

*Universal and language-specific
connected speech characteristics of
bilingual speakers with Alzheimer's
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structurally distinct languages*

Article

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12 **Universal and Language-Specific Connected Speech Characteristics of Bilingual Speakers**
13 **with Alzheimer’s Disease: Insights from Case Studies of Structurally Distinct Languages**

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26

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40

Abstract

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43 **Purpose:** Connected speech analysis has been effectively utilized for the diagnosis and disease
44 monitoring of individuals with Alzheimer’s Disease (AD). Existing research has been conducted
45 mostly in monolingual English speakers with a noticeable lack of evidence from bilinguals and
46 non-English speakers, particularly in non-European languages. Using a case study approach, we
47 characterized connected speech profiles of two Bengali-English bilingual speakers with AD to:
48 determine the universal features of language impairments in both languages, identify language-
49 specific differences between the languages, and explore language impairment characteristics of
50 the participants with AD in relation to their bilingual language experience.

51 **Method:** Participants included two Bengali-English bilingual speakers with AD and a group of
52 age-, gender-, education- and language-matched neurologically healthy controls. Connected
53 speech samples were collected in L1 (Bengali) and L2 (English) using a novel storytelling task
54 (i.e., “Frog, where are you?”). These samples were analyzed using an augmented Quantitative
55 Production Analysis and Correct Information Unit analyses for productivity, fluency, syntactic
56 and morpho-syntactic features, lexical and semantic characteristics.

57 **Results:** Irrespective of the language, AD impacted speech productivity (speech rate and
58 fluency) and semantic characteristics in both languages. Unique language-specific differences
59 were noted on syntactic measures (reduced sentence length in Bengali), lexical distribution
60 (fewer pronouns and absence of reduplication in Bengali) and inflectional properties (no
61 difficulties with noun or verb inflections in Bengali). Among the two participants with AD, the
62 individual who showed lower proficiency and usage in L2 (English) demonstrated reduced
63 syntactic complexity and morpho-syntactic richness in English.

64 **Conclusion:** Evidence from these case studies suggest that language impairment features in AD
65 are not universal across languages, particularly in comparison to impairments typically
66 associated with language breakdowns in English. This study underscores the importance of
67 establishing connected speech profiles in AD for non-English speaking populations, especially
68 for structurally different languages. This would in turn lead to the development of language-
69 specific markers that can facilitate early detection of language deterioration and aid in improving
70 diagnosis of AD in individuals belonging to underserved linguistically diverse populations.

71 **Introduction**

72 Alzheimer's Disease (AD) is a progressive neurodegenerative disease that can impair a
73 range of cognitive skills including memory, language, attention, processing speed, and executive
74 functioning (McKhann et al., 2011; Weiner et al., 2008). The assessment of connected speech
75 (also referred to as *spoken discourse*) or the use of language beyond individual words and
76 sentences, has sparked significant interest in AD research and clinical practice. This is due to its
77 ease of administration, minimal burden on clients, and usefulness in diagnosing and monitoring
78 disease progression (Ahmed et al., 2013; Boschi et al., 2017; Filiou et al., 2020; Forbes-McKay
79 et al., 2013; Mueller et al., 2018; Slegers et al., 2018). Existing empirical research in connected
80 speech in AD has focused primarily on studying monolingual English speakers. Consequently,
81 very little is known regarding the connected speech profiles of non-English speakers and/or
82 bilingual individuals (Bose et al., 2021; Calabria et al., 2017; Stilwell et al., 2016). With over
83 half of the world's population speaking more than one language and the incidence of older
84 bilingual speakers with AD rising globally, it is important to expand research beyond English
85 and identify language impairment patterns of persons with AD who speak different languages,
86 particularly non-European languages (Petti et al., 2020). These lines of research would lead to

87 the development of language-specific impairment markers and facilitate early identification of
88 language decline and improve language assessment in these underserved populations.

89 ***Bilingualism and AD***

90 Bilingualism and AD research has been undertaken from the perspective of establishing
91 links between the benefits of bilingualism and cognitive reserve and its consequences on the
92 onset of dementia (Alladi et al., 2013; Bak & Robertson, 2017; Bialystok et al., 2016). However,
93 limited research exists in how dementia impacts languages spoken by bilingual speakers, and
94 particularly how AD impacts linguistic features across different languages (see review by
95 Stilwell et al., 2016). Untangling the effects of AD on both languages spoken by bilinguals is a
96 critical line of research for clinical and theoretical reasons. First, comprehensive linguistic
97 assessments such as connected speech analysis can aid in identifying language-universal and
98 language-specific impairments in structurally different languages spoken by bilingual speakers
99 with AD. Second, profiling linguistic impairments in both languages of bilingual AD can help
100 determine the progression (deterioration) of each language through the course of the disease, and
101 their relationship to bilingualism variables and typological factors. Third, detailed
102 characterization can play an important role in facilitating early diagnosis and effective
103 intervention. Collectively, this information is clinically useful for early identification of language
104 decline, developing appropriate assessments and generating functional communication strategies
105 for individuals with AD.

106 ***Connected speech characteristics in AD across languages***

107 Persons with AD frequently demonstrate impairments in connected speech which can
108 affect both the structural (i.e., microlinguistic) and global (i.e., macrolinguistic) levels of
109 language (Carlomagno et al., 2005; Mueller et al., 2018; Slegers et al. 2018). Research primarily

110 from English speaking populations has shown that specific connected speech features distinguish
111 AD from neurologically healthy adults. These include reduced speech rate and spontaneity
112 characterized by increased repetitions and revisions (Ahmed et al., 2013; Sajjadi et al., 2012),
113 simplified syntax and sentence structures including shorter sentences with reduced grammatical
114 complexity (Fraser et al., 2015), word finding difficulties, increased use of pronouns (Forbes-
115 McKay et al., 2013; Gayraud et al., 2010), inflectional errors in nouns and verbs (Ahmed et al.,
116 2013; Sajjadi et al., 2012), and reduced semantic content and less informative language output
117 (Cuetos et al., 2007). Although language-universals exist in impairments (i.e., overlap in
118 linguistic features that would be similarly impaired across languages), prior research indicates
119 that features of language impairments and specific linguistic markers in AD vary with the
120 structure of the language being studied (Bose et al., 2021, 2022; Kavé & Levy, 2003; Paradis,
121 1998). To illustrate, whereas increased production of pronouns is a characteristic feature in
122 English speakers with AD (Ahmed et al., 2013), decreased pronoun production was identified to
123 be a feature of pro-drop languages such as Bengali (Bose et al., 2021) and Hebrew (Kavé &
124 Goral, 2016; Kavé & Levy, 2003). These differences are not idiosyncratic findings across studies
125 but represent the linguistic characteristics of a language. As Bengali is an inflectionally rich pro-
126 drop language and allows dropping of the subject, the subject can be inferred from the other
127 inflected parts of speech. In languages where subjects are obligatorily spelled out, such as in
128 English, dropping the subject is not an option. A simple deduction from this cross-linguistic
129 observation is that when a language allows the avoidance of a linguistic feature or structure, such
130 as subject drop in Bengali, individuals with AD will avoid retrieving and producing the subject,
131 as it may be more cognitively demanding. This finding implies that over-production of pronouns
132 in AD, which is a characteristic feature in English, is not a relevant linguistic marker for a pro-

133 drop language, such as Bengali. Importantly, linguistic impairments in AD are not comparative
134 across languages and differ from the language breakdowns typically observed in English (Bose
135 et al., 2021, 2022; Kavé & Levy, 2003). With the majority of the research focusing on English-
136 speaking monolingual individuals (refer to Supplementary Table 1 for a summary of relevant
137 experimental speech and language studies in bilingual AD), we lack knowledge about the
138 linguistic impairment profiles of bilinguals and native speakers of languages other than English,
139 particularly in relation to language-specific features.

140 ***Factors influencing the presentation of language deficits in bilingual AD***

141 Several factors such as the type of linguistic task, bilingualism variables, language
142 combinations studied, all contribute to the heterogeneity of findings across bilingual AD studies
143 (see Supplementary Table 1). First, a wide range of *language tasks* have been used to explore the
144 linguistic deterioration in bilingual speakers with AD. Most studies have predominantly used
145 single word level tasks focusing on lexical-semantic processing (e.g., confrontational naming,
146 word repetition, object recognition, lexical decision, oral reading, verbal fluency (e.g., Calabria
147 et al., 2017; De Picciotto et al., 2001; Ivanova et al., 2014; Meguro et al., 2003; Nanchen et al.,
148 2017). While these tasks are sensitive in capturing lexical-semantic deficits in AD, they do not
149 provide information regarding individuals' abilities to communicate in everyday conversational
150 situations. Very few studies have examined discourse or conversational-level language in
151 bilingual speakers with AD, and the existing ones have mainly evaluated code switching and
152 language mixing in AD (e.g., Friedland & Miller, 2010; Hyltenstam & Obler, 1989; Hyltensam
153 & Stroud, 1993). To the best of our knowledge, no study has conducted a comprehensive analysis
154 of linguistic features of connected speech across two languages in bilingual speakers with AD.

155 Individual-specific *bilingualism profiles* also influence the presentation of linguistic
156 deficits in bilingual individuals with AD. For instance, Gollan et al. (2010), Ivanova et al.
157 (2014), and Salvatierra et al. (2007) studied non-balanced Spanish-English bilingual speakers
158 with AD. While Salvatierra et al. (2007) reported equal deterioration of both languages in their
159 participants; both Gollan et al. (2010) and Ivanova et al. (2014) reported differential impairments
160 between dominant and non-dominant languages. That is, Gollan et al. (2010) found that the
161 dominant language was more impaired; in contrast, Ivanova et al.'s longitudinal analysis
162 revealed that the non-dominant language deteriorated faster than the dominant language.
163 Although participants of all three studies were sequential Spanish-English speakers, participants
164 in Gollan et al. (2010) and Ivanova et al. (2014) were English-dominant and Spanish-dominant
165 bilinguals respectively whereas, participants in Salvatierra et al. (2007) were equally proficient in
166 both English and Spanish. Therefore, this highlights the differential impact that bilingualism
167 profiles can have on linguistic impairments in bilingual speakers with AD. In addition to
168 bilingualism profiles of the participants, the varied findings across these three studies could be
169 due to different tasks and designs used (i.e., picture naming in Gollan et al. [2010] and Ivanova
170 et al. [2014]; phonemic and semantic verbal fluency in Salvatierra et al. [2007]; see
171 Supplementary Table 1). Another critical issue regarding the bilingual profile characterization
172 pertains to the various definitions used for L1 (first language) and L2 (second language) across
173 different studies. It is important to note that individuals may not necessarily be proficient and/or
174 frequently use their L1, as highlighted in a study by Ellajosyula et al. (2020) on bilingual
175 individuals with primary progressive aphasia. Nevertheless, it is still essential to account for
176 these variables when interpreting bilingual language characteristics in neurologically impaired
177 populations (Costa et al., 2012; Lerman et al., 2019).

