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Indicators of Mild Cognitive Impairment Associated with Language Processing and Production

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by

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Abstract

The research purpose of the present study was to (1) examine cognitive-linguistic features related to processing and production across a series of tasks that are representative of everyday discourse and (2) compare older adults with and without mild cognitive impairment (MCI) across linguistic features. Twenty-seven participants, including 12 individuals with- and 15 individuals without MCI, were enrolled from a larger study (Hudak et al., 2019). Cognitive status was initially assessed as part of the larger study using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). Participants who scored ≤ 25 on the MoCA received a standardized neuropsychological evaluation and a physician's examination to confirm or exclude a diagnosis of MCI.

For the current study, participants were additionally administered cognitive-linguistic measures. Measures consisted of obtaining a severity rating and complexity index from the Boston Diagnostic Aphasia Examination (BDAE) and extrapolating linguistic features from a series of speech-language samples (i.e., Semi-Structured Interview/Free Conversation adapted from the BDAE, Picture Description adapted from the BDAE, Story Narration task). For the purposes of this dissertation, the analytic sample for the BDAE and speech-language measures consisted of 16 participants (n=8 MCI, n= 8 Non-MCI) of the total sample of 27 older adults. This study also examined Lexical Decision-Making from the larger sample of 27 older adults with and without MCI.

Descriptive analysis of 98 linguistic features extrapolated across the three speech-language sample types was completed to identify potentially promising

variables for further analyses. Thirty-eight variables had zero variance and were not further analyzed. Correlation analysis was conducted to assess the relationships among the remaining 60 linguistic features within type of speech-language sample. To further reduce the number of dependent variables for subsequent analyses, composites were created by combining linguistic variables that were highly correlated (i.e., $r \geq .6$), as they are likely assessing the same skill. Next, correlation analysis of the linguistic variables to MoCA scores was completed. Results indicated seven linguistic variables with medium-strong correlations ($r \geq .45$) with MoCA: these variables were examined in subsequent analyses. These seven variables included two composites related to (1) empty utterances, phonemic errors, repetitions and (2) filled pauses and indefinite terms and five individual linguistic variables related to agrammatic deletions, mean length of utterances (in both free conversation and story narration task), repetitions, and correct informational units. It was also noted that four of the seven variables correlated to MoCA performance were from the story narration-wordless picture book task.

Next, a multivariate analysis of variance (MANOVA) was conducted to examine group performance on the seven dependent variables (two composites and five individual linguistic variables) that were correlated with MoCA at $r \geq .45$. Overall, individuals with and without MCI did not differ significantly across linguistic features, Wilk's $\Lambda = .484$, $F(7, 8) = 1.218$, $p=.391$, partial η 2 = .516. Results of follow-up univariate analysis of variance (ANOVA) indicated significant differences between older adults with and without MCI on linguistic features extrapolated from the wordless picture book - story narration task, related to agrammatic deletions, $p=.020$ and mean length of utterances, p=.020. Those with MCI had more agrammatic deletions and shorter mean length of utterances than those without MCI.

Finally, to examine group differences in Lexical Decision-Making average accuracy rate, a two (high versus low-density) x three (word, filler, pseudo) repeated measures ANOVA was completed. Results indicated no significant differences between those with and without MCI on the Lexical Decision-Making task, Wilk's Λ = .992, F(3, 23) = .065, p = .978, partial η^2 = .008. Findings additionally indicated statistically significant effects for high versus low-density conditions, Wilk's Λ = .358, F (3, 23) = 13.750, p < .001, partial η^2 = .642, but no significant interaction between high versus low-density conditions and MCI group, Wilk's Λ = .950, F (3, 23) = .403, p = .752, partial η^2 = .050. Average accuracy rates were better in the low-density condition for the word- and filler stimuli and better in the high-density condition for the pseudo stimuli.

Overall, findings indicate that linguistic features extrapolated from connected speech-language samples are useful in identifying cognitive-linguistic performance that is correlated to MoCA and shows group differences between persons with and without MCI. Specifically, the composite linguistic features correlated to MoCA score were related to (1) empty utterances, phonemic errors, repetitions and (2) filled pauses and indefinite terms. Individual linguistic variables correlated to MoCA were related to agrammatic deletions, repetitions, mean length of utterances, and correct informational units. The linguistic features that differed by MCI status were related to agrammatic deletions and mean length of utterances. These features affect the quality of syntax and speech-language processing and production. Deficits in these areas often result in increased communication breakdowns, losing their communicative turns, significant impacts on interpersonal relationships, and as a result have increased social isolation (M. Johnson & Lin, 2014; Mueller, Hermann, Mecollari, & Turkstra, 2018). Findings further support the importance of utilizing higher-level discourse tasks that facilitate observation of natural interactions of lexical units at the sentence or conversational level to detect cognitive-linguistic deficits. Specifically, the current findings indicated that the story narration – wordless picture book task was more effective in eliciting cognitive-linguistic features that significantly differ between persons with and without MCI. Additionally, the present study supports previous research highlighting the importance of developing optimal manual and/or automated ways to measure and analyze cognitive-linguistic features.

Chapter 1: Introduction

Overall quality of life and well-being become ever more important topics as adults pass from midlife to older age. Reports indicate that the United States population of adults age 65 and older is expected to double from 49 million to 95 million by 2060 (US Census Bureau, 2018; Vespa, Armstrong, & Medina, 2018). Older adults fear the development of neurodegenerative diseases such as mild cognitive impairment (MCI) or dementia such as Alzheimer's disease (AD; Corner & Bond, 2004; Kelley, McGarry, Gorges, & Skinner, 2015; Morris et al., 2001), which pose a threat to their health, quality of life, independence in daily function, and increase in health care costs (Knopman & Petersen, 2014; Langa, 2018; Reese, Cherry, & Norris, 1999). The negative impact of MCI and dementia extends to the family and caregivers of the individuals diagnosed, as well as the health care systems (Hill, Fillit, Thomas, & Chang, 2006; Kronborg Andersen, Lauridsen, Andersen, & Kragh-Sørensen, 2003). The overall goal of the present work is to explore the relationships between MCI and aspects of language processing and production, referred to as linguistic features. In order to understand the relevance of this work several areas will be briefly reviewed starting with a description of MCI.

