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Linguistic features of cognitive decline in aging adults

Mai Ahmed* · **Soon-Bok Kwon****
(Ain Shams University · Pusan National University)

Ahmed, Mai and Soon-Bok Kwon. 2025. Linguistic features of cognitive decline in aging adults. *Linguistic Research* 42(Special Edition): 213-231. With increasing life expectancy, there is a growing need to address age-related challenges, including cognitive decline. This study aims to investigate the semantic and syntactic linguistic characteristics of cognitive decline in the speech of Korean speakers. Speech samples were collected from 51 Korean-speaking participants using two tasks: picture description and interview. Participants were categorized into three groups based on cognitive status: Normal Cognitive (n=17), Mild Cognitive Impairment (n=17), and Dementia (n=17). The collected speech samples were manually transcribed, and various linguistic features were extracted and analyzed using One-way ANOVA. The findings revealed that cognitive decline significantly impacts both semantic and syntactic aspects of language. Specifically, noun, verb, and case marker usage decreased with increasing cognitive impairment. Additionally, cognitive decline was associated with simplified syntax, characterized by shorter sentences and fewer clauses. Lexical diversity decline was also observed in individuals with cognitive impairment. These findings demonstrate that cognitive decline significantly affects both semantic and syntactic characteristics of speech in Korean speakers. Future research should consider longitudinal studies to further investigate the dynamic progression of language changes across different stages of cognitive deterioration. **(Ain Shams University · Pusan National University)**

Keywords cognitive decline, semantic cohesion, syntactic complexity, lexical richness, mild cognitive impairment

* First author
** Corresponding author

1. Introduction

According to the World Health Organization's 2023 fact sheet, the number of people worldwide living with dementia has reached an estimated 55 million. This figure is alarming, with an estimated 10 million new cases emerging each year (WHO 2023). In 2018, the global dementia prevalence was estimated at 35 million (Banovic et al. 2018), indicating a significant increase of 20 million within five years, largely attributed to the aging global population. This trend is particularly pronounced in South Korea, which boasts a rapidly growing elderly population (aged 65 and older). In 2011, the number of people aged 65 and older with dementia in South Korea exceeded 50,000, constituting approximately 9.2% of the population (Kim 2012). This figure has surged to 786,000 in 2021 and is projected to rise dramatically as the population aged 65 and older is expected to comprise over 39% of the older adult population by 2030 (Shin 2022).

Dementia (hereafter, De) poses a significant challenge in the modern era of increasing human life expectancy. The rapidly aging population necessitates a societal shift in focus towards the needs of the elderly, including addressing the challenges associated with cognitive decline. As no definitive cure currently exists for De, particularly Alzheimer's Disease (hereafter, AD), early detection of cognitive decline and the implementation of interventional memory training methods are crucial. These strategies aim to delay or mitigate the progression of cognitive decline (Riley et al. 2022).

Driven by the need for cost-effective and non-invasive methods of detecting cognitive decline, research efforts have expanded to encompass various domains, including motor skills, eye movements, and speech detection (Alsuhaibani et al. 2024). This paper focuses on the latter, exploring the detection of cognitive decline in elderly speech by analyzing linguistic features. As highlighted by König et al. (2015) and Huang et al. (2024), speech signals can serve as valuable biomarkers for tracking the progression of cognitive decline. Since syntactic information and linguistic retrieval is connected with memory(Lee and Yoo 2023), decline in memory functions is bound to affect language use.

Prior research extensively analyzes the impact of cognitive decline on speech, revealing that various linguistic indicators serve as crucial signs of cognitive impairment. Studies have consistently shown that cognitive decline affects lexical usage,

syntactic complexity, speech fluency, and content coherence. These findings underscore the potential of language analysis as a non-invasive diagnostic tool.

Specifically, research highlights changes in lexical and content-related features. Forbes-McKay and Venneri (2005) observed that AD patients struggled with specific descriptions in picture tasks, increasing their use of non-specific terms, indicating a decline in semantic language abilities linked to cognitive impairment rather than just age. Bueno-Cayo et al. (2022) found a positive correlation between higher lexical density and better cognitive function, suggesting that richer vocabulary is linked to stronger cognitive abilities. Furthermore, multiple studies including Fraser et al. (2016, 2019), Mueller et al. (2018), Pompili et al. (2020), and Gumus et al. (2024) consistently reported a decrease in noun and verb usage alongside an increase in pronoun use as cognitive function declines. Fraser et al. (2016) attributed this to impaired semantic processing, leading to a reliance on more abstract pronouns. Taler and Philips (2008) also observed that individuals with neurodegenerative diseases often experience impairments in semantic content and lexical fluency, noting that these deficits can manifest even in the early stages of Mild Cognitive Impairment (hereafter, MCI).