178 Specific linguistic impairments in bilingual speakers with AD also vary based on the
179 *language combinations* studied. Costa et al. (2012) studied two groups of early and highly
180 proficient Catalan-Spanish speakers with mild (n = 23) and moderate (n = 24) AD in comparison
181 to a control group of participants with mild cognitive impairment (MCI; n = 24) on lexical-
182 semantic tasks. Results revealed that both languages were similarly affected in participants with
183 AD indicating a parallel decline in the underlying lexical-semantic system and shared neural
184 network supporting both languages. These findings from Costa et al.'s study was not surprising
185 as Catalan and Spanish are structurally similar languages. In contrast, Meguro et al. (2003)
186 studied four Japanese-Portuguese bilingual speakers using several single word lexical-semantic
187 tasks; participants demonstrated differential patterns of impairments in single word reading tasks
188 across Japanese and Portuguese, which are two structurally distinct languages.

189 As can be seen from the ongoing evaluation of the research evidence of linguistic
190 impairments in the two languages spoken by bilinguals with AD, impairment profiles are
191 determined by a complex interaction of methodological variables (e.g., task used, linguistic level
192 analyzed), bilingualism profiles of the AD participants, and linguistic characteristics of the
193 languages studied. At present, the extant literature is limited to make strong claims regarding
194 how the two languages will deteriorate with the progression of AD. Contemporary bilingual
195 research has primarily focused on specific languages such as Spanish. Aside from the Spanish-
196 speaking community, South Asians represent one of the most rapidly expanding demographic
197 groups in the United States (Faroqi-Shah, 2012; Mahendra, 2012). Moreover, as AD is becoming
198 more prevalent in South Asian and Western Pacific regions, including countries like China and
199 India (Li et al., 2022), it is imperative to broaden our empirical knowledge regarding how AD
200 affects other languages such as Bengali, Hindi, and Urdu. This expansion of research is crucial

201 for discerning early identification of language decline which could facilitate prompt and accurate
202 dementia diagnosis as well as rehabilitation of individuals from these linguistic backgrounds.
203 The following section highlights the key linguistic characteristics of Bengali and English, as this
204 knowledge is pertinent to understanding the characterization of connected speech profiles of the
205 two case studies we will be discussing in this paper.

206 ***Bengali and English: Cross-Linguistic Differences***

207 Bengali (*Bangla*) is an Indo-Aryan language and is spoken by an estimated 272 million
208 people as a first or second language globally and it is the sixth most commonly spoken language
209 in the world (Noack & Gamio, 2015; Census of India, 2011; U.S. Census Bureau., 2017).

210 Bengali and English are syntactically, lexically, and morphologically distinct languages. Table 1
211 provides a summary of the cross-linguistic differences between Bengali and English that are
212 relevant for characterizing language features in AD. Key differences between English and
213 Bengali include the word order: English adopts a rigid SVO (Subject-Verb-Object) order,
214 whereas Bengali adopts a more fluid word order with SOV (Subject-Object-Verb), as it's
215 canonical form. Further, Bengali is an agglutinative language with extensive, complex and
216 systematic inflectional morphology (Thompson, 2010). In terms of lexical distribution, in
217 contrast to English, Bengali has fewer closed-class words (Bengali: pronouns, postpositions,
218 indeclinables vs. English: prepositions, determiners, pronouns, conjunctions, modals,
219 auxiliaries). In Bengali, extensive inflectional properties of open-class words serve the role of
220 closed-class words that are utilized in English. As a pro-drop language, Bengali allows for
221 context-based omission of pronouns in the subject position, whereas English does not allow for
222 omission of obligatory pronouns. Reduplication is a prevalent linguistic feature found in several
223 Indian languages, including Bengali. It involves the duplication of a word, either wholly or

224 partially, to create a new word that is different in form and adds a new sense in meaning.
225 Reduplication serves multiple semantic functions, such as sense of multiplicity, continuation of
226 action, recurrence of an event or emotional state, or emphasis (e.g., [ɖin] “day” à [ɖinɖin] “day-
227 by-day”; [ɖʒol] “water” à [ɖʒolɖʒole] “watery”; [gʰor-e] “house- locative ”à[gʰore gʰore]“in every
228 house”).

229 These linguistic differences between the languages are likely to manifest distinctively in
230 connected speech characteristics – *language-specific features*. It is important to reiterate that
231 certain features will be affected in both languages - *universal features* - among bilingual
232 individuals with AD. Thus, considering the variations between languages, detailed examination
233 of language impairment and decline in both languages is warranted.

234 **Insert Table 1 about here.**

235 ***Research Gaps and the Current Study***

236 Despite increased recognition that linguistic impairments are important markers for AD
237 (e.g., Cuetos et al., 2007; Fraser et al., 2015), very little is known regarding patterns of linguistic
238 deficits in speakers of languages other than English and in bilingual speakers. Given the lack of
239 research on detailed characterization of connected speech in bilingual speakers with AD, these
240 case studies are the first ever attempt to document and comprehensively analyze the language
241 profiles of Bengali-English bilingual speakers with AD. Additionally, the inclusion of Bengali-
242 English speakers serves to extend the diversity of published research in acquired neurogenic
243 communication disorders (Beveridge & Bak, 2011).

244 ***Research Questions and Predictions***

245 In this study, we aimed to characterize connected speech profiles of two Bengali-English
246 bilingual speakers with AD in Bengali (L1) and English (L2) across six linguistic levels (speech

247 rate, syntactic, lexical, morphological, semantic and speech fluency). The specific aims of this
248 research were to:

- 249 1. Determine the universal features of language impairment in the two bilingual individuals
250 with AD, that is, linguistic features which are affected in both languages.
- 251 2. Identify the language-specific impairments between Bengali and English, that is,
252 linguistic features which are only affected in the specific language.
- 253 3. Explore connected speech features of individual bilingual AD participants in relation to
254 their language experiences and background.

255 Based on the distinct linguistic properties of Bengali and English, we expected to find
256 differential impairment patterns in L1 (Bengali) and L2 (English) across some of the linguistic
257 levels but not all. Specifically, we predicted that individuals with AD would present similar
258 patterns of impairments in both languages in terms of speech productivity, semantic content, and
259 fluency. However, we expected to observe language-specific variations in syntax, morphology,
260 and lexical distribution between Bengali and English (i.e., proportion of pronouns, postpositions,
261 reduplications, word order, nouns and verb inflections), given the structural differences between
262 both languages. Additionally, we hypothesized that cross-linguistic patterns of deficits would
263 vary with the participants' bilingualism profiles.

264 **Methods**

265 *Participants*

266 Two Bengali-English bilingual adults (AD03; AD09) with a clinical diagnosis of
267 probable AD based on the NINCDS/ADRAA criteria (McKhann et al., 2011) and eight age-,
268 gender-, education- and language-matched neurologically healthy controls (HC) participated in
269 the study. AD03 and AD09 were part of a larger research project investigating language

270 production in bilingual AD involving six participants. Of these six individuals, only two of them
271 (AD03; AD09) were able to complete the connected speech tasks in both languages. All
272 participants were right-handed urban community dwelling sequential Bengali-English bilingual
273 speakers with better proficiency and higher usage in Bengali (L1) than English (L2). AD03 and
274 AD09 were recruited from the Duttanagar Mental Health Centre, Kolkata, eastern India, and
275 were living with their families at the time of the study.

276 HC participants were recruited from a volunteer participant pool. Exclusion criteria for
277 both groups included: (1) a known history of alcohol or drug abuse, (2) a history of other
278 neurological or psychiatric illness, or (3) less than ten years of education. Ethical approval for
279 this study was obtained from the University of Reading (2017-035-AB). The demographic
280 details for all participants are provided in Table 2.

281 Participant AD03 was a retired electrical supervisor. As per his wife, his symptoms began
282 36 months prior to receiving his AD diagnosis. His initial presenting symptom was impaired
283 memory, evidenced by forgetting recent conversations and meals. He was reported to have
284 difficulty recognizing his house, among other visuospatial difficulties. Moreover, he was
285 reported to present with neuropsychiatric symptoms such as increased aggression. Participant
286 AD09 used to work as an English teacher at a high school. However, as per her husband, she
287 retired as she was no longer able to cope with the job's demands. Her symptoms began four years
288 prior to receiving her AD diagnosis and initially presented with progressive loss of memory
289 evidenced by difficulties with recalling the names of places, remembering recent conversations
290 and books she had read, and remembering meals she had eaten. She exhibited behavioral changes
291 such as withdrawal from social groups, confabulations, and difficulties with recognizing familiar
292 places. Additionally, she demonstrated difficulty with comprehension and an increased reliance

293 on her spouse for activities of daily living. AD09 was noted to need more time understanding
294 instructions while completing the assessments in this study.

295 **Insert Table 2 about here.**

296 ***Background Assessments***

297 *Neuropsychological assessments.* General cognitive functioning was measured using the
298 *Kolkata Cognitive Screening Battery* (KCSB), an adapted Bengali version of *Mini-Mental State*
299 *Examination* (BMSE; Das et al., 2006), the Bengali adapted version of *Addenbrooke's Cognitive*
300 *Examination* (ACE-III; Hsieh et al., 2013) and the *Clinical Dementia Rating Scale* (CDR,
301 Morris, 1993). The CDR is a measure of dementia severity based on the individual's cognitive
302 and daily functions across several domains including memory, orientation, judgement, problem
303 solving, community affairs, home and hobbies, and personal care. The study participants as well
304 as their family members completed the CDR. In addition, the *Instrumental Activities of Daily*
305 *Living Scale for Elderly* (IADL-EDR; Mathuranath et al., 2005) was completed by the
306 participants' family members as a proxy measure of each participant's ability to undertake day-
307 to-day activities; this included cognitive activities, social and recreational activities, community
308 activities, household activities and self-care activities. A composite percentage score derived
309 from the questionnaire indicated overall physical and cognitive disability.