1.1 Mild Cognitive Impairment

MCI is a clinical condition between normal aging and dementia, characterized by significant impairment(s) in one or more cognitive domains (e.g., executive function, attention, visuospatial) in the presence of otherwise normal global cognitive functioning

(Petersen, 2004). According to epidemiological studies, approximately 22% of adults over the age of 70 have cognitive impairment, 14% have dementia, and approximately 7.7 million new cases of dementia are diagnosed each year (Kelley et al., 2015; Plassman et al., 2008; Sosa-Ortiz, Acosta-Castillo, & Prince, 2012; Williams, Plassman, Burke, Holsinger, & Benjamin, 2010). These findings are of importance to MCI research as they indicate that approximately 12% of persons with MCI convert to AD per year (Petersen et al., 1999; Roberts & Knopman, 2013) . This represents a six-fold increase compared to older adults without MCI indicating that persons with MCI have a higher probability of progressing to dementia. Thus, MCI is a risk factor for dementia such as AD.

1.2 Early Identification of Cognitive Impairment

The time that elapses from when the individual starts experiencing declines in their cognitive-linguistic abilities to the time they are diagnosed with MCI and/or AD can span many years (Petersen et al., 1999; Plassman et al., 2008; Voleti, Liss, & Berisha, 2019). During this time, the individual may discuss these declines with their family, friends, caregiver, or even mention it to their primary care physician during their yearly wellness check. However, such concerns are often overlooked or attributed to normal aging when in fact, these are the early subtle signs of cognitive decline (Clionsky & Clionsky, 2011; De Lepeleire, Heyman, & Buntinx, 1998). The growing number of older adults with cognitive-linguistic impairment and the lack of awareness among healthcare professionals indicate a dire need for advances in research focused on identifying effective approaches to early detection (Alzheimer's Association, 2019). As healthcare is increasingly encouraging interprofessional education and practice (A. Johnson, 2016), it is imperative that primary care physicians as well as allied health professionals work collaboratively to identify early signs and symptoms of cognitive decline, know when to screen, know what to screen for, educate their patients and caregivers, and know when to refer in order to initiate intervention as early as possible. Interestingly, although interprofessional education and interprofessional practice have been advocated for more than 40 years by the Institute of Medicine, studies indicate that physicians need improvement in recognition and documentation of early cognitive-linguistic impairment and are, in fact, unaware of MCI in more than 40% of their patients (Chodosh et al., 2004). Therefore, it can be concluded that cognitive screenings are not part of older adult patients' routine annual physical examinations and cognition is only addressed if the patient or family/caregiver informs of noticeable cognitive changes that are affecting their everyday function. It is estimated that if intervention delayed the onset or progression of AD by just one year, it would result in 9.2 million fewer cases of the disease in 2050 (Hebert, Scherr, Bienias, Bennett, & Evans, 2003). The impact would not only extend to individuals diagnosed with MCI but also their family, caregivers, community, as well as the health care systems (Hill et al., 2006; Kronborg Andersen et al., 2003).

1.3 Linguistic Indicators of Mild Cognitive Impairment

Neurogenerative disease such as MCI and dementia share characteristic changes related to speech and language processing and production (Boschi et al., 2017; Voleti et al., 2019). They additionally share changes related to memory dysfunction, executive deficits, and speed of processing. However, memory dysfunction in addition to semantic and verbal linguistic impairments are accentuated in MCI and dementia (Drummond et al., 2015; Toepper, 2017). Therefore, assessment of language processing and production could be a vital part in the clinical process of diagnosing MCI. This is especially important in cases where language impairment is masked by other age-related deficits. Impairments in processing of visual or auditory information, working memory, speed of processing, and comprehension and transmission of linguistic information (Boschi et al., 2017; V. B. Fleming, 2013; V. B. Fleming, & Harris, J. L., 2008) sometimes make it difficult to differentiate the cognitive-linguistic deficits attributed to normal aging from those that are indicative of cognitive impairment. For this reason, language difficulties of people with MCI or AD are described as cognitive-linguistic impairments because, as the term highlights, linguistic deficits are secondary to deficits in cognitive abilities (Hallowell, 2016).

1.4 Cognitive-Linguistic Ability

The term cognitive-linguistic highlights the fact that language is an intrinsic part of cognition (Ibarretxe-Antuñano, 2004). Theories of resource capacity, speed of processing, and inhibition indicate that, as individuals age, their capacity to complete increasingly demanding cognitive-linguistic tasks diminishes (Burke & Shafto, 2008; Hasher, Lustig, & Zacks, 2007). For example, age-related reductions in speed of processing affect the ability to store, retain, and retrieve new lexical and semantic information (Thornton & Light, 2006), resulting in word finding difficulties and decreased word generation abilities as compared to younger adults. However, in people with MCI this is noted to a greater extent (Cuetos, Arango-Lasprilla, Uribe, Valencia, & Lopera, 2007; V. B. Fleming, & Harris, J. L., 2008). The difficulty lies in distinguishing normal age-related cognitive-linguistic performance from performance that are pathological.

One avenue to distinguish between normal versus pathological cognitive-linguistic deficits is to assess cognitive-linguistic abilities at initial stages of concern (Chapman et al., 2002). The next step would be to follow individuals to determine if these abilities predict later cognitive decline. Our scientific premise is that subtle changes in linguistic processing and production may be sensitive indicators of MCI and could lead to early diagnosis and early treatment (V. B. Fleming, 2013; Voleti et al., 2019).