Regarding syntactic and coherence features, research indicates a simplification of sentence structures. Kemper et al. (1993) noted that while syntactic structures might remain relatively intact in AD, speech coherence often suffers, characterized by reduced clause counts and conjunction usage. Moreover, Croot et al. (1999) observed a decline in sentence comprehension in patients during cognitive decline. While Pompili et al. (2020) and Gumus et al. (2024) reported that neurodegenerative diseases lead to simpler sentences, shorter vocabulary, and reduced use of prepositional phrases, signifying an impaired ability to construct complex sentences. De Looze et al. (2021) further elaborated that spontaneous speech requires integrated cognitive functions, implying that damage to these processes can lead to diminished linguistic coherence.

Lastly, in terms of speech fluency, Yeo and Kim (2020) investigated language characteristics in De and AD, focusing on working memory's impact on language production and reception, revealing significant differences in phonological fluency and narrative comprehension between these two groups. Meanwhile, Antonsson et al. (2021) demonstrated the predictive power of analyzing speech content for cognitive decline in individuals with MCI. Their findings indicated that speech unrelated to the main topic was a highly effective distinguishing feature.

This study aims to investigate the linguistic characteristics in the spontaneous

speech of elderly Korean native speakers with cognitive decline. While a growing body of research explores the link between speech patterns and cognitive decline in various languages, there remains a notable gap in comprehensive studies focusing on Korean native speakers. Given the distinct grammatical structure, unique vocabulary, and cultural nuances of the Korean language, findings from studies in other languages may not be directly transferable, especially since cultures play a big role in forming and differentiating language patterns and linguistic behaviors (Lee 2024). Therefore, by analyzing spontaneous speech samples from elderly Korean native speakers, this research specifically intends to address and fill this critical gap in understanding the specific linguistic changes that emerge as a result of cognitive decline within this population.

2. Method

2.1 Participants

This study included a total of 51 Korean-speaking volunteers (42 females, 9 males) recruited from Busan and surrounding areas. Participants were divided into three groups based on their cognitive health status: a Normal Cognitive group (NC), a Mild Cognitive Impairment group (MCI), and a Dementia Suspected group (De).

Group assignment was determined by the Cognitive Impairment Screening Test (CIST), a standardized screening tool developed specifically to assess cognitive abilities for elderly Koreans. Each participant underwent the CIST, and group placement was adjusted based on the individual's age and education level, as the CIST score is interpreted relative to these factors.

Participants achieving scores at or above the age- and education-adjusted threshold for cognitive health were classified as belonging to the NC group. Those scoring within 6 points below the threshold were categorized as MCI, and those scoring below this range were classified as De. The study comprised 17 participants in the NC group (15 females, 2 Males), 17 in the MCI group (13 females, 4 males), and 17 in the De group (14 females, 3 males). Demographic information of the participants is presented in Table 1. As presented in the table the differences in age and education between the three groups were not of statistical significance. Only the differences in

CIST scores were proven to be statistically significant.

Table 1. Demographic information by group (mean and standard deviation)

Category	NC	MCI	De	P-value
N (%)	17 (33.3%) 15 F, 2 M	17 (33.3%) 13 F, 4 M	17(33.3%) 14 F, 3 M	
Age (SD)	82.3(5.26)	83.8(6.4)	81.6(6.34)	0.565
Education (SD)	8.5(4.53)	7.35(2.73)	8.53(5.35)	0.675
CIST (SD)	21.9(3.72)	12.35(3.08)	7.11(3.67)	<.0001

Note. SD= standard deviation.