310 None of the HC participants exhibited any cognitive symptoms or neurological disorders
311 and performed within the normal range on the KCSB, ACE-III, CDR and IALD-EDR
312 assessments. Compared to HC, both AD03 and AD09 demonstrated significantly lower ACE-III
313 and KCSB scores, marked difficulties in IADLs, and an overall severity of mild dementia (i.e.,
314 CDR global score of 1). All clinical interviews and assessments were performed by the fifth and

315 sixth authors (RN, AD) who are clinical neuropsychologists with extensive research experience
316 in cross-cultural neuropsychology. See Table 2 for neuropsychological test results.

317 *Bilingualism measures.* All participants completed a set of subjective language
318 background questionnaires (language acquisition history, language of instruction, self-rated
319 language proficiency, language usage, and language dominance). For individuals with AD,
320 information was corroborated by their family members. To measure language acquisition history,
321 self-rated language proficiency (in speaking, comprehension, reading, and writing), and the
322 current language usage pattern, we adapted and modified the questionnaire developed by Muñoz
323 et al. (1999). Language dominance was measured using the language dominance questionnaire
324 (Dunn & Fox Tree, 2009). See Patra et al. (2020) for the adapted versions of these
325 questionnaires. In addition, participants completed a questionnaire regarding their medium (i.e.,
326 language) of instruction during different levels of education. Bilingualism profiles generated
327 from the bilingualism measures are presented in Table 3.

328 **Insert Table 3 about here.**

329 The onset of exposure to Bengali for all participants began since birth as they all grew up
330 in Bengali households and were educated in Kolkata. The language acquisition questionnaire
331 indicated that AD03, AD09 and the HC participants all had greater immersion in Bengali
332 compared to English. AD09 reported an early onset of exposure to English (at around 5 years),
333 both formally and informally in contrast to AD03 who was formally exposed to English in
334 primary school at the age of six years and informally with friends and neighbors at around 11
335 years. All participants were exposed to English after the age of three years.

336 In terms of formal education, AD03's primary medium of instruction until high school was
337 Bengali, and only in his undergraduate degree the medium of instruction included both Bengali

338 and English. In contrast, AD09 had mixed medium of instruction during schooling (i.e., both
339 Bengali and English) from primary school to her postgraduate master's degree.

340 Data from the usage and proficiency questionnaires indicated that both AD03 and AD09
341 had greater current language proficiency in L1 compared to L2. Following the guidelines provided
342 by Dunn and Fox Tree (2009), scores from the *Bilingual Dominance Scale* showed similar results
343 for both AD participants, with L1 (Bengali) being their dominant language (AD03 dominance
344 scores for L1 = 26, L2 = -4; AD09 dominance scores for L1 = 23, L2 = 7; total possible score =
345 31). For purposes of interpretation, higher scores showed higher dominance in one language (i.e.,
346 Bengali) compared to the other language (i.e., English). Furthermore, both participants indicated
347 higher frequency and greater use of L1 compared to L2. An important difference of note between
348 AD03 and AD09 was that for the measures of proficiency, dominance and current use, the
349 difference in measures between L1 and L2 was smaller in AD09 (i.e., proficiency rating L1 = 7,
350 L2 = 5.88; usage L1 = 5, L2 = 3.75); in contrast to AD03 whose difference between L1 and L2 on
351 these parameters were greater (i.e., proficiency rating L1 = 7, L2 = 2.38; usage L1 = 5, L2 = 2). It
352 is worthy to reiterate that AD09 had a master's degree in English and was working as a high school
353 English teacher until her dementia onset, likely indicating a greater proficiency in English
354 compared to AD03.

355 In summary, based on the bilingualism profiles, AD03 and AD09 in addition to all HC
356 participants were considered sequential bilinguals, with Bengali as their L1 and English as their
357 L2. Both AD03 and AD09 were dominant in L1 with greater proficiency and current use in L1.
358 However, compared to AD03, AD09 was more "balanced" with lesser difference in L1 and L2
359 proficiency and usage.

360

361 ***Connected speech task***

362 *Data collection and recording.* Narrative samples using the wordless picture book, “Frog,
363 where are you?” (Mayer, 1969) were elicited by author RN in Bengali and English on separate
364 testing days. Storytelling was chosen as it has shown to elicit richer and more descriptive
365 language samples with the greater sensitivity to capture language-specific distinctions when
366 compared to single-picture descriptions (Bose et al., 2022). This story was selected to ensure that
367 the participants found the story relevant and culturally appropriate. While most studies in English
368 speakers with AD and other dementias have used the Cinderella Story retelling narrative task
369 (e.g., Fraser et al., 2015; Kavé et al., 2007), Bengali speakers residing in Kolkata, India, are less
370 likely to be familiar with all the specifics of Cinderella, even if they are acquainted with the
371 general concept of the story. The “Frog, where are you?” story has been used dementia literature
372 (e.g., Ash et al., 2007; Clark et al., 2021) and does not rely on specific knowledge of specific
373 story concepts (such as those in Cinderella), therefore making the story more appropriate for the
374 participants.

375 Prior to administering the narrative task, participants were given a brief background
376 about the story and were told that the main characters of the story are a boy, his dog, and a frog.
377 The story is about a boy who is searching for his missing frog along with his dog. Participants
378 were instructed to look through the wordless picture book and then asked to narrate the story
379 using complete sentences. Instructions for eliciting connected speech tasks in Bengali were
380 delivered in Bengali, while instructions for the English samples were presented in English.
381 Participants could keep the book with them while narrating the story. Other than occasional
382 prompts and generic encouragement, tester interruptions were kept to a minimum. No feedback
383 was provided during narrative elicitation. Instructions for testing and feedback were written

384 down for the tester to ensure consistency in instruction across participants. Testing was
385 conducted in a quiet room. The language samples were recorded using the digital audio recorder
386 Olympus voice recorder WS-833 for subsequent orthographic transcription.

387 *Transcription and data extraction.* Each narrative sample was transcribed manually verbatim,
388 segmented, and analyzed in accordance with the procedures outlined in the Quantitative
389 Production Analysis (QPA; Berndt et al., 2000). All raters involved in the scoring process
390 listened the full audio samples for each participant, transcribing the entirety of the samples.
391 Author YC completed the transcriptions in English and author ND performed the transcriptions
392 in Bengali. As in the original QPA, utterances were defined as segments of running speech that
393 were coherent in terms of syntax and/or prosody. Placement of sentence boundaries was guided
394 by semantic, syntactic, and prosodic features. An utterance did not have to constitute a fully
395 grammatical sentence. Using the QPA rules of extracting the narrative core, words that did not
396 contribute to the narrative (i.e., repetitions, repairs, examiner's prompts, discourse markers,
397 nonwords) were removed (see Berndt et al., 2000; Rochon et al., 2000 for specific steps in
398 extracting the narrative words). Authors AB and NSD performed the narrative core extraction
399 individually for all the 10 speech samples (AD $n = 2$; HC $n = 8$) in Bengali, and authors YC and
400 AB performed the narrative core extraction individually for all the English (AD $n = 2$; HC $n = 8$)
401 samples.

402 The minimum length of the language sample for obtaining meaningful results from a
403 narrative production has been widely debated (e.g., Berndt et al., 2000; Sajjadi et al., 2012). The
404 QPA analysis protocol recommends a corpus of 150 words for narrative analysis (Berndt et al.,
405 2000). Moreover, previous research with different sample lengths have shown that a 150
406 narrative word corpus produced an adequate and reliable analysis (Sajjadi et al., 2012).

407 Following the abovementioned recommendations and to keep the sample length consistent across
408 participants, we derived the measures after extracting 150±10 narrative words. The total
409 narrative duration and total number of words produced by each participant were also recorded.
410 To ensure reliability, transcriptions and coding were further reviewed and agreed upon by
411 multiple authors (AB, MD, NSD, YC, and TMD). Authors AB and NSD (a linguist with
412 extensive expertise in Bengali linguistics) jointly scored all language samples and coded for the
413 variables in Bengali. Given that this was the first time QPA was being augmented for Bengali,
414 the scoring process was conducted collaboratively to ensure the analysis was linguistically
415 robust. Authors YC and TDM coded and analyzed the English samples. For CIUs, authors MD,
416 AB, and YC jointly conducted the coding for variables. Any disagreements in narrative core
417 extraction or utterance segmentation were resolved through review of the QPA rules, and re-
418 listening of the audio samples. Variable scores for each sample were finalized only after
419 unanimous agreement among all scorers. The coding agreement between scorers was 100%.
420 Excerpts of transcripts in Bengali and English for the two participants with AD (AD03 and
421 AD09) and one HC participant are provided in the Table 4. Best Practice Guidelines for
422 Reporting Spoken Discourse in Aphasia and Neurogenic Communication Disorders by Stark et
423 al. (2022) were followed (see Supplementary Table 2 for completed checklist).

424 **Insert Table 4 about here.**

425 *Quantitative Analysis of Narratives.* The QPA and the Correct Information Unit (CIU;
426 Nicholas & Brookshire, 1993) analyses were implemented to calculate a set of count and
427 proportional measures for each connected speech sample. The QPA scheme was augmented, and
428 additional variables were included in the analysis scheme to capture specific linguistic features
429 of Bengali (e.g., verbal and nominal morphology, proportion of postpositions, number of

430 reduplications; see Table 5). CIUs are a widely used metric in narrative analysis that assess the
431 informativeness and efficiency of information conveyed through connected speech (Ahmed et
432 al., 2013). The multidimensional nature of connected speech analysis and the large number of
433 different variables used by researchers makes the choice of reporting appropriate variables a
434 challenging task, especially for cross-linguistic comparisons. To keep the comparisons succinct
435 for facilitating cross-linguistic comparisons, we focused on the proportional measures that
436 provide insights into cross-linguistic differences and also capture language-specific features of
437 Bengali (e.g., proportion of postpositions) and English (e.g., proportion of prepositions). The
438 measures reported in the current study are aligned with the recommendations from recent
439 reviews regarding the linguistic levels that are essential for characterizing language in AD
440 (Slegers et al., 2018; Filiou et al., 2020). Previous studies examining connected speech in AD
441 (e.g., Ahmed et al., 2013; Boschi et al., 2017; Frazer et al., 2016) have quantified six different
442 aspects of language production: (1) speech rate; (2) structural and syntactic measures; (3) lexical
443 measures; (4) morphological and inflectional measures; (5) semantic measures; and (6) measures
444 of spontaneity and fluency disruptions.