Given the high prevalence (Plassman et al., 2008; Williams et al., 2010) and health and economic burdens associated with MCI and AD, (Kelley et al., 2015) there is an increased focus on identifying early indicators of cognitive decline that may lead to early diagnosis and effective treatments to deter dementia. However, research has focused on subjective complaints of memory impairment as the primary indicator of MCI (V. B. Fleming, 2013; Luck, Luppa, Briel, & Riedel-Heller, 2010), and limited research has given attention to indicators of MCI associated with language processing and production (Snowdon et al., 1996; Voleti et al., 2019). One of the early studies examining MCI and language processing was conducted by Snowdon and colleagues (1996) who investigated linguistic ability in early life as a predictor of cognitive impairment or presence of AD in later life. Linguistic abilities (i.e., idea density and grammatical complexity) derived from written autobiographies of 93 participants with a mean age of 22 years. The participants' cognitive function was again assessed approximately 58 years later. Results indicated that 80% of subjects who lacked grammatical complexity in early life later developed mental or cognitive disabilities or developed AD. These results suggest that early assessment of cognitive-linguistic deficits related to linguistic ability and complexity may serve as an indicator of dementia

(Snowdon et al., 1996). Early detection may create an opportunity for implementation of cognitive-linguistic interventions that may enhance cognition and maintenance of everyday abilities, thereby delaying the onset of dementia and reducing social and economic impact.

1.5 Measuring Cognitive-Linguistic Ability

Linguistic features are used to describe quantitative and qualitative variables of language production such as words per minute, speech rate, semantic errors, information content, mean length of utterance, etc. Unfortunately, across studies, linguistic features have been measured using a variety of tools and using varying levels of speech complexity (i.e., word, sentence, conversation) limiting the ability for studies to be replicated and reproduced (Mueller, Koscik, et al., 2018). In addition, only one or two features are often measured and the manner in which linguistic features are classified varies among studies, making generalizations and comparisons difficult (Boschi et al., 2017; Voleti et al., 2019). Some studies (Adlam, Bozeat, Arnold, Watson, & Hodges, 2006; Albert, Moss, Tanzi, & Jones, 2001; Berisha, Wang, LaCross, & Liss, 2015) use low-demand language tasks like counting particular words types or naming at the word level. These types of language tasks do not elicit a natural flow of communication exchange, making them less cognitively demanding. Other studies (Arkin & Mahendra, 2001; Boschi et al., 2017; Cannizzaro & Coelho, 2013; Peintner et al., 2008; Smith, Ash, Xie, & Grossman, 2018) utilized higher-level cognitive-linguistic tasks that require interactions of lexical units at the sentence or conversational discourse level, which emulates a more natural form of communication.

Natural discourse is elicited via semi-spontaneous connected speech tasks, such as picture description, story narration, and spontaneous connected speech tasks via an interview. This level of communication requires concurrent use of executive functions such as working memory, planning, inhibition, and self-regulation and elicits all levels of language organization and production (i.e., phonetic, phonological, lexico-semantic, morpho-syntactic, and pragmatic processing) (Boschi et al., 2017). Cognitive-linguistic disorders can affect one or more of these stages (Voleti et al., 2019). From natural discourse, one may pull a variety of linguistic features (e.g. speech rate, reaction time, number and length of pauses, phonemic errors, semantic errors, word finding difficulties, repetitions, perseverations, length of utterances, form and syntax, coherence, efficiency, lexicality, information units). Therefore, natural discourse tasks, such free conversation, picture description, and story narration tasks, may be more useful for detecting the early subtle linguistic changes in MCI than utilizing word level tasks (Boschi et al., 2017; Cannizzaro & Coelho, 2013; Chapman et al., 2002; Tsantali, Economidis, & Tsolaki, 2013).

While extrapolating linguistic features from connected speech-language samples is a promising tool, it is difficult, time consuming, and requires expertise in manual and automated speech analysis procedures (Boschi et al., 2017). Analysis procedures are highly variable, depending on the length of the sample. For example, analysis of one ten-minute speech-language sample alone can take between three to four hours between transcribing, editing the audio recording (e.g. separating clinician speech from client's speech), and extrapolating the linguistic features (e.g. identifying and measuring pauses from breaths, counting morphemes, counting semantic errors). While automated systems (Owren, 2008; Team, 2014) can aid in some of these analyses, manual analyses are often still required to capture variables related to context, variety of syntactic structure, and implicit meaning (Crowston, Allen, & Heckman, 2012). Additionally, prior to utilizing the automated systems and in order to effectively use them, the clinician must invest time in learning how to use the software to complete the analyses.

1.6 Linguistic Markers of Cognitive Impairment

Research studies (Chapman et al., 2002; V. B. Fleming, & Harris, J. L., 2008; Taler, 2008) investigating markers of MCI or AD indicate that deficits in language ability such as longer response times and lower accuracy rates (Duong, Whitehead, Hanratty, & Chertkow, 2006) present early in the course of the disease, even before subjective complaints of memory impairment or MCI diagnosis. These findings highlight the importance of identifying speech-language processing and production deficits associated with or predictive of cognitive impairment. Furthermore, early assessment of speech-language processing and production in combination with memory screening measures could provide a more comprehensive and accurate representation of an individual's cognitive-linguistic abilities. Researchers (Cuetos et al., 2007; Fraser, Meltzer, & Rudzicz, 2016) analyzing the cognitive-linguistic abilities of normal healthy adults and adults with MCI noted that although symptoms were not overtly noticeable, the MCI group presented with subtle deficits in cognitive-linguistic abilities related to information content (i.e., semantic units and objective situations) during connected speech tasks. It is important to note that none of the participants (Cuetos et al., 2007) reported subjective memory complaints and that the cognitive-linguistic deficits were the earliest indicators of cognitive impairment. Other researchers (Ahmed, Haigh, de Jager, & Garrard, 2013) similarly found that patterns of cognitive-linguistic deficits such as less informative discourse content, reduced syntactic complexity, and impairments of speech production, fluency, and semantic content noted early at the MCI stage continued to decline until an AD diagnosis was made.