2.2 Speech tasks

Two tasks were employed to elicit spontaneous speech from participants: a picture description task and an interview task. The picture description task utilized the "Cookie Theft" picture from the Boston Diagnostic Aphasia Examination(Goodglass and Kaplan 1983), a widely used tool in previous research on speech analysis in cognitive impairment (Muller et al. 2018; Slegers et al. 2018; Sadeghian et al. 2021; Shimoda et al. 2021; Kim et al. 2024). This iconic picture depicts a scene of a mother washing dishes at a sink overflowing with water, while a boy stands precariously on a chair attempting to reach a cookie jar on a shelf, and a young girl reaches for a cookie (Meilán et al. 2020).

The interview task consisted of three questions designed to elicit responses across a range of emotional states: "What is a happy memory you remember?", "What is a sad memory you remember?", and "Explain how to make Myeokkuk (seaweed soup) or Ramyeon (noodle soup)". The latter question aimed to elicit responses related to neutral emotional states.

Both tasks were selected to capture spontaneous speech. Notably, the interview task aimed to elicit speech that relied on long-term memory and recollection, providing valuable insights into the participants' memory function.

2.3 Linguistic features

Spontaneous speech production requires significant cognitive resources, including complex neural processes for word retrieval, syntactic sentence construction, and semantic coherence (De Looze et al. 2021). Furthermore, simplified syntactic structures can be indicative of cognitive decline (Gumus et al. 2024).

Building upon the observations of Fraser et al. (2016), Mueller et al. (2018), and Gumus et al. (2024) this study will examine syntactic and semantic features such as the mean length of sentence, number of clauses per sentence, and the use of subordinate phrases. This study will also investigate lexical diversity features that include part-of-speech distributions (e.g., nouns, pronouns, verbs, adverbs, adjectives), vocabulary richness measures (type-token ratio, Honore's statistics, Hapax legomena, Hapax dislegomena), and content density.

Furthermore, following Mueller et al. (2018), who identified semantic measures as indicators of cognitive decline, this study will analyze coherence-related features such as the ratio of repetitions, word revisions (false starts), pronoun and verb index relative to text size, and the frequency of conjunctions and case markers, as these features may reflect the regularity and coherence of speech. An overview of features under analysis and their definitions is demonstrated in Table 2.

Table 2. Definitions of linguistic variables under analysis

Variable		Definition
Semantic	pronoun index	no. of pronouns divided by the sum of nouns+ pronouns
	verb index	no. of verbs divided by the no. of utterances
	ratio of word type	ratio of nouns to verbs, ratio of pronouns to nouns
	Dysfluency	no. of false starts and revisions, no. of repetitions, no. of fillers
	Coherence	no. of conjunctions, no. of case markers, no. of connective endings
Syntactic	mean length of sentence	total number of words (excluding dysfluencies and repetitions) divided by the number of sentences
	text size	total number of sentences

	syntactic complexity	no. of clauses per sentence, no. of subordinate phrases (no. of transformative endings + no. of connective endings)
	type-to-token ratio	total number of types divided by number of tokens TTR = V/N
Lexical	Honore's Statistics	measures lexical density but where higher values meaning denser texts.
	Hapax legomena	no. of words mentioned once
	Hapax dislegomena	no. of words mentioned twice
	Content density	total number of verbs, nouns, adjectives, and adverbs divided by the number of tokens
	Part of speech ratio	no. of nouns, no. of verbs, no. of pronouns, no. of adjectives, no. of adverbs

2.4 Analysis tools

The speech recordings were captured using a TASCAM Portacapture X8 (TEAC AMERICA, INC. CA, USA) at a sampling rate of 192 kHz and 32-bit quantization. The recordings were saved in WAV format.

Manual transcriptions of speech samples were created. Part-of-speech tagging was then performed using UTagger 4, a Korean text tagging tool developed by Ulsan University. The tagged text was subsequently analyzed with AntConc (version 4.0.0) to extract features such as part-of-speech ratios, type-token ratio, filler words, conjunctions and case marker frequency. Additional features, including the number of utterances and average sentence length, were determined manually.

All extracted features were statistically analyzed using one-way ANOVA to assess overall group differences. Subsequently, a post-hoc analysis with Least Significant Difference (LSD) was conducted to identify specific pairwise group differences.

3. Results

Table 3 presents the results of the statistical analysis conducted on the extracted linguistic features.