445 The following section provides a brief description of the six linguistic levels and specific
446 variables used for characterizing the samples and to capture the cross-linguistic differences
447 between Bengali and English. See Table 5 for the definition of these variables and features
448 relevant for Bengali versus English (see Supplementary Table 3 for a complete list of variables
449 derived from the QPA and CIU analyses).

- 450 • **Speech rate:** defined as the number of words produced per minute.

- 451 ● **Structural and syntactic measures:** this level measured the mean length, complexity, and
452 grammaticality of sentences to capture the structural and syntactic aspects of language
453 production.
- 454 ● **Lexical measures:** these measures captured participant's production of various types of
455 lexical items (e.g., nouns, verbs, pronouns, postpositions, prepositions) across all extracted
456 narrative words, independent of utterance type. For this study, the following set of variables
457 were calculated: proportion of open class words, closed class words, nouns, personal
458 pronouns, verbs, postpositions (Bengali only), prepositions (English only), and number of
459 reduplications (Bengali only).
- 460 ● **Morphological and inflectional measures:** in QPA, morphosyntactic properties of nouns
461 and verbs in English are indexed by two metrics “noun determiner index” and “verb
462 inflection score”. To capture the morphological richness and intricacies of Bengali noun and
463 verb inflectional system, we generated the following measures (see Supplementary Table 3
464 for definitions): For nominal inflections, we determined the total number of: (1) nouns, (2)
465 nouns in their base form (i.e., uninflected forms), (3) nouns that are possible to be inflected,
466 (4) nouns with appropriate inflections, and (5) inflections on each noun (i.e., one, two, > two
467 inflections). From these count measures, we derived the noun inflection index, which
468 indicated if inflected nouns are correctly inflected or not. For verbs, we determined the total
469 number of: (1) verbs, (2) inflectable verbs, and (3) inflected verbs with appropriate
470 inflections. From these count measures, the verb inflection index was calculated to indicate if
471 inflected verbs are inflected correctly or not. By doing this, we aimed to arrive at comparable
472 metrics of noun and verb inflections between the languages (i.e., noun determiner index and
473 verb inflection score in English; noun inflection index and verb inflection index in Bengali).

- 474 • **Semantic measures:** semantic content of the narrative samples was quantified separately
475 using the CIU measures. Three measures were derived from the CIU analysis: number of
476 CIUs, idea density and idea efficiency.
- 477 • **Measures of spontaneity and fluency disruptions:** the total counts of disruption in
478 spontaneity and fluency were included to capture the number of repetitions, revisions, and
479 reformulations in the narrative samples.

480 **Insert Table 5 about here.**

481 *Statistical analysis*

482 Given that we report two case studies, we implemented the well-established single-subject
483 statistical method by Crawford and colleagues for comparing a single case to a small control
484 group (at least five) to identify differences between each AD participant and controls (Crawford
485 & Garthwaite, 2002; 2006; Crawford et al., 2010). The score for each variable was extracted and
486 compared to the HC group's average scores for the variable in the same language (i.e., a within-
487 language comparison) with the significance value set at 0.05 ($p < 0.05$, one-tailed).

488 **Results**

489 Table 6 presents the data from participants AD03 and AD09, and the means and standard
490 deviations from HC participants along with the results of the single-subject statistics. Figure 1
491 illustrates the variables that were affected in both languages for AD03 and AD09 (i.e., language-
492 universal variables) and those that were affected only in one language for both participants (i.e.,
493 language-specific variables). The readers are encouraged to review Table 4 of illustrative
494 examples of narrative productions of AD03 and AD09 and their comparison with a control
495 participant.

496 **Insert Table 6 and Figure 1 about here.**

497 ***Universal features of connected speech impairments in bilingual speakers with AD***

498 For both Bengali and English, participants AD03 and AD09 showed reduced speech rate,
499 increased number of dysfluencies, and reduced CIU% (idea density) and CIUs per minute (idea
500 efficiency) in their narrative productions compared to the control group.

501 ***Language-specific differences between Bengali and English in bilingual speakers with AD***

502 Prominent differences in Bengali and English emerged on the structural and syntactic,
503 lexical, and inflectional measures (see Table 6). Compared to HC, participants AD03 and AD09
504 both produced shorter mean length of utterance (MLU) with fewer embeddings in Bengali. In
505 terms of lexical distribution, AD03 and AD09 showed reduced proportion of pronouns in
506 Bengali, with no such difference in English. Both participants showed an absence of
507 reduplications in Bengali, which is a characteristic feature of Bengali. Neither individual with
508 AD showed any difficulty with noun and verb inflectional indices in Bengali.

509 ***Connected speech characteristics in AD in relation to language experience and background***

510 As a reminder to our readers, AD03 and AD09 were sequential bilinguals, with Bengali as
511 their L1 and English as their L2, with greater dominance, proficiency, and usage in L1. However,
512 compared to AD03, AD09 was a more “balanced bilingual” with lesser difference in L1 and L2
513 proficiency and usage, and her medium of instruction during all school years had been both in
514 Bengali and English.

515 In English, participant AD03 showed reduced well-formedness of sentences, whereas
516 AD09 demonstrated no impairments on syntactic and structural measures. Additionally,
517 participant AD09 showed significant differences in the proportion of open class and closed class
518 words for both Bengali and English; however, the direction of the difference was opposite in two
519 languages: The proportion of open class words in Bengali increased, however in English, there

520 was a notable decrease in their proportion. AD03's difficulty with noun inflections was indicated
521 by reduced noun determiner index in English. Although, AD03's verb inflection index score was
522 lower than the HC mean, the statistical analysis did not reveal a significant difference, possibly
523 due to higher variability in the control group.

524 In summary, for both participants AD03 and AD09, speech productivity (i.e., speech rate,
525 fluency) and semantic measures were affected in both languages; cross-linguistic differences
526 appeared in syntax, lexical distribution, and inflectional properties. Bengali-specific features that
527 were consistently observed in both participants included reduced well-formedness of sentences,
528 decrease in pronouns, absence of reduplications, and no difficulty with noun or verb inflections
529 in Bengali. In terms of English variables, AD09 showed fewer differences from HC on the
530 syntactic/structural and morphological variables than AD03 who demonstrated less well-formed
531 sentences and difficulty with noun inflections in English.

532 Discussion

533 These case studies present a comprehensive analysis of connected speech to evaluate
534 cross-linguistic profiles of two sequential Bengali-English bilingual individuals diagnosed with
535 AD. In line with the existing monolingual AD literature (e.g., Ahmed et al., 2013; Ash et al.,
536 2007; Forbes-McKay et al., 2013; Sajjadi et al., 2012), our findings revealed that both bilingual
537 participants with AD performed significantly differently compared to age-, education-, and
538 gender-matched HC on the narrative language task, affecting all linguistic levels. Impairments in
539 speech productivity, fluency, and semantics were universally affected in both languages; while
540 language-specific differences were noted in the syntactic, lexical, and morphological domains.
541 Additionally, the two bilingual speakers with AD showed differential patterns of impairments in
542 their L1 (i.e., Bengali) and L2 (i.e., English) on select linguistic measures and these patterns

543 varied with the participants' language experiences and background. Our results add to the extant
544 literature and demonstrate that not all linguistic levels in connected speech are equally affected
545 as a result of AD in bilingual individuals.

546 *Universal features of connected speech impairments in bilingual speakers with AD*

547 We found that both AD03 and AD09 demonstrated slower speech rate, more frequent
548 fluency disruptions, and reduced informativeness and efficiency of ideas in their narrative
549 productions in both Bengali and English. These features are typically known to be affected in
550 AD (e.g., Ahmed et al., 2013; Fraser et al., 2016; Sajjadi et al., 2012). However, in the context of
551 bilingualism, similar deficits in both languages as evidenced by the two case studies highlight
552 that the degenerative changes associated with AD universally impact certain domains
553 irrespective of the language. These deficits reflect the ongoing deterioration in the underlying
554 semantic networks causing slowed retrieval of lexical-semantic content, and changes in cognitive
555 skills including processing speed, working memory, planning, and monitoring of information
556 (Gayraud et al., 2010; Grossman & Rhee, 2001). Furthermore, semantic impairment in both
557 languages among AD03 and AD09 are consistent with the notion that the semantic system and
558 conceptual representations involved during a narrative task are perhaps common across both
559 languages (Costa et al., 2012). Our results are consistent with Costa et al. (2012) and Gollan et
560 al. (2010) and indicate that these linguistic features are similarly affected due to cognitive
561 decline and can be universally impacted irrespective of the language used.

562 *Language-specific differences between Bengali and English in bilingual speakers with AD*

563 Cross-linguistic differences were observed on the syntactic, lexical, morphological, and
564 inflectional measures. Several linguistic features and impairment patterns were unique to Bengali
565 and were consistently observed for both AD participants. In terms of structural and syntactic

566 variables, both individuals with AD produced syntactically simpler and shorter sentences with
567 lower embeddings in their narrative output. It is important to note that these differences were
568 more prominent in the participants' L1 (i.e., Bengali) and were not manifested in their less
569 proficient language, English (L2). It could be that the L2 of HC participants was not as proficient
570 as their L1 as they were sequential bilinguals themselves, and thus the magnitude of the between
571 group difference was smaller in L2 than in L1. Our results generally align with previous studies
572 that have reported reduced syntactic complexity of productions in AD (e.g., De Lira et al., 2011;
573 Forbes-McKay et al., 2013; Sajjadi et al., 2012), but differ from a bilingual study by Gómez-
574 Ruiz et al. (2012) who noted preservation of syntactic skills in spontaneous speech productions
575 of Catalan-Spanish bilingual speakers with AD cross-linguistically. The key finding is that at the
576 syntactic level, unique profiles are observed across languages, which relate to the linguistic
577 properties of the languages being compared.

