group ($p = 0.011$) on syllable rate, adjusting for age, plasma p-tau217, sex, and education.
- b. DDK rate increased across sessions (e.g., session 8 > session 1; $p < 0.01$), indicating a robust familiarization or motor learning effect with repeated practice.
- c. No group $\times$ session interaction ($p > 0.05$), indicating comparable practice effects for both groups.
- d. Both the absolute SD ($p = 0.038$) and CV ($p = 0.010$) were higher in the subtle-to-mild impairment group, indicating greater intra-individual variability compared to CUS.
- e. No significant group effects were observed for rhythmicity.

DISCUSSION

1. Rather than “finding” words, “repeating” nonsense syllables minimizes semantic and episodic memory demand. Our DDK results raise the possibility that early cognitive changes related to AD may involve subtle slowing in articulatory-motor implementation in addition to commonly emphasized semantic memory deficits.
2. Repeated sampling better capture day-to-day intra-individual variability. Future digital marker studies should model practice effects explicitly and consider variability metrics alongside mean performance.
3. Our findings demonstrate the feasibility and potential utility of *TalkTracker* as a low-burden, affordable, self-administered platform for the remote collection of speech-based digital markers relevant to AD risk and early cognitive change.

PARTICIPANTS

	Overall	Cognitively Unimpaired-Stable	Subtle-to-Mild Cognitive Impairments	p
N	85	52	33	
Age (m±sd)	68.59 (6.44)	68.06 (6.30)	69.41 (6.67)	0.351
Primary Language (English %)	82 (96.5)	49 (94.2)	33 (100.0)	0.373
Gender (Female %)	54 (63.5)	34 (65.4)	20 (60.6)	0.83
Primary Race (%)				0.411
White	59 (69.4)	38 (73.1)	21 (63.6)	
Black or African American	25 (29.4)	13 (25.0)	12 (36.4)	
Asian	1 (1.2)	1 (1.9)	0 (0.0)	
Education Years (m±sd)	15.84 (2.10)	16.25 (1.90)	15.18 (2.27)	0.022*
Family History of Dementia (Yes %)	55 (64.7)	38 (73.1)	17 (51.5)	0.073
≥1 APOE-ε4 allele (%)	0.27 (0.45)	0.27 (0.45)	0.27 (0.45)	0.975
Plasma ptau217 level (m±sd)	0.41 (0.31)	0.41 (0.34)	0.40 (0.25)	0.862
Mini-Mental State Examination (m±sd)	29.07 (1.41)	29.42 (0.95)	28.53 (1.81)	0.005*
DDK Syllable Rate (m±sd)	4.74 (0.76)	4.88 (0.78)	4.52 (0.68)	0.036*
DDK Rhythmicity (m±sd)	0.21 (0.05)	0.21 (0.05)	0.22 (0.04)	0.159

- Participants from AD risk-enriched cohorts, i.e., Wisconsin Registry for Alzheimer’s Prevention (WRAP) & Wisconsin Alzheimer’s Disease Research Center (WADRC).
- N = 85 with ≥7 valid DDK recordings (age = 68.59; 63.5% female)
- Cognitive status:
 - n = 52 cognitively unimpaired stable (CUS);
 - n = 33 subtle-to-mild cognitive impairment (CI); comprising n = 29 cognitively unimpaired–declining (CUD) and n = 4 mild cognitive impairment (MCI).