Table 3. Statistical analysis of speech linguistic characteristics data

Variable	Mean	SD	F	P-value
Pronoun index	0.67	0.30	2.75	0.074
Verb index	2.47	1.65	1.79	0.178
Noun to verb ratio	1.77	0.75	2.36	0.105
Pronoun to noun ratio	1.49	1.36	1.49	0.235
Fillers	8.16	5.36	2.24	0.118
Revisions and false starts	6.15	4.52	0.07	0.937
Repetitions	7.61	5.32	0.96	0.392
Conjunction	0.59	1.72	1.54	0.225
Case markers	12.47	9.83	5.65	0.006**
Connective endings	28.94	14.63	2.33	0.108
Mean length of sentence	10.30	3.67	6.02	0.005**
Count of sentence	19.41	7.94	0.92	0.404
Clauses per sentence	3.89	1.08	8.22	>.001***
Subordinate phrases	37.57	18.70	3.35	0.04*
Word type to token ratio	1.31	0.22	1.66	0.2
Honore's statistics	407.6	86.36	4.59	0.015*
Hapax legomena	48.22	21.51	3.70	0.03*
Hapax dislegomena	12.61	7.27	3.96	0.02*
Content density	1.50	0.16	0.94	0.396
Nouns	25.84	15.45	5.21	0.009**
Pronouns	11.12	7.37	0.08	0.924
Verb	29.69	14.78	4.38	0.018*
Adverb	8.47	6.68	0.39	0.678
Adjective	13.69	9.52	2.03	0.142

Note *p<.05, **p<.01, ***p<.001

The table reveals significant group differences across several categories, including semantic, syntactic, and lexical variables. Notably, the frequency of case marker usage between the three groups demonstrated statistically significant differences, which may be indicative of variations in coherence with cognitive decline progression. Regarding syntactic characteristics, significant group differences were observed in mean sentence length, the number of clauses per sentence, and the frequency of subordinate clause-related endings. Furthermore, several semantic and lexical density features, such as noun frequency, verb frequency, Honore's statistics, and the frequency of hapax legomena and hapax dislegomena, exhibited significant differences across the groups.

3.1 Semantic features

Figure 1 presents boxplots illustrating the distribution of noun, pronoun, and verb usage across the three groups.

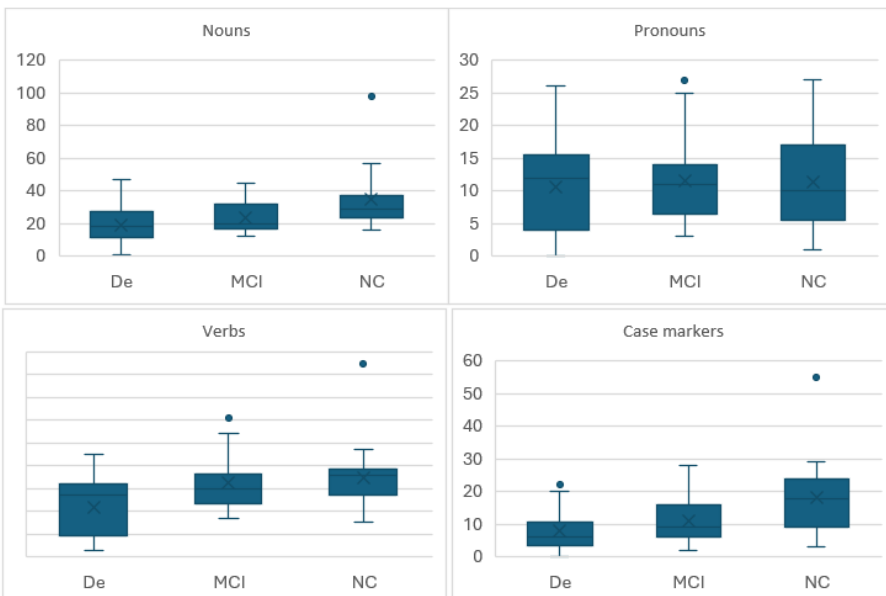

Figure 1. Boxplot of statistically significant part of speech variables

A clear pattern emerges in which the distribution of nouns and verbs decreases as cognitive ability deteriorates. However, contrary to the expected increase in pronoun

usage as a potential substitute for nouns, no clear trend or significant difference in pronoun frequency was observed across the groups. This lack of a significant trend is reflected in both the part-of-speech pronoun frequency feature and the pronoun index, neither of which showed statistically significant differences between the groups. Statistically significant differences were observed only in noun and verb frequencies across the groups. As for the frequency of case markers, it exhibited a similar trend to noun and verb frequencies decreasing with increasing cognitive impairment. These differences of case marker frequency were also statistically significant across the groups.