578 In the current study, we evaluated Bengali and English which are structurally distinct
579 from each other (with differences in word order, fluidity of word order, and morphosyntax). As
580 noted previously, Bengali is a highly inflectional language with a fluid word order that allows
581 dropping of the subject (i.e., pro-drop, discussed below), while English has less flexibility in
582 terms of the structure. This is in stark contrast to a language combination such as Catalan and
583 Spanish, which are structurally and morpho-syntactically more similar languages, as both are
584 pro-subject drop languages sharing comparable word order and morpho-syntactic properties.
585 Accordingly, patterns of linguistic impairments vary based on the structural differences across
586 the languages.

587 Differences in Bengali language-specific markers were consistently observed for both
588 AD participants in the lexical, morphological and inflectional domains. In terms of the lexical

589 features, neither person with AD showed significant differences when compared to HC in the
590 proportion of nouns, verbs, or prepositions/postpositions produced in either in L1 or L2.
591 However, compared to controls, participants AD03 and AD09 demonstrated the use of fewer
592 pronouns in Bengali. As mentioned previously, Bengali is an inflectionally rich pro-drop
593 language and allows the dropping of the subject; the subject can be inferred from the other
594 inflected parts of speech. Contrastingly, in languages where subjects are obligatorily spelled out,
595 such as in English, dropping the subject is not an option. Therefore, speakers with AD of those
596 languages such as English, will opt for a cognitively less demanding option and prefer
597 overproducing pronouns over nouns as the former is semantically vague and more frequently
598 used, and thus might be easier to retrieve (Almor et al., 1999; Bloom, 1990). One simple
599 deduction from this cross-linguistic observation is that when a language allows the avoidance of
600 a linguistic feature or structure, such as subject drop in Bengali, participants with AD will avoid
601 retrieving and producing the subject, as it is more cognitively demanding. Therefore, this finding
602 implies that over-production of pronouns in AD, which is a characteristic feature in English, is
603 not a relevant linguistic marker for a pro-drop language, such as Bengali.

604 Interestingly, we did not observe an overuse of pronouns in either AD participant in
605 English, a feature that is commonly documented in English speakers with AD (e.g., Ahmed et
606 al., 2013; Fraser et al., 2015). This finding may be attributed to the lower proficiency of both AD
607 participants in their second language. Speakers who are predominantly Bengali-dominant with
608 limited English proficiency may replicate the pronoun usage patterns of Bengali. Currently, this
609 remains a speculation, which can be tested empirically in future with greater number of
610 participants. Furthermore, compared to HC, both AD participants demonstrated an absence of
611 reduplications, a feature unique to Bengali and many other Indian languages (Bose et al., 2021).

612 We posit that the reduced quantity of reduplications in AD could signify a potential underlying
613 impairment with semantic processing that results in difficulties retrieving and producing
614 reduplications. The speculation for underlying cause of the lack of reduplication in AD would
615 need to be experimentally tested in future.

616 The morphological and inflectional measures indicated that, contrary to some studies
617 involving English speakers with AD (e.g., Sajjadi et al., 2012; Ahmed et al., 2013), both AD03
618 and A09 performed similarly to HC in terms of the noun and verb inflections produced in
619 Bengali revealing no inflectional impairments. They produced similar amounts of correctly
620 inflected nouns and verbs to the bilingual control group. This is consistent with previous studies
621 in languages with high inflectional morphology, in that, the inflectional morphology is spared in
622 cases of language impairments (Auclair-Ouellet et al., 2019). In contrast to English where
623 overproduction of pronouns and inflectional impairments are common, bilingual speakers with
624 AD in the current study tended to omit the pronouns while still maintaining the correct syntax
625 (albeit simpler) and demonstrated no difficulties with verb and noun inflections.

626 Collectively, these cross-linguistic differences highlight the importance of developing
627 language-specific connected speech markers for early identification of language decline across
628 structurally distinct languages. Furthermore, these language-specific markers of Bengali
629 identified in the current case studies (i.e., pronouns, reduplications, noun/verb inflections) must
630 be taken into account in evaluation and language therapy.

631 ***Connected speech characteristics in AD in relation to language experience and background***

632 The current findings also highlight that extent to which linguistic impairments in L2
633 (English) vary with the participants' bilingualism profiles such as usage, proficiency, and
634 educational background. The manifestation of cross-linguistic patterns varied between AD03 and

635 AD09 in certain linguistic domains. Participant AD09, in comparison to AD03 demonstrated
636 fewer significant differences compared to the bilingual control speakers on syntactic and
637 morphological levels in her English. Further, AD03 produced significantly fewer well-formed
638 sentences in English while AD09 did not show any significant differences on this measure
639 compared to controls. Moreover, AD03 produced fewer determiners relative to nouns but only in
640 English, suggesting reduced grammaticality in his connected speech. Reduced grammatical
641 output is a common observation in less-proficient bilingual speakers. This could potentially be
642 related to AD03's later exposure to English informally and in schooling compared to AD09 who
643 had greater exposure to English through her education, having earned a master's degree in
644 English, and through her occupation as an English school teacher. As a result, she was
645 considered a more proficient bilingual than AD03 with relatively similar proficiency in both
646 languages.

647 *Limitations and Future Directions*

648 The present study acknowledges some limitations that warrant consideration. First, the
649 use of a case study methodology was necessitated by the relatively small sample size, comprising
650 only two bilingual individuals with AD and a matched control group. Recruitment of clinical
651 participants is a universal challenge for any research study, this problem is exacerbated when
652 working in locations with limited research infrastructure, lack of awareness for the importance of
653 research and when study goal targets underrepresented populations, such as bilingual speakers
654 who have been underexplored in previous studies. Although, this research provides a detailed
655 profile of connected speech for Bengali and English in bilingual participants, the results must be
656 interpreted with caution as small sample size limits the generalizability of findings.

657 Second, the current study focused on a novel storytelling task. Future studies must extend
658 this research by incorporating more ecologically valid language tasks (e.g., free speech,
659 conversations with familiar and unfamiliar partners). Furthermore, the efficient production of
660 meaningful narratives involves interaction of both micro- and macro-linguistic levels and
661 impairments in the structural elements can impact quality of narratives at the global level
662 (Farivar et al., 2019). Needless to say, future research should prioritize multi-level language
663 analysis (i.e., examination of both micro- and macro-linguistic variables and the interactions
664 between them). These limitations collectively suggest the need for larger-scale studies with
665 diverse samples (e.g., varying AD profiles, monolingual populations from structurally distinct
666 languages, variables related to bilingualism and demographics, different levels of education,
667 race, ethnicities), other language combinations (including both similar and dissimilar language
668 structures), and multiple language tasks to corroborate and expand upon the current findings.
669 This would allow more systematic investigations of cross-linguistic effects in bilingual speakers
670 and establish connected speech impairment profiles in the AD population and other types of
671 dementia pathologies.

672 ***Conclusion and Empirical Contributions***

673 To the best of our knowledge, this research is the first ever attempt to provide detailed
674 microlinguistic analysis of connected speech in two structurally different languages – Bengali
675 and English – spoken by bilingual individuals with AD. By researching English and a non-
676 European language combination, the findings add to and improve the diversity of research in the
677 field and languages studied in bilingual speakers with AD. The findings from the two case
678 studies revealed that domains of speech productivity, fluency, and semantic content were
679 universally impacted, irrespective of the language used. Also, as Bengali and English differ in

680 syntactic, morpho-syntactic and lexical distributions, unique language-specific profiles were
681 noted on syntactic measures, lexical distribution and inflectional properties. Thus, in contrast to
682 English where overproduction of pronouns and inflectional impairments are common,
683 individuals with AD in Bengali tended to omit the pronouns while still maintaining the correct
684 yet simpler syntax and demonstrated no difficulties with verb and noun inflections. In addition,
685 the participant with lower proficiency and usage in L2 (English) showed impoverished syntactic
686 and morpho-syntactic features in their English output.

687 This research also makes important methodological contributions. First, with bilingual
688 AD becoming increasingly relevant in clinics, research such as this should strive to move beyond
689 restricted language tasks and provide an exhaustive analysis of connected speech to facilitate
690 cross-linguistic comparisons and establish unique linguistic markers across various languages.
691 As observed in the findings from this study, the patterns of linguistic changes observed in
692 bilingual speakers with AD would depend on the linguistic level investigated, specific cross-
693 linguistic differences between languages and bilingualism variables. Second, we provide an
694 analysis framework for studying different language combinations, more so, for structurally
695 different languages. For instance, the current study employed a story retelling task, which is a
696 more natural and ecologically valid method to elicit connected speech samples in AD. Compared
697 to structured language tasks, narrative samples are relatively less restricted, and they capture a
698 more extensive range of language features, making them a valuable tool for language assessment
699 in both clinical and research settings (Bose et al., 2022). Although we followed the general QPA
700 framework to assess connected speech, we were able to adapt and incorporate Bengali-specific
701 features into the analysis. These methodological contributions can encourage researchers to

702 pursue future studies by thinking about the different linguistic levels to target and tap into cross-
703 linguistic variations.

704 Comprehensive connected speech analysis is receiving increasing empirical attention due
705 to its importance in diagnosing and monitoring AD, as well as in determining therapy
706 approaches. Given its theoretical and clinical importance, our findings emphasize the need to
707 incorporate the evaluation of connected speech more frequently in research and focus on
708 examining AD-related changes in languages that continue to remain under-researched. To
709 enhance communication efficiency of bilingual speakers with AD, it is critical to first identify
710 and establish patterns of impairments and language-specific markers of language decline, which
711 will in turn inform clinical decision making for these individuals.

712 **Data Availability Statement:** Data collected for this study (i.e. deidentified participant data)
713 will be made available under a signed data access agreement, after the online publication date, in
714 response to reasonable requests from academic researchers emailed to the corresponding author.

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905
906 **FIGURES**

907 **Figure 1.** The top two panels illustrate the variables (speech rate, fluency disruptions, idea
908 density and idea efficiency) that were affected both in Bengali and English for AD03 and AD09
909 in comparison to the neurologically healthy controls (HC). The lower bottom panel illustrates
910 variables (mean sentence length and proportion of pronouns) that were only affected in Bengali
911 for both participants. An asterisk indicates significant difference from control group.

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914 **SUPPLEMENTARY MATERIALS**

915 **Supplementary Table 1.** A summary of relevant experimental speech and language studies in
916 bilingual AD (adapted from Stilwell et al., 2016 and Calabria et al., 2017).

917

918 **Supplementary Table 2.** Best Practice Guidelines for Reporting Spoken Discourse in Aphasia
919 and Neurogenic Communication Disorders (Stark et al., 2021).