In a recent effort to provide an exhaustive description of studies characterizing cognitive-linguistic profiles of people with neurogenerative diseases, a systematic review (Boschi et al., 2017) reported a total of 120 linguistic features across 61 studies that showed significant group differences in at least one statistical comparison. The linguistic features reported in this review of various studies were categorized in one of five linguistic levels: phonetic-phonological (i.e., speech and sound level), lexico-semantic (i.e., word and content level), morpho-syntactic (i.e., word inflection and agreement), syntactic (i.e., general structural grammatical violations and incomplete sentences), and discourse-pragmatic (i.e., continuation of conversation, cohesion, coherence, correct use of pronouns and conjunctions). For example, speech rate was measured by number of words per minute while mean length of utterance was measured by averaging the number of morphemes (i.e., smallest grammatical unit in a language) or words per utterance. The linguistic features were extrapolated from speech-language samples and measured independently from each other to create linguistic profiles for healthy controls and neurodegenerative disease groups (Boschi et al., 2017; Smith et al., 2018). Results indicated the MCI linguistic profile included lexico-semantic differences between persons with and without different types of MCI, and in the case of AD, linguistic profiles indicated higher number of pronouns, decreased topic maintenance, and global coherence differences between the AD group and normal healthy participants. It should be noted that, although the overall discussion of the systematic review was positive for using analysis of linguistic features as a clinical tool, the studies were plagued with small sample size and mixed use of methodology (i.e., types of tasks and data analysis procedures), making direct comparisons across studies difficult (Boschi et al., 2017). For example, 75% of the studies investigating connected speech in MCI or AD analyzed these samples at the lexico-semantic and discourse-pragmatic levels while 35% of the studies looked at morphological domains (Boschi et al., 2017). Only two studies looked at the phonetic and phonological levels affecting MCI. Therefore, this indicates the importance of further research of cognitive-linguistic features utilizing standardized methodology in order to encourage comparisons and develop effective clinical protocols that can be reproduced, replicated, and applied across patient populations. Additionally, further research is needed to elucidate which linguistic variables provide the most valuable information across patient populations (Voleti et al., 2019).

The long-term goal of this line of research is to identify cognitive-linguistic features that can serve as predictors of MCI. The research purpose of the present study was to (1) examine cognitive-linguistic features related to processing and production across a series of tasks that are representative of everyday discourse and (2) compare older adults with and without MCI across linguistic features.

Chapter 2: Method

2.1 Participants

Participants were recruited from the Keys to Staying Sharp study (Hudak et al., 2019) at the University of South Florida (USF). For the larger study, participants were required to be at least 60 years of age, have the ability to speak, understand, and read English, have adequate hearing acuity (pure-tone thresholds <70 dB HL in the mid-frequency range (e.g., 1000, 2000 Hz) in at least one ear as determined by a standard hearing evaluation, and intact vision (binocular near visual acuity of 20/40 or better). Additional inclusion criteria were a Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) score ≥ 20. Those with moderate or worse depression as determined through a score on the Geriatric Depression Scale (GDS; Sheikh & Yesavage, 1986; Yesavage, 1988) of a score ≥5 or those with evidence of dementia, head injury, stroke, or other neurological disorders were excluded. For detailed inclusion/exclusion criteria for Keys to Staying Sharp study, please see the complete study description (Hudak et al., 2019).

Participants from the larger study were required to further meet additional inclusion criteria of willingness to have study visit audio recorded and willingness to come to the USF Motor Systems lab for up to two visits. Participants who reported a diagnosis of a neurological disorder, such as dementia including Alzheimer's disease were excluded. Additional criteria were applied for recruitment of a joint dissertation study focused on balance function as indicators of MCI (Nasreddine et al., 2005).

These additional criteria excluded participants who had experienced back or neck pain, recent cervical or spinal fracture, neck surgery or trauma that restricts torsional movement, discomfort or difficulty moving head up, down, left and right. Participants were also excluded if they were not willing to be observed by students, could not walk unassisted for two minutes, or had any known allergies to skin lotions, topical creams, or gels.

Twenty-seven participants in total were enrolled from the larger study (Hudak et al., 2019). The 27 participants included 12 diagnosed with MCI- and 15 without MCI. The criteria for MCI diagnosis and assessments used in the determination of MCI are described below. Participant demographics are presented in Tables 1 and 2. An analytic sub-sample for the current study consisted of 16 participants (n=8 MCI, n=8 Non-MCI). Demographics for the analytic sample are shown in Table 3 below.

Table 1

Frequency Statistics for Participant Demographics.

Demographic Category	**Frequency**	**Percentage**
Females	15	55.6%
Black	3	11.1%
Biracial	1	3.7%
Other Race	1	3.7%
Hispanic/Latino Ethnicity	2	7.4%

Table 2

Summary Statistics for Participants by Cognitive Status.

Measure	Non-MCI (n = 15)		MCI (n = 12)	
	M	*SD*	*M*	*SD*
Age in years	72.73	6.912	72.67	7.037
Education in years	16.93	2.576	16.75	2.563
MoCA score out of 30	25.80	2.145	23.58	1.676

Note. MCI = mild cognitive impairment; MoCA = Montreal Cognitive Assessment.

2.2 Measures

Study measures included a cognitive evaluation from the Keys To Staying Sharp study and a cognitive-linguistic evaluation for the current study.

2.2.1 Cognitive Evaluation

2.2.1.a Montreal Cognitive Assessment (MoCA)

The MoCA (Nasreddine et al., 2005) was administered to screen cognitive status and determine potential eligibility. The MoCA is a standardized cognitive screening tool with a 94% sensitivity in identifying dementia and 90% sensitivity in identifying MCI. Participants who received a score of 26 or above were considered cognitively normal, deemed eligible, and did not complete a clinical evaluation. Participants who scored below 20, which is indicative of dementia were excluded (Nasreddine et al., 2005). Those who received a score between 20 and 25 were asked to complete a clinical evaluation consisting of standardized neuropsychological tests to further determine MCI status and exclude dementia.

2.2.1.b Clinical Dementia Rating Scale

The clinical evaluation included the administration of the Clinical Dementia Rating Scale, which is an instrument for dementia staging (Hughes, Berg, Danziger, Coben, & Martin, 1982). The scale requires ratings in six categories of function (e.g., memory, orientation, judgment and problem solving, community affairs). This instrument is widely used for staging severity of dementia and demonstrates strong convergent validity with cognitive measures and acceptable inter-rater reliability (kappa .58-.85) (McCulla et al., 1989). A Clinical Dementia Rating Scale score of 0.5 was required to be diagnosed with MCI (Hughes et al., 1982).