Post-hoc analysis of statistically significant data revealed that significant differences in noun frequency and case marker frequency were observed between the NC group and both the MCI (MCI-NC) and De (De-NC) groups. Significant differences in verb frequency were found between the De group and both the MCI group (De-MCI) and the NC group (De-NC). These findings suggest that noun frequency and case marker use are significantly impacted across the different stages of cognitive deterioration, while verb use impairment is particularly pronounced in the De stage. However, the post-hoc analysis did not reveal significant differences in noun usage between the MCI and De groups, indicating that the impact of cognitive decline on noun usage may not necessarily progress consistently across all stages of deterioration.

3.2 Syntactic features

Figure 2 illustrates the group differences observed for the statistically significant syntactic variables.

Both mean sentence length and the number of clauses per sentence were highest in the NC group, followed by the MCI group, and then the De group. This trend, however, was not reflected in subordinate clause endings frequency. The NC and MCI groups exhibited relatively similar averages in subordinate clause endings usage, whereas the De group demonstrated a reduced tendency to employ subordinate clauses or markers indicative of subordinate clauses.

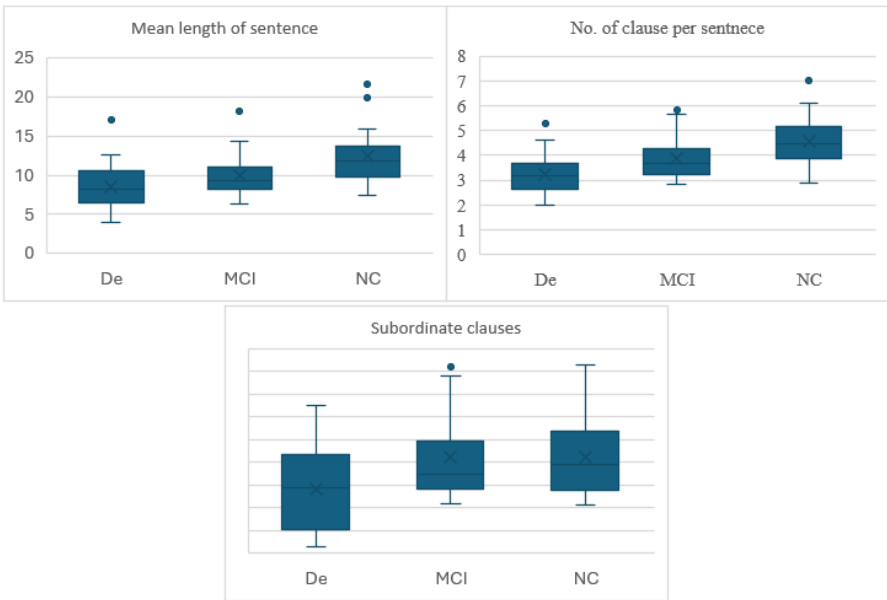

Figure 2. Boxplot of statistically significant Syntactic variables

Post-hoc analysis of the statistically significant variables revealed that significant differences in mean sentence length and the number of clauses per sentence were found between the De group and the NC group (De-NC), and the MCI group and the NC group (MCI-NC). This suggests that syntactic factors may also be affected across the different stages of cognitive deterioration compared to healthy cognitive ability. However, syntax complexity may be primarily affected in the more progressed stage, as significant differences regarding subordinate clauses were only found between the De and NC groups, and the De and MCI groups.

3.3 Lexical diversity

Figure 3 showcases the group differences observed for the statistically significant lexical diversity reflecting variables.