920

921 **Supplementary Table 3.** A complete list and definitions of variables derived from the
922 Quantitative Production Analysis (QPA) and Correct Information Unit (CIU) analyses.

923
924

925 **Table 1.** Cross linguistic differences in Bengali and English.

| Linguistic features | Bengali | English |
|---|--|----------------------------------|
| Syntactic and structural characteristics | | |
| Canonical word order | SOV (Subject-Object-Verb) | SVO (Subject-Verb-Object) |
| Flexibility of word order | Fluid, at least for canonical forms; can be extended to other forms | Rigid |
| Branching | Left branching | Right branching |
| Passive constructions | Rare | Common |
| Pro-drop | Yes (subject); Object (rarely dropped) | No |
| Negation | Postverbal (preverbal in conditional constructions) | Preverbal (with added auxiliary) |
| Complementizer | Optional (sense of the complementizer is implicit) | Optional (that) |
| Lexical characteristics | | |
| <i>Open class words</i> | | |
| Nouns | Present | Present |
| Verbs | Present | Present |
| Copular verbs | Not used in simple declarative present tense, available in other tenses. | One in number (to be) |
| Adjectives | Present, inflected for comparative and superlative | Present, uninflected |
| Adverbs | Present | Present |
| Reduplication | Pervasive use | Rare use |
| <i>Closed class words</i> | | |
| Pronouns | Present: overt and null | Present: overt in most contexts |
| Prepositions | Absent | Present |
| Postpositions | Present | Absent |
| Auxiliaries | Absent as independent form, but marked in the main inflected finite verb | Present |
| Clitics | Present (mostly emphatic in sense) | Absent (but debated) |
| Modals | Absent as independent form but marked by inflections on verbs. | Present |
| Articles | Absent as independent form, but marked by inflections on nouns. | Present |
| Morphological characteristics | | |
| <i>Nominal morphology</i> | Highly inflected morphology | Limited inflectional morphology |

| | | |
|-----------------------------------|--|--|
| Base form (uninflected) | Yes | Yes |
| Nouns can be inflected for: | | |
| Number | Marked with suffix, and words of multitude | Marked with suffix |
| Definiteness | Marked with suffix | Use of determiner |
| Case | Marked with suffix and postposition | Not marked |
| Particles | Marked with suffix | |
| <i>Pronoun morphology</i> | Some inflected morphology | Limited inflectional morphology |
| Pronouns can be inflected for: | | |
| Number | No | Yes |
| Person | Yes | Yes |
| Case | Yes | Yes but limited |
| <i>Verbal morphology</i> | Highly inflected morphology | Limited inflectional morphology |
| Base form (uninflected) | No (with the exception of unmarked 2nd person, imperative) | Yes |
| Verbs can be inflected for: | | |
| Mood | Marked with suffix | Marked with auxiliary and suffix |
| Tense | Marked with suffix | Marked with suffix |
| Aspect | Marked with suffix | Marked with auxiliary and suffix (-ing) |
| Person | Marked with suffix | Marked with suffix but limited |
| Number | Not marked | Marked with suffix, limited to third person singular |
| Gender | Not marked | |
| Honorification | Marked with suffix | Not marked |
| Particles (emphatic & negative) | Marked with suffix | Expressed analytically |
| Auxiliaries can be inflected for: | | |
| Mood | Not applicable | |
| Tense | Not applicable | Marked with suffix |
| Number | Not applicable | Marked with suffix but limited |
| Person | Not applicable | Marked with suffix but limited |

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931 **Table 2.** Demographics and neuropsychological assessment data for participants with
 932 Alzheimer's Disease (AD03 and AD09) and neurologically healthy controls (HC).

| Demographic | AD03 | AD09 | HC (n = 8) Mean (SD) |
|---|-------------------------------|-------------------------|---------------------------------|
| Age at the time of study (years) | 76 | 56 | 71.4 (4.2) |
| Education (years) | 14 | 17 | 16 (1.2) |
| Age at the onset of symptoms (years) | 73 | 52 | - |
| Sex | M | F | M=4 F=4 |
| Handedness | R | R | R |
| Occupation | Retired Electrical Supervisor | Retired English Teacher | |
| Neuropsychological measures | | | |
| Bengali version of Addenbrooke's Cognitive Examination-III^a | | | |
| Total (/100) | 40 | 31 | 92.6 (2.5) |
| Attention (/18) | 10 | 8 | 17.6 (0.7) |
| Memory (/26) | 9 | 4 | 25.4 (0.7) |
| Fluency (/14) | 1 | 1 | 8.0 (1.1) |
| Language (/26) | 12 | 15 | 25.9 (0.4) |
| Visuoconstructional (/16) | 8 | 3 | 15.8 (0.5) |
| Kolkata Cognitive Screening Battery (KCSB)^b | | | |
| Total (/30) | 20* | 16* | 30 (0) |
| Clinical Dementia Rating Scale^c | | | |
| Rating | 1* | 1* | 0 |
| Instrumental Activities of Daily Living (IADL-EDR)^d | | | |
| % Impairment | 50* | 36* | 0 |
| Verbal Fluency Scores | | | |
| Semantic (Animals) | | | |
| Bengali | 8 | 5 | 14.4 (3.6) |
| English | 6 | 7 | 12.3 (4.2) |
| Letter | | | |
| Bengali (Average) | | | |
| K | 15 | 6.6 | 12.7 (3.2) |
| P | 17 | 6 | 12.6 (3.7) |
| M | 15 | 4 | 12.3 (3.2) |
| M | 13 | 10 | 13.1 (2.8) |
| English (Average) | | | |
| F | 11.3 | 5 | 12.3 (4.5) |
| F | 9 | 5 | 12.4 (4) |
| A | 18 | ** | 13 (4.8) |
| S | 7 | ** | 11.6 (4.7) |

a- Hsieh et al. (2013)
 b- Adapted Bengali version of the Mini-Mental State Examination, BMSE (Das et al., 2006)
 c- Morris (1993); CDR score 0 = no dementia; 0.5 = questionable dementia; 1 = mild dementia; 2 = moderate dementia; 3 = severe dementia
 d- Mathuranath et al. (2005); IADL score of > 16 indicate impairment, with higher scores indicating greater impairment. Values in bold font = Score for each participant with AD was significantly lower compared to the control group mean ($p < 0.054$ on SingleBayes_ES; Crawford et al., 2010)
 *Statistical difference unable to be computed due to a standard deviation of 0
 **Participant was unable to complete these tests.

Table 3. Bilingualism Profiles of Participants with Alzheimer’s Disease (AD03 and AD09) and neurologically healthy controls (HC).

| Bilingualism measures | AD03 | | AD09 | | HC (n=8) | | | |
|---|--------------|--------------|--------------|--------------|--------------|-------------|--------------|-------------|
| | Bengali (L1) | English (L2) | Bengali (L1) | English (L2) | Bengali (L1) | | English (L2) | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Language Acquisition History | | | | | | | | |
| Language Acquisition ^a (/7) | 6 | 1 | 6.5 | 0.5 | 7 | 0 | 0 | 0 |
| Onset of exposure (age in years) | | | | | | | | |
| Formal (in classrooms, schooling) | 5 | 6 | 3 | 5 | 3.9 | 1.4 | 6.9 | 1.6 |
| Informal (interactions with friends, neighbors) | Since birth | 11 | Since birth | 5 | Since birth | 0 | 10.9 | 3.2 |
| Medium of instruction in education ('✓' indicates language(s) of instruction in school) | | | | | | | | |
| Primary school | ✓ | | ✓ | ✓ | | | | |
| Secondary school | ✓ | | ✓ | ✓ | | | | |
| High school | ✓ | | ✓ | ✓ | | | | |
| Undergraduate | ✓ | ✓ | ✓ | ✓ | | | | |
| Postgraduate | n/a | n/a | ✓ | ✓ | | | | |
| Current Language Proficiency Rating^b (/7) | | | | | | | | |
| Average | 7 | 2.38 | 7 | 5.88 | 7 | 0 | 5.08 | 1.58 |
| Speaking | 7 | 2 | 7 | 5.5 | 7 | 0 | 4.44 | 1.92 |
| Comprehension | 7 | 2.5 | 7 | 6 | 7 | 0 | 4.75 | 1.6 |
| Reading | 7 | 3 | 7 | 6 | 7 | 0 | 5.75 | 1.49 |
| Writing | 7 | 2 | 7 | 6 | 7 | 0 | 5.38 | 1.85 |
| Bilingual Language Dominance^c (/31) | | | | | | | | |
| Total score | 26 | -4 | 23 | 7 | 24 | 1.93 | 4.75 | 4.71 |
| Current language usage and frequency of usage^d | | | | | | | | |
| Average scores | 5 | 2 | 5 | 3.75 | 4.83 | 0.24 | 2.86 | 0.49 |
| At home | 5 | 1 | 5 | 3 | 5 | 0 | 1.63 | 0.74 |
| At community gatherings | 5 | 1 | 5 | 3 | 5 | 0 | 2.25 | 0.71 |
| At social gatherings | 5 | 2 | 5 | 4 | 4.75 | 0.71 | 2.75 | 0.89 |
| At formal situations | 5 | 4 | 5 | 5 | 4.75 | 0.71 | 3.14 | 1.07 |
| With Friends | 5 | 2 | 5 | 4 | 5 | 0 | 2.13 | 0.64 |
| Telecommunication | 5 | 1 | 5 | 3 | 5 | 0 | 2.75 | 0.89 |
| Reading | 5 | 3 | 5 | 4 | 5 | 0 | 3.88 | 0.64 |
| Writing | 5 | 2 | 5 | 4 | 4.13 | 0.64 | 4.5 | 0.76 |
| <p>a- Munoz et al. (1999), adapted by Patra et al. (2020); Maximum score of 7, with higher scores indicating greater immersion in that language in childhood.</p> <p>b- Munoz et al. (1999), adapted by Patra et al. (2020); Maximum score of 7, with 0 indicating no proficiency and 7 indicating native-like proficiency.</p> <p>c- Dunn & Fox Tree (2009), adapted by Patra et al. (2020); Maximum score of 31, with a higher score indicating greater dominance in that language compared to the other language.</p> <p>d- Rating of 1 indicates ‘not at all’ and 5 indicates ‘very often.’</p> | | | | | | | | |

935 **Table 4.** Illustrative samples of the “Frog, where are you?” story narrations in English and
 936 Bengali by AD03 and AD09, and one control participant (HC05). The excerpts are the first five
 937 utterances from their transcripts. English narration is transcribed orthographically. Bengali
 938 transcription follows five tier system: Tier 1 (Bengali orthographic transcription); Tier 2
 939 (transliteration with Indic Roman script); Tier 3 (Leipzig interlinear glossing*); Tier 4 (Word-by-
 940 word translation in English); Tier 5 (possible meaning in English).