2.2.1.c National Alzheimer's Coordinating Center Data Set

Next subtests of the National Alzheimer's Coordinating Center Uniform Data Set (Morris et al., 2006; Weintraub et al., 2018) neuropsychological battery was administered. The battery subtests included the Functional Assessment Scale which was administered to the participant's informant, the Craft Story 21 Recall immediate and delayed subtests, the Benson Complex Figure Copy immediate and delayed subtests, the Multilingual Naming Test, and Clinical Diagnosis Form completed by study physician. These subtests assess functional activities of older adults in everyday and community activities, immediate and delayed memory, processing speed, executive function, language, and constructional ability.

2.2.2 Cognitive-Linguistic Evaluation

The cognitive-linguistic evaluation for the current study consisted of obtaining a severity rating and complexity index from the Boston Diagnostic Aphasia Examination (BDAE) 3rd Edition (Goodglass, Kaplan, & Barresi, 2001) applied to the scoring of the speech-language samples and extrapolating linguistic features from three types of speech-language samples (i.e., Semi-Structured Interview/Free Conversation adapted from the BDAE, Picture Description adapted from the BDAE, Story Narration task), and a visual Lexical Decision-Making task, which was analyzed for the larger sample.

Scoring of the BDAE 3rd Edition (Goodglass et al., 2001) was applied to performance on the adapted free conversation, picture description, and story narration tasks in order to obtain a severity rating based on speech output characteristics. A complexity index which provides information regarding the complexity of the participants utterances was also derived based on performance on the adapted free conversation and picture description tasks. These scores provide information related to the participants language skills based on perceptual modalities (auditory, visual, and gestural) and processing functions (comprehension, analysis, problem-solving). The BDAE's reliability coefficients based on The Kuder-Richardson method (Kaplan, 1983) indicate good internal consistency, with about two-thirds of the coefficients reported ranging from .90 upwards among the subtests. The reading, writing, and extended sections (i.e., oral agility, automatized sequences, repetition, Boston Naming Test, screening of special categories) of the BDAE were not administered.

For the semi-structured interview and free conversation task, the participant was engaged in an interview which included a combination of predefined open-ended and close-ended questions. The semi-structured interview was adapted from the simple social response portion of the BDAE combined with a free conversation task. The participant was subsequently prompted to talk about a topic of their choice and include as much detail as possible for approximately 3 to 5 minutes. This type of interview imposes output related to pragmatic and discourse processing (i.e., individual utterances in context and organized set of utterances) (Horn & Kecskés, 2013).

The picture description task was adapted from the BDAE utilizing the Cookie Theft Picture scene. The participant was instructed to tell a detailed story that contains a beginning, middle, and end about everything they see in the scene. The picture description is a visual cognitive-linguistic task with a highly variable task duration that can range between 1 and 10 minutes. This type of task imposes a predictable speech output that should contain key elements of the depicted scene.

For the final story narration-wordless picture book task, the participant was given a wordless picture book (i.e., Frog Where Are You?) (Mayer, 1969; Reilly, Losh, Bellugi, & Wulfeck, 2004) where a sequence of pictures depicted a story and given time to preview and familiarize themselves with the book. The participant was then asked to tell a story including as much detail as possible using the pictures of the wordless book starting from the first page through the end of the book. They were told that they could use their imagination, as well as the pictures in the book. They were additionally told that the story should include a beginning, a middle, and an end. The participants were given as much time as they needed to complete the task. The story narration task is a visual cognitive-linguistic task that imposes a relatively structured speech output that should follow a predefined temporal and sequential order. The task duration is highly variable and can range between 5-20 minutes.

A visual Lexical Decision-Making task composed of 320 randomly presented trials that was adapted from a previous study (Azevedo, Kehayia, Atchley, & Nair, 2015) and administered to participants by computer using MATLAB 2018 experiment software

(MATLAB MathWorks, 2018). For each trial, participants had a fixation cross that appeared as an “X”, followed by a stimulus of lower-case string of letters that remained on the screen until the participant made a response via a button press. All stimuli were controlled in terms of frequency and length (Azevedo et al., 2015). Latency (i.e., response time in seconds measured from stimulus presentation until a response was made) and accuracy scores for each trial were collected. These scores contribute to the average accuracy rate collected on 80 nonwords and three types of words (1) 80 experimental English words, (2) 80 filler words (3) 80 pseudowords across two conditions (1) high neighborhood density (HND) and (2) low neighborhood density (LND), meaning the numbers of words that can be generated by substituting one letter of a target stimulus while preserving letter positions. Thus, the seven categories of stimuli were HND Experimental English Words, LND Experimental English Words, HND Filler Words, LND Filler Words, HND Pseudowords, LND Pseudowords, and Nonword stimuli. Participants were administered three practice trials consisting of six items randomly presented for each trial. The participant was required to achieve 80% accuracy on each practice trial in order to move on to the next. For the present study average accuracy rates were obtained based on accurately the participant decided whether the visual stimuli represented a word or not.

2.3 Procedures

All participants were recruited from a prior study (Hudak et al., 2019) in which up to two in person study visits (i.e., cognitive evaluation) were completed to assess their eligibility. Participants from the larger study who demonstrated interest in volunteering were telephone screened to assess additional inclusion criteria. Those who met the inclusion criteria were scheduled for an in-person study visit to complete cognitive-linguistic testing. Thus, the present study included data from the prior study for the cognitive evaluation in addition to the cognitive-linguistic testing for the current study. Cognitive-linguistic testing for the current study consisted of obtaining a BDAE severity rating and complexity index score, sampling of speech-language processing and production through three cognitive-linguistic tasks (i.e., free conversation adapted from the BDAE, picture description adapted from the BDAE, and story narration-wordless picture book) for 16 of the 27 participants, and a visual lexical-decision making task for the larger sample of 27 participants. Written informed consent was obtained at the start of the study visit prior to enrollment.

2.3.1 Cognitive Evaluation

Cognitive function testing took place at the USF Cognitive Aging Lab. For those showing potential cognitive impairment, a clinical evaluation was completed to determine if participants presented with MCI or dementia. The duration of the clinical evaluation was about 2½ to 3 hours. Prior to the clinical evaluation, participants were reminded to bring a copy of any lab results that have been completed in the past year and bring their reading glasses and hearing aids, if they used them. They were also asked to have an adult accompany them who was knowledgeable of their daily routines (such as a spouse, child, sibling, or good friend) to serve as an informant regarding change in cognition and everyday activities. The testing visit consisted of a brief interview with the informant who was asked to leave the testing room and the visit continued with the individual participant. Trained clinicians administered the neuropsychological tests to the participants. Once the testing visit was completed, the certified tester scored all instruments and provided the results to as well as escorted the participant to the study physician. The study physician reviewed the results, conducted an exam and interview with the participant, and then provided final diagnosis or exclusion of MCI or dementia.