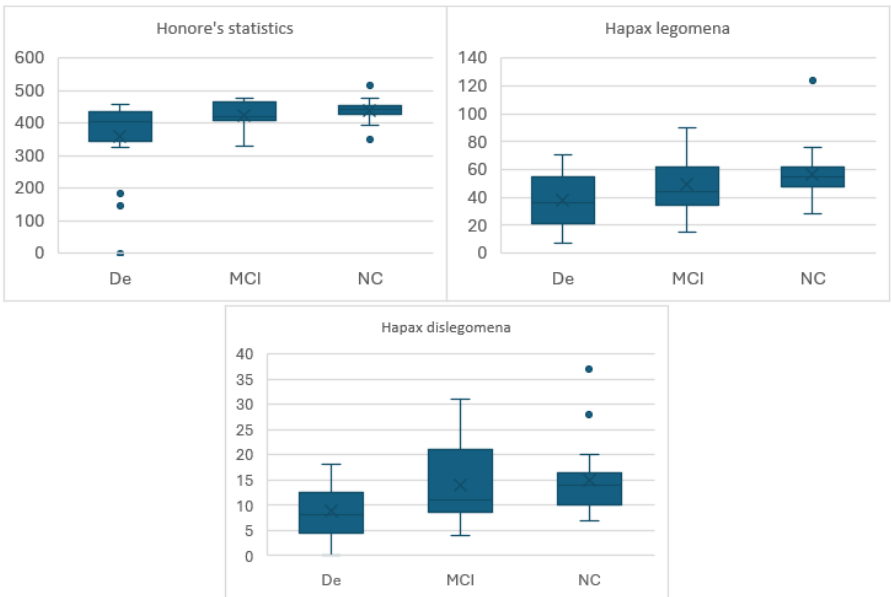

Figure 3. Boxplot of statistically significant Lexical diversity variables

Lexical diversity also appears to be affected in the latter stages of cognitive impairment, as both Honore's statistics and Hapax dislegomena showed significant differences between the De-NC and De-MCI groups. Hapax legomena also showed significant differences but only between the De group and the NC group. This indicates that while lexical diversity is significantly impacted by cognitive impairment, the effect may not necessarily follow a consistent progression that mirrors the progression of cognitive decline.

4. Conclusion

This study aimed to investigate the relationship between cognitive decline and language abilities for Korean speakers. Participants were divided into three groups based on their cognitive status (NC, MCI, and De). And spontaneous speech samples were collected from each participant using a picture description task and an interview task. The collected speech samples were manually transcribed and analyzed for various linguistic features, including part-of-speech distributions, lexical diversity, syntactic

complexity, and semantic density. Then One-way ANOVA was employed to analyze the overall group differences in these linguistic features.

This study demonstrated that cognitive deterioration significantly impacts both semantic and syntactic aspects of language. Noun and verb usage were significantly affected by cognitive decline, reflecting impairments in semantic retrieval abilities, which are closely linked to memory function. Significant differences were also observed in syntactic features such as mean sentence length, the number of clauses per sentence, and subordinate clause marker frequency, suggesting that individuals with impaired cognitive functions tend to produce shorter and simpler sentences compared to those with normal cognitive function. Among the examined features related to coherence, only case marker usage exhibited significant differences across groups, specifically a decrease with increasing cognitive impairment. The results also show that lexical diversity is affected by cognitive impairments. However, this effect is not pronounced in the earlier stages of decline, as post-hoc analysis revealed that these features are primarily affected in the De stage.

Post-hoc analysis revealed significant group differences primarily in noun and case marker frequency, mean sentence length, and the number of clauses per sentence. In these features, differences were observed between both the De group and the NC group, and the MCI group and the NC group, indicating that these markers might be affected even in the early stages of cognitive impairment. These findings suggest that cognitive decline, particularly memory-related difficulties in word retrieval, impacts not only semantic and lexical density features but also syntactic features of language use.

Our findings align with previous research on the impact of cognitive decline on language. Previous research (Choi et al. 2013; Mueller et el. 2018; Vigo et al. 2022) findings observed that early-stage cognitive impairment is often reflected in changes in semantic and lexical features of speech. Individuals with MCI show a decrease in noun and verbal fluency. In some cases MCI even exhibit greater deficits in verb retrieval compared to noun retrieval when compared to cognitively healthy individuals. Furthermore, these findings demonstrated that the impact of cognitive impairment extends beyond verbal fluency and affects grammatical abilities (Yeung et al. 2021), such as the use of case markers, as observed in our study.

Regarding semantics, Kemper et al. (1993), Pompili et al. (2020), and Gumus et al. (2024) have found that De, particularly AD, significantly impacts coherence which

is a crucial aspect of semantic ability. Decreased coherence is manifested by a reduction in the number of clauses and conjunctions, indicating difficulties with composing complex sentences and maintaining grammatical complexity in individuals with De. There is a clear link between neurological deterioration and simplified sentence structures, reduced word formation, and a decrease in the use of prepositional phrases.