941
 942 **AD03 (English)**

- 943 1) Boy is with the frog
 944 2) Dog
 945 3) Boy sleeping
 946 4) And the dog trying to go away trying to go out trying to go out
 947 5) The boy get up not seeing the dog

948
 949 **AD09 (English)**

- 950 1) The moon can be seen from the window
 951 2) And there is a there is a window below it
 952 3) And the child was there with um his um dog
 953 4) And and on the back the oh on the back there was ka ka cushion and and which the um child was sleeping
 954 5) And then the child come to the come to the and come to the went to the and started talking to him

955
 956 **HC05 (English)**

- 957 1) A child had two pets a frog and a dog
 958 2) While the dog roamed all over the house, the frog remained confined in a jar
 959 3) One day it so happened the frog went out of the jar
 960 4) The child was very anxious not to find his dear frog
 961 5) He looked for it within the house he turned many things

962
 963 **AD03 (Bengali)**

| | | |
|-----|---------|-----------|
| (1) | একটা | ছেলে |
| | ektā | chele |
| | ADJ-DET | NN-3.M.SG |
| | one | boy |
| | 'A boy' | |

964

| | | | | | | | | | |
|-----|--|---------|-----------|-----------|------|------|-----------|---------|-----------|
| (2) | এটা | একটা | কুকুর ... | কুকুর | ও | বা | সামথিং | এলস্... | বেডাল |
| | eṭā | ektā | kukur... | kukur | o | bā | something | else... | berāl |
| | PN-DEM | ADJ-DET | NN-3.N.SG | NN-3.N.SG | CONJ | COMP | PN-INDF.N | ADV | NN-3.N.SG |
| | this | one | dog... | dog | and | or | something | else... | cat |
| | This is a dog and a cat or something else' | | | | | | | | |

965

| | | | | |
|-----|------------------|--------------|-------|-----------|
| (3) | এটা | ফ্রগ ... | হ্যাঁ | ব্যাঙ |
| | eṭā | frog ... | hyā | byāñ |
| | PN-DEM | NN-3.N.SG... | FILL | NN-3.N.SG |
| | this | frog ... | yes | frog |
| | 'This is a frog' | | | |

966

| | | | | | | |
|-----|-----------|-----------|-----------|--------|-----|------|
| (4) | কুকুর | ছেলে | ডগ ... | এই | তিন | জন |
| | kukur | chele | ḍog... | ei | tin | jan |
| | NN-3.N.SG | NN-3.M.SG | NN-3.N.SG | PN-DEM | ADJ | QNTF |

| | | | | | | |
|--|---------------------------------------|-----|-----|------|-------|---------|
| | dog | boy | dog | this | three | persons |
| | 'Dog, boy and dog these three people' | | | | | |

967

| | | |
|-----|----------------|---------|
| (5) | আরেকটা | ঘর |
| | ārektā | ghar |
| | ADJ-CONJ.DET | NN-N.SG |
| | another | room |
| | 'Another room' | |

968

969

AD09 (Bengali)

| | | | |
|-----|----------------------|---------|-----|
| (1) | ঘরে | জানলা | 970 |
| | ghare | jānlā | 971 |
| | NN-N.SG-LOC | NN-N.SG | 972 |
| | in room | window | 973 |
| | 'Window in the room' | | 974 |
| | | | 975 |

| | | | | |
|-----|-------------------------------------|------|---------|------------------|
| (2) | বাইরে | উমম | চাঁদ | দেখা যাচ্ছে |
| | bāire | umm | cād | dekhā_ýacche |
| | ADV-LOC | FILL | NN-M.SG | FV-PRS-PROG-PASS |
| | at outside | umm | moon | is being seen |
| | 'The moon is being seen at outside' | | | |

976

| | | | | | | |
|-----|---------------------------------------|---------|---------|-----------|------|------------|
| (3) | নিচে | এখানে | একটা | কুকুর | অতঅ | বসে_আছে |
| | niche | ekhāne | ektā | kukur | aaa | base_āche |
| | POST-LOC | ADV-LOC | ADJ-DET | NN-3.N.SG | FILL | FV-PRS-3 |
| | At underneath | here | one | dog | aaa | is sitting |
| | 'A dog is sitting here at underneath' | | | | | |

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|-----|------------------------------|-------|---------|---------|---------------|----------|-----------|-----------|
| (4) | তার | নিচে | এখানে | একটা | ব্যাঙের | মতো | ব্যাঙ | বসে আছে |
| | tār | nice | ekhāne | ektā | byāner | mato... | byāñ | base_āche |
| | PN-3.N.SG | POST | ADV-LOC | ADJ-DET | NN-3.N.SG-GEN | ADJ | NN-3.N.SG | FV-PRS-3 |
| | of it | under | here | one | frog | like... | frog | sits |
| | 'A frog is sitting under it' | | | | | | | |

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|-----|---------------------|---------------|--------------|
| (5) | পেছনে | খাটটা | রয়েছে |
| | pechane | khāṭṭā | rayeche |
| | POST | NN-3.N.SG-DET | FV-PRS-PRF-3 |
| | behind | the cot | is present |
| | 'The cot is behind' | | |

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HC05 (Bengali)

| | | |
|-----|-------------|-----------|
| (1) | একটি | বাচ্চা |
| | ekṭi | bācchā |
| | ADJ-DET | NN-3.N.SG |
| | One | child |
| | 'One child' | |

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|-----|-----------|--------|-----|-----------|------|---------|-----------|
| (2) | তার | ছিল | এক | কুকুর | আর | একটি | ব্যাঙ |
| | tār | chhila | ek | kukur | ār | ekṭi | byāñ |
| | PN-3.N.SG | FV-PST | ADJ | NN-3.N.SG | CONJ | ADJ-DET | NN-3.N.SG |

| | | | | | | | |
|--|-------------------------------|-----|-----|-----|-----|-----|------|
| | His | had | one | dog | and | one | frog |
| | 'He had one dog and one frog' | | | | | | |

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|-----|---------------------------------------|-----------|--------|--------------|
| (3) | দুটোকেই | সে | খুব | ভালোবাসতো |
| | duṭokei | se | khub | bhālobāsto |
| | NN-3.N.PL.DET.EMPH | PN-3.M.SG | ADV | FV-PST.HAB.3 |
| | to both of them | he | deeply | love used to |
| | 'He used to love both of them deeply' | | | |

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|-----|--|--------------|--------------|------|---------------|--------------|---------|-----------|--------|
| (4) | কুকুর | বাইরেই | ঘুরে_ বেড়াত | আর | ব্যাঙটা | থাকত | একটা | জারের | মধ্যে |
| | kukur | bāirei | ghure_berāta | ār | byāñṭā | thākta | ekṭā | jārer | madhye |
| | NN-3.N.SG | ADV-LOC-EMPH | FV-PST.HAB.3 | CONJ | NN-3.N.SG.DET | FV-PST.HAB.3 | ADJ-DET | NN-3.N.SG | POST |
| | Dog | outside only | used to roam | and | the frog | used to live | one | of jar | inside |
| | 'Dog used to roam only outside and the frog used to live inside a jar' | | | | | | | | |

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|-----|---|---------------|---------------|---------------|--------|-----------|-------|--------------|
| (5) | যখন | ছেলেটি | ঘুমোচ্ছিল | ব্যাঙটি | সেই | জার | থেকে | বেরিয়ে পড়ল |
| | ṡakhan | chheleṭi | ghumochchhila | byāñṭi | sei | jār | theke | beriyē_paṛla |
| | ADV | NN-3.M.SG.DET | FV-PST.PROG.3 | NN-3.N.SG.DET | PN-DEM | NN-3.N.SG | POST | FV-PST.3 |
| | When | the boy | was sleeping | the frog | that | jar | from | went out |
| | 'When the boy was sleeping the frog got out of the jar' | | | | | | | |

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*Leipzig interlinear glossing codes: ADJ=Adjective; ADV=Adverb; COMP=Complementizer; CONJ=Conjunction; DAT=Dative; DEM=Demonstrative; DET=Determiner; EMPH=Emphatic; F=Feminine; FILL=Filler; FV=Finite verb; GEN=Genitive; INDF=Indefinite; INF=Indefinite; LOC=Locative; M=Masculine; N=Neuter; NN=Noun; PART=Particle; PASS=Passive; PN=Pronoun; POST= Postposition; PRF=Perfect; PROG=Progressive; PRS=Present; PST=Past; QNTF= Quantifier; SG=Singular; 1, 2, 3=1st, 2nd and 3rd person, respectively.