The diagnosis of MCI was based on stringent clinical and neuropsychological criteria with a detailed clinical history including medications that could affect cognition, assessment of cognitive and functional decline, assessment of depressive symptoms, and rigorous neurological and psychiatric exams. Criterion for MCI diagnosis (Albert et al., 2001) included (a) evidence of change in cognition obtained from an informant or a skilled clinician, (b) cognitive performance on one or more cognitive domains at least 1 standard deviation lower than expected based on age and education, (c) preservation of independence in functional abilities despite some cognitive problems, and (d) no dementia.

2.3.2 Cognitive-linguistic Evaluation

Cognitive-linguistic testing took place at the USF Speech Motor Systems Lab in a sound booth testing room by two master's level students, and one undergraduate senior enrolled in the Communication Sciences and Disorders program at the USF. Prior to enrolling participants and to establish consistency, each student completed two mock sessions utilizing tester step by step administration protocols and was observed by the study coordinator. After each student completed their mock sessions and their mock folders were re-scored by the study coordinator, they were certified as testers.

The duration of the cognitive-linguistic evaluation visit was approximately 2 ½ to 3 hours. Speech-language samples were recorded in a sound booth using a headset with XLR microphone (Shure WH20, Shure, Niles, IL, USA). Signals were digitized via a Komplete Audio 6 external sound card with XLR inputs (Native Instruments, Los Angeles, CA) at a sampling rate of 44.1 kHz and 16-bit quantization level. Mic-mouth distance was maintained at 4-5 cm and microphone was placed at 45-degree angle. A sound level meter was placed on the table 30 cm from the participants mouth to ensure a stable loudness recording level.

2.3.2.a Scoring and Linguistic Feature Extrapolation

Agreement for scoring of the samples and extrapolating the linguistic features was established next using two samples initially coded by each student. Each student individually scored the samples and then met to review the errors and their feature classifications with the study coordinator and with each other. If there was a disagreement in the way a feature was to be coded, the differences were discussed during a weekly lab meeting and resolved by looking at the linguistic features through various perspectives based on the literature until agreement was established. After each session, the folders were scored, the audio-recordings of the participants' verbal responses for each of the speech-language samples were saved and transcribed. The linguistic features were then extrapolated from each of the samples, classified, and entered into the USF Box drive computer system containing study data for later analyses. Inter-rater agreement was defined as the consistency in coding across different testers. The samples used to check inter-rater agreement were randomly selected by a third party. The study coordinator recoded 10% of already scored folders for each tester. Inter-rater agreement was computed at 98%. Overall, the testers demonstrated a high degree of accuracy in their coding of the speech-language samples.

Due to the time commitment and complexity of extrapolating linguistic features from connected speech-language samples and for the purposes of this dissertation, linguistic features were extrapolated and analyzed from three types of speech-language samples (i.e., Semi-Structured Interview/Free Conversation, Picture Description from the BDAE, Story Narration task) for 16 (8 MCI and 8 Non-MCI) of the participants. See Table 3 for demographics of this analytic sample. For the current study, a total of 30 linguistic features (see Table 4) adapted from a prior systematic review (Boschi et al., 2017) were extrapolated utilizing a combination of manual and automated (Owren, 2008; Team, 2014) methods. Linguistic features were extrapolated and analyzed from a total of 48 speech-language samples.

Table 3

Participant Demographics for Analytic Sample.

Measure	**Non-MCI** (n = 8)		**MCI** (n = 8)	
	M	*SD*	*M*	*SD*
Age in years	75.00	7.329	71.75	4.979
Education in years	16.93	2.576	16.75	2.563
MoCA score out of 30	23.75	2.082	25.75	2.188

Note. MCI = mild cognitive impairment; MoCA = Montreal Cognitive Assessment.

Table 4

Linguistic Features Obtained from Speech-Language Samples and their Definitions.

Linguistic Level	Linguistic Feature	Description
Phonetic and Phonological		
	Speech rate	Total number of words per minute including fillers
	Number of pauses (≥ 50 ms)	Total number of pauses produced greater than 50 milliseconds in the middle 60 seconds of the sample.
	Number of pauses (≥ 250 ms)	Total number of pauses produced greater than 250 milliseconds in the middle 60 seconds of the sample.
	Number of pauses WHOLE SAMPLE (≥ 30 ms)	Total number of pauses produced greater than 30 milliseconds in the whole sample.
	Number of pauses WHOLE SAMPLE (≥ 50 ms)	Total number of pauses produced greater than 50 milliseconds in the whole sample.
	Phonemic errors	Total number of phoneme substitutions, additions, and deletions.
	Hesitation ratio (≥ 30 ms)	The number of times there is an absence of speech lasting more than 30 milliseconds, not attributed to taking a breath. The absence must occur before a thought/content word.
	Total locution time	Total time of speech sample in seconds, containing both speech and pauses.
	Filled pauses	Total number of words such as “um”, “hmmm”, “uhu”, and “aah.”
	False starts	Total number of partial words.
Lexico-Semantic		
	Pronoun rate	Total number of pronouns divided by total number of words.
	Semantic errors	Number of times a target word is replaced by a term that could be identified as a semantically related item.
	Word finding difficulties	Total number of word-finding difficulties indicated by a pause, an immediate repetition of a previous word, or production of an indefinite term.
	Indefinite terms	Total number of empty words without specific meaning, non-specific nouns or pronouns that made ambiguous or general reference.
	Revisions	Total number of pause positions where the speaker retraces a preceding error and then makes a correction.
	Perseverations	Total number of items appearing out of context after or before the appearance at the grammatically correct place.
	Repetitions	Total number of immediate word repetitions.