However, Beltrami et al. (2018), Abvien et al. (2021), and Antonsson et al. (2021) have highlighted the significance of speech dysfluencies, such as fillers, as indicators of cognitive deterioration. This finding is also supported by Ha et al. (2009) who studied the effect of cognitive deterioration on increased production of fillers in Korean patients. But these findings were not observed in our results. That is, our study did not observe statistically significant differences in speech dysfluencies, such as repetitions and false starts, across the groups. Additionally, several studies such as Fraser et al. (2016), Mueller et al. (2018), Fraser et al. (2019), and Pompili et al. (2020) have reported an increase in pronoun usage alongside a decrease in noun usage in individuals with cognitive impairment. While our study also observed a decrease in noun usage, we did not find a statistically significant increase in pronoun usage.

These discrepancies between our findings and those of previous studies may be attributed to several factors such as linguistic differences. The observed differences might be partially attributed to general tendencies in specific languages. Meaning the general linguistic tendencies of Korean language use is different than that of English or French. Another explanation would be the differences in population size (analysis sample) and tasks used to derive speech which seem to affect the significance of features. That is, a feature's statistical significance of relation with cognitive impairment seems to depend to some extent on the task that has been used to derive the speech of the participant (Yamada et al. 2022; Yoshii et al. 2023).

In conclusion, the findings of this study provide compelling evidence that cognitive deterioration significantly impacts various aspects of language production for Korean speakers. Firstly, our results demonstrate a clear association between cognitive decline and word retrieval difficulties, manifested by a decrease in the use of both nouns and verbs, and lexical diversity related features such as Honore's statistics and Hapax legomena and dislegomena. Secondly, we found that the frequency of case markers and subordinate clause markers can also serve as valuable indicators of cognitive impairment in the speech of Korean patients. And lastly, our analysis revealed that cognitive deterioration significantly affects syntactic complexity, as evidenced by

reductions in mean sentence length and the number of clauses per sentence. These findings collectively suggest that cognitive decline not only impacts semantic fluency but also exerts a profound influence on grammatical and syntactic aspects of language production.

The analysis of speech characteristics from this study offers innovative possibilities for the clinical diagnosis of cognitive decline, presenting a significant advantage over current assessment methods which are often time-consuming, costly, and demand specialized personnel. By leveraging speech features, diagnosis can become non-invasive and highly accessible, utilizing readily available and inexpensive tools like voice recorders. The integration of these findings with AI-powered automated speech analysis systems holds immense future potential for large-scale, early screening, facilitating prompt intervention, reducing burdens on patients and caregivers, and enhancing healthcare system efficiency. Specifically, our findings demonstrate a clear association between cognitive decline and word retrieval difficulties, providing a promising avenue for early detection through speech fluency. Furthermore, observed changes in syntactic complexity, offer vital content-based linguistic markers for diagnosing cognitive decline, emphasizing the importance of detailed speech analysis in future clinical evaluations.

Finally, this study has several limitations that warrant consideration for future research. One of these limitations is the relatively small sample size which may have limited the results. A larger sample size would enhance the statistical power of the analysis and potentially uncover additional significant features. Another is that the study relied on only two speech tasks to elicit spontaneous speech once for sampling the speech of each participant. A longitudinal study employing these tasks would provide valuable insights into the linguistic changes across the progression of cognitive deterioration. Additionally, the current study involved manual transcription of the Korean speech data, which is a time-consuming and labor-intensive process. Investigating the feasibility and efficiency of using automatic speech recognition (ASR) systems for Korean speech transcription would significantly enhance the efficiency and scalability of future studies on cognitive impairment detection using linguistic features.

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Mai Ahmed
Assistant Teacher
Department of Korean Language and Literature
Ain Shams University
2, Busandaehak-no
83beon-gil, Geumjeong-gu,
Busan, 46241, Korea
E-mail: ahmed.mai@pusan.ac.kr

Soon-Bok Kwon
Professor
Department of Language & Information
Pusan National University
2, Busandaehak-no
83beon-gil, Geumjeong-gu,
Busan, 46241, Korea
E-mail: sbkwon@pusan.ac.kr

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