1011 **Table 5.** Definition of connected speech variables extracted. Checkmarks with an * (✓*) indicate
 1012 cross-linguistic differences expected in these variables due to the differences in linguistic
 1013 properties between Bengali and English.

| Variable Name | Variable Definition | Relevant for Bengali | Relevant for English |
|--|--|----------------------|----------------------|
| Speech rate | | | |
| Words per minute | Speech rate was defined as the number of words per minute, including repetitions, corrections, restarts, and paraphasias as well as patients' direct responses to the questions, but excluding indistinct strings of phonemes and discourse markers. | ✓ | ✓ |
| Structural and syntactic measures | | | |
| Mean sentence length | The average number of words produced per sentence. | ✓* | ✓* |
| Proportion of well-formed sentences | Total number of well-formed sentences divided by the total number of sentences. | ✓* | ✓* |
| Embedding index | Total number of embeddings divided by the total number of sentences. This measure provides a quantification for utterance complexity. Fewer embedding would imply less complex utterances. | ✓ | ✓ |
| Lexical measures | | | |
| Proportion of open class words | Total number of open class words divided by total number of narrative words. | ✓ | ✓ |
| Proportion of closed class words | Total number of closed class words divided by total number of narrative words. | ✓* | ✓* |
| Proportion of noun (N/all NW) | Total number of nouns divided by total number of narrative words. | ✓ | ✓ |
| Proportion of pronoun (P/all NW) | Total number of personal pronouns divided by total number of narrative words. | ✓ | ✓ |
| Proportion of verb (V/all NW) | Total number of verbs divided by total number of narrative words. | ✓ | ✓ |
| Proportion of postposition (Po/all NW) | Total number of postposition divided by total number of narrative words. | ✓* | NR |
| Proportion of preposition (Pr/all NW) | Total number of preposition divided by total number of narrative words. | NR | ✓* |
| Number of reduplication | Total sum of all reduplications. | ✓ | |
| Morphological and inflectional measures | | | |
| <i>Nouns inflections</i> | | | |
| Noun inflection index | Total number of appropriately inflected nouns to the number of nouns that are possible to be inflected. | ✓* | NR |
| Determiner index (determiner/noun) | Proportion of determiners produced in obligatory contexts. | NR | ✓* |
| <i>Verb inflections</i> | | | |
| Verb inflection index | Total number of appropriately inflected verbs to the number of verbs that are possible to be inflected. This is conceptually similar to the verb inflection index of the QPA in English. | ✓ | ✓ |
| Auxiliary Index (Aux/MV-1) | It is an index of elaboration of the auxiliary in matrix verbs and derived by taking the ratio of total auxiliary score to total number of matrix verb minus 1. | NR | ✓* |
| Semantic measures | | | |
| Number of CIU | The total number of intelligible, accurate and informative words that were relevant to the "Frog, where are you?" story (Nicholas & Brookshire, 1993) | ✓ | ✓ |
| CIU% (Idea density) | Total number of CIUs (i.e., semantic units) divided by the total number of words used in the sample. | ✓ | ✓ |
| CIUs per minute (Idea efficiency) | Total number of CIUs (i.e., semantic units) divided by the duration of the sample used for calculation of the CIUs. | ✓ | ✓ |
| Measures of spontaneity and fluency disruptions | | | |
| Total count of disruption of spontaneity and fluency | Sum of count of repetitions, revisions and reformulations. | ✓ | ✓ |
| NR = Not Relevant | | | |

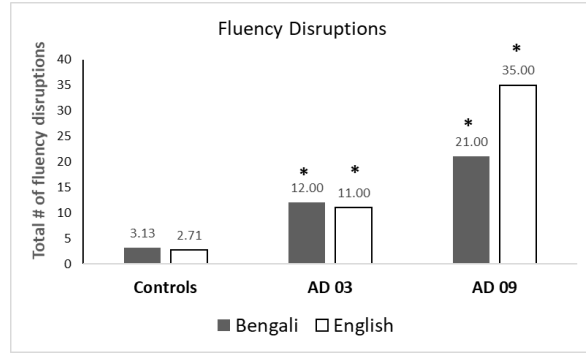
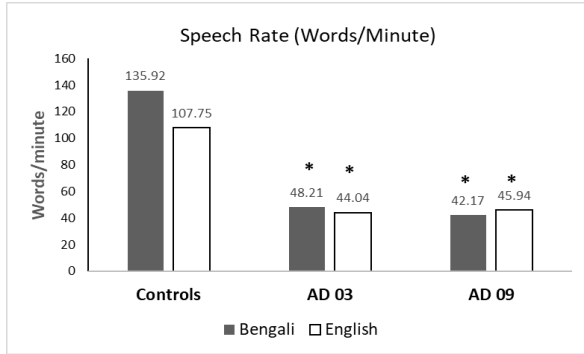
1014 **Table 6.** Results from the single-subject statistical analysis of connected speech variables for
 1015 participants with Alzheimer’s Disease (AD03 and AD09) in relation to neurologically healthy
 1016 controls (HC).

| Variable Name | AD03 | | AD09 | | HC | |
|---|---------------|---------------|---------------|----------------|----------------|----------------|
| | Bengali | English | Bengali | English | Bengali M (SD) | English M (SD) |
| Speech rate | | | | | | |
| Words per minute | 48.21* | 44.04* | 42.17* | 45.94* | 135.92 (31.89) | 107.75 (10.74) |
| Structural and syntactic measures | | | | | | |
| Mean sentence length | 4.31* | 5.77 | 3.34* | 6.70 | 7.59 (0.73) | 8.95 (2.16) |
| Proportion of well-formed sentences | 0.88 | 0.46* | 0.87 | 0.78 | 0.92 (0.07) | 0.89 (0.12) |
| Embedding index | 0.00* | 0.04 | 0.00* | 0.09 | 0.50 (0.18) | 0.21 (0.14) |
| Lexical measures | | | | | | |
| Proportion of open class words | 0.78 | 0.47 | 0.86* | 0.39* | 0.76 (0.04) | 0.47 (0.03) |
| Proportion of closed class words | 0.22 | 0.53 | 0.14* | 0.61* | 0.24 (0.04) | 0.53 (0.03) |
| Proportion of noun (N/all NW) | 0.31 | 0.23 | 0.32 | 0.19 | 0.33 (0.03) | 0.22 (0.03) |
| Proportion of pronoun (P/all NW) | 0.02* | 0.10 | 0.04* | 0.15 | 0.10 (0.03) | 0.14 (0.03) |
| Proportion of verb (V/all NW) | 0.25 | 0.24 | 0.28 | 0.18 | 0.24 (0.04) | 0.18 (0.03) |
| Proportion of postposition (Po/all NW) | 0.06 | NR | 0.12 | NR | 0.08 (0.02) | NR |
| Proportion of preposition (Pr/all NW) | NR | 0.10 | NR | 0.11 | NR | 0.11 (0.02) |
| Number of reduplications | 0* | NR | 0* | NR | 3 (2.78) | NR |
| Morphological and inflectional measures | | | | | | |
| <i>Nouns inflections</i> | | | | | | |
| Noun inflection index | 1.00 | NR | 0.92 | NR | 1.00 (0.00) | NR |
| Determiner index | NR | 0.82* | NR | 0.96 | NR | 0.98 (0.03) |
| <i>Verb inflections</i> | | | | | | |
| Verb inflection index | 1 | 0.89 | 1 | 1.00 | 1.00 (0.00) | 0.94 (0.07) |
| Auxiliary Index | NR | 1.07 | NR | 1.23 | NR | 1.00 (0.12) |
| Semantic measures | | | | | | |
| Number of CIU | 154 | 151.00 | 143* | 136.00* | 161.63 (5.71) | 149.43 (3.74) |
| CIU% (Idea density) | 63.90* | 59.92* | 49.48* | 51.71* | 90.87 (5.54) | 89.72 (4.86) |
| CIUs per minute (Idea efficiency) | 47.87* | 29.04* | 33.78* | 24.21* | 98.24 (15.93) | 97.91 (11.16) |
| Measures of spontaneity and fluency disruptions | | | | | | |
| Total count of disruption of spontaneity and fluency | 12* | 11* | 21* | 35* | 3.13 (2.90) | 2.71 (2.43) |
| Values in bold with asterisk = Score for each participant with AD was significantly lower compared to the control group mean ($p < 0.054$ on SingleBayes_ES; Crawford et al., 2010); NR = Not Relevant; N= Number of nouns; NW=Number of narrative words; P=Number of pronouns; V=Number of verbs; Po=Number of postpositions; Pr=Number of prepositions; CIU=Correct Information Units. | | | | | | |

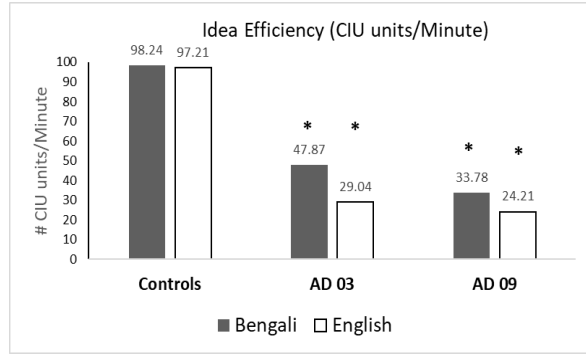
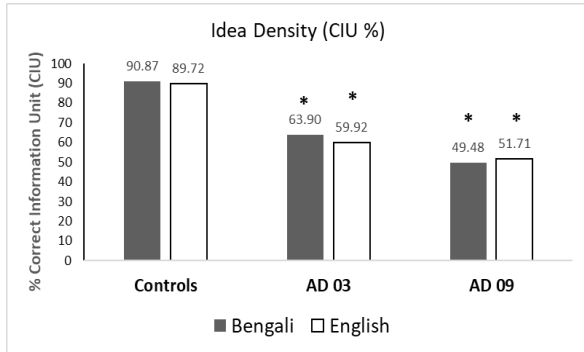
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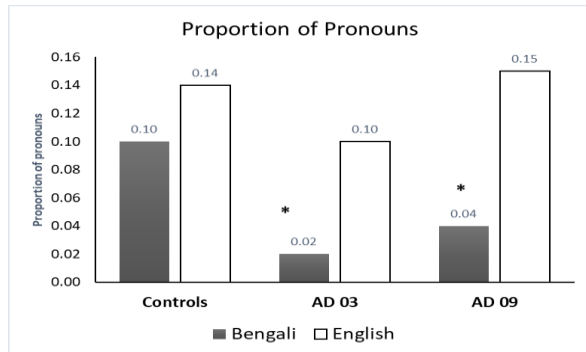
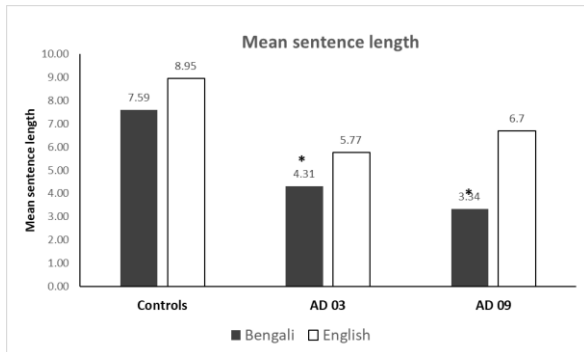
Figure 1. The top two panels illustrate the variables (speech rate, fluency disruptions, idea density and idea efficiency) that were affected both in Bengali and English for AD03 and AD09 in comparison of the healthy control group (HC). The lower bottom panel illustrates variables (mean sentence length and proportion of pronouns) that were only affected in Bengali for both participants. Asterix indicates significant difference from control group.



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