Table 4 (Continued)

Linguistic Level	Linguistic Feature	Description
Morphosyntactic Syntactic		
	Mean length of utterance	Mean number of morphemes per utterance.
	Total number of utterances	Total number of sentences or any effort to express a thought that is terminated by a pause with a falling inflection
	Incomplete sentences	Total number of sentences that are abandoned after producing subjects and verbs.
	Empty utterances	Total number of interjections or comments that are not related to the picture or story at hand (i.e., "oh my goodness…", "this is hard!", "I can't remember!").
	Agrammatic deletions	Total number of omissions of a grammatically obligatory word ("he was boy" vs. "he was a boy") or inflectional ending (i.e., "he was run" instead of "he was running").
	Complexity index (BDAE)	Based on the Free Conversation and Picture Description tasks, the complexity index is derived from the number of multi-clause utterances and excludes the number of empty utterances.
Discourse and Pragmatic		
	Total number of words	Total number of words in the speech sample including fillers.
	Correct pronoun	Total number of correct pronominal reference.
	Information content	Total number of relevant, truthful, and non-redundant utterances.
	Correct informational units	Total number of accurate current informational units related to subjects, places, objects, and actions, and narrative sequences.
	Implausible or irrelevant details	Total number of utterances that are not reasonable or connected and are given in addition to the central topic.
	Topic Maintenance	Total number of information content as described above divided by total number of disruptive topic shifts.
	Efficiency	Total number of correct informational units as described above divided by duration of speech sample in seconds.
	Severity rating (BDAE)	Using the BDAE standardized severity rating scale a severity rating is assigned based on performance across the Free Conversation, Picture Description, and Story Narration Tasks.

Note. Table adapted from "Connected Speech in Neurodegenerative Language Disorders: A Review" by, Boschi, V., Catricala, E., Consonni, M., Chesi, C., Moro, A., & Cappa, S. F. (2017), *Frontiers in Psychology, 8, 269.*

2.4 Data Analysis

Independent samples *t* tests were conducted to compare groups (i.e., MCI, Non-MCI) on age and education. Next, chi-square statistic was calculated to determine if there were group differences in terms of sex or race.

For research purpose 1, two approaches to data analysis were used to examine cognitive-linguistic outcomes. First, descriptive analysis of linguistic features in terms of means and variance was conducted. The purpose of this analysis was to identify potentially promising variables to differentiate MCI group performance. Additionally, completing descriptive analysis allowed for further data reduction to eliminate variables that gave no information (i.e., zero variance). Variables with zero variance were not included in subsequent analysis.

Next, correlation analysis was conducted to assess the relationships among the linguistic features within type of speech-language sample including free conversation (see Appendix B), picture description (Appendix C), and story narration (Appendix D). The purpose of this analysis was to reduce the number of dependent variables by creating composites of linguistic variables that were highly correlated (i.e., $r \geq .6$), meaning they assess the same skill. The strength of the correlation coefficient is considered weak at .10, moderate at .30, and strong at .50 or larger (Cohen, 2003). If a correlation of $r \geq .6$ was found between the linguistic variables, those variables were combined into a composite linguistic variable by summing the z-scores. Linguistic variables that were negatively correlated were reverse scored prior to forming the composite. Follow up correlation analysis was conducted using the derived composites and linguistic variables not included in composites in order to identify variables correlated to MoCA scores at $r \geq .45$. Such variables were included in subsequent analyses.

To address research purpose 2, two approaches to data analysis were used to compare participants with and without MCI across linguistic features and a Lexical Decision-Making task. First, a Multivariate Analysis of Variance (MANOVA) was conducted to examine overall group performance on composite linguistic variables and individual linguistic variables that were correlated with MoCA at $r \geq .45$. Next, follow up Univariate Analysis of Variance (ANOVAs) were conducted to examine group differences among the individual linguistic features. Effect sizes are reported as partial eta squared (η^2_p). A small η^2_p effect size is 0.01 – 0.05, medium is 0.06 – 0.13, and large is 0.14 and above (Fritz, Morris, & Richler, 2012). Lastly, a two (high versus low-density) x three (word, filler, pseudo) repeated measures ANOVA was conducted to examine group differences in lexical decision making.

Chapter 3: Results

Independent samples *t* tests comparing groups revealed no significant differences in age, $t(25) = .025$, $p = .980$, or education, $t(25) = .184$, $p = .855$. Chi-square analyses indicated no significant differences between the groups (i.e., MCI, Non-MCI) in terms of sex, X^2 (1, N=27)=.068, $p = .795$ or race, X^2 (1, N=27)=.049, $p = .825$.

3.1 Research Purpose 1

To address research purpose 1, descriptive analysis of the 98 linguistic features conducted in terms of means, standard deviation, and variance (See Appendix A) indicated 38 linguistic features had zero variance and 60 linguistic features with variance > 0. Of the 60 linguistic features, nine of them had a variance ≥ 5and are shown in Table 5. Variables with zero variance were excluded from subsequent analyses.

Table 5

Means and Standard Deviation of Linguistic Features by Status with Variance ≥ 5.

Sample Type	Linguistic Feature	Non-MCI (*n* = 8)		MCI (*n* = 8)		Total (*n* = 16)	
		M	*SD*	*M*	*SD*	*M*	*Variance*
Free Conversation	Total # of pauses ≥ 30 ms	165.880	83.535	151.130	32.180	158.500	7.850
	Total # of pauses in whole sample ≥ 50 ms	150.880	73.554	135.380	24.640	143.130	7.321
	Total Locution Time	241.880	114.121	205.000	38.859	223.440	9.194
	Total # of Words	661.000	392.796	505.750	152.516	583.370	17.286

Table 5 (Continued)

Sample Type	Linguistic Feature	Non-MCI (*n* = 8)		MCI (*n* = 8)		Total (*n* = 16)	
		M	*SD*	*M*	*SD*	*M*	*Variance*
Picture Description	Total # of Words	162.620	65.391	176.000	67.712	169.310	8.042
Story Narration – Wordless Picture Book	Total # of pauses ≥ 30 ms	153.880	41.461	203.630	79.986	178.750	8.167
	Total # of pauses in whole sample ≥ 50 ms	140.880	39.909	181.500	71.986	161.190	7.747
	Total Locution Time	229.500	54.209	293.380	102.352	261.440	9.259
	Total # of Words	573.000	165.214	691.750	216.413	632.380	13.994

Note. MCI = mild cognitive impairment

Correlation analysis of 60 variables within sample type (i.e., free conversation, picture description, story narration – wordless picture book) yielded a total of 18 composite linguistic variables (See Appendix B–D). There were four composites derived from the free conversation sample, six composites derived from the picture description sample type, and eight composites derived from the story narration – wordless picture book sample type. Composite variable names and descriptions are summarized in Table 6 below.

Table 6

Composite Variable Name by Sample Type and Description

Sample Type	Variable Name	Composite Description
Free Conversation		
	Ambiguous Planning	Filled pauses and phonemic errors
	Empty Terms Relative to Rate	Empty utterances and speech rate

Table 6 (Continued)

Sample Type	Variable Name	Composite Description
	Pauses_1	Pauses ≥ 30 ms and pauses greater than ≥ 50 ms in the whole sample
	Length Effects	Total number of words, total number of utterances, and total locution time
Picture Description		
	Coherence	Empty utterances and mean length of utterances
	Execution	Filled pauses and total number of utterances
	Relevant Discourse	Information content and total locution time
	Incomplete Message	Incomplete sentences and total number of words
	Pauses_2	Pauses ≥ 50 ms and pauses ≥ 250 ms
	Pauses_1	Pauses ≥ 30 ms and pauses ≥ 50 ms in the whole sample
Story Narration – Wordless Picture Book		
	Coherence	Empty utterances, phonemic errors, and repetitions
	Content	False starts and implausible and irrelevant details
	Ambiguous Meaning	Filled pauses and indefinite terms
	Correction	Incomplete sentences and revisions
	Relevant Discourse	Information content and total number of utterances
	Pauses_2	Pauses ≥ 50 ms and number of pauses ≥ 250 ms
	Pauses_1	Pauses ≥ 30 ms and number of pauses ≥ 50 ms in the whole sample
	Discourse Length	Total locution time and total number of words

Next, follow up correlation analysis between the 18 composite variables and 36 other individual linguistic variables not included in composites to MoCA scores was conducted. The composites and linguistic features that yielded a correlation with MoCA scores $r \geq .45$ are presented in Appendix E. There were seven linguistic variables with medium-strong correlations of $r \geq .45$ to MoCA scores. Two of the seven correlations with MoCA performance were to composite linguistic variables and five were to individual linguistic variables (see Table 7). Composite variables correlated to MoCA scores were related to (1) empty utterances, phonemic errors, repetitions and (2) filled pauses and indefinite terms. Individual linguistic variables correlated to MoCA were related to agrammatic deletions, repetitions, mean length of utterances (in both free conversation and story narration task), and correct informational units. It was also noted that four of the seven variables correlated to MoCA performance were from the story narration-wordless picture book task.

Table 7

Linguistic *Features with Medium-Strong Correlations to Montreal Cognitive Assessment Score*

	Task-Composite and Individual Linguistic Variables	Correlation Coefficient ***r*** *(n = 16)*
1	Story Narration - Composite variable comprised of Empty Utterance, Phonemic Errors, Repetitions	0.508*
2	Story Narration - Composite variable comprised of Filled Pauses and Indefinite Terms	0.529*
3	Story Narration - Agrammatic Deletions	0.576*
4	Story Narration - Mean Length of Utterances	0.686*
5	Picture Description - Correct Informational Units	0.511*
6	Picture Description – Repetitions	0.497
7	Free Conversation - Mean Length of Utterances	0.453

* Correlation is significant at the .05 level (2-tailed).

3.2 Research Purpose 2

To address research purpose 2, these seven dependent variables were used in subsequent analyses and included two composites linguistic variables and five individual linguistic variables (see Table 8 for descriptions and associated task). The first composite variable was comprised of empty utterances, phonemic errors, and repetitions. The second composite variable was comprised of filled pauses and indefinite terms. The individual linguistic variables were agrammatic deletions, correct informational units, repetitions, and mean length of utterances (both in the free conversation and story narration task). Results of the MANOVA conducted to examine overall group performance across these linguistic variables indicated that individuals with and without MCI did not differ significantly , Wilk's Λ = .484, F (7, 8) = 1.218, p=.391, partial η 2 = .516.

Table 8

Description and Associated Task of Composite and Individual Linguistic Variables with Moderate-Strong Correlations with MoCA Used in MANOVA.

Linguistic Level	Linguistic Feature	Description	Associated Task – Composite or Individual Variable
Phonetic and Phonological			
	Phonemic errors	Total number of phoneme substitutions, additions, and deletions.	Story Narration - Composite
	Filled pauses	Total number of words such as "um", "hmmm", "uhu", and "aah."	Story Narration - Composite
Lexico-Semantic			
	Indefinite terms	Total number of empty words without specific meaning, non-specific nouns or pronouns that made ambiguous or general reference.	Story Narration - Composite

Table 8 (Continued)

Linguistic Level	Linguistic Feature	Description	Associated Task – Composite or Individual Variable
	Repetitions	Total number of immediate word repetitions.	Story Narration - Composite Picture Description - Individual
Morphosyntactic Syntactic			
	Mean length of utterance	Mean number of morphemes per utterance.	Free Conversation - Individual Story Narration - Individual
	Empty utterances	Total number of interjections or comments that are not related to the picture or story at hand (i.e., “oh my goodness…”, “this is hard!”, “I can’t remember!”).	Story Narration - Composite
	Agrammatic deletions	Total number of omissions of a grammatically obligatory word (“he was boy” vs. “he was a boy”) or inflectional ending (i.e., “he was run” instead of “he was running”).	Story Narration - Individual
Discourse and Pragmatic			
	Correct Informational Units	Total number of accurate current informational units related to subjects, places, objects, and actions, and narrative sequences.	Picture Description - Individual

Note. MoCA = Montreal Cognitive Assessment; MANOVA = Multivariate Analysis of Variance.

Follow-up univariate ANOVA results for the seven dependent variables are presented in Table 8. There were significant differences between those with and without MCI on linguistic features from the wordless picture book - story narration sample related to agrammatic deletions and mean length of utterances. The MCI group had more agrammatic deletions (M = 1.250, SD = 1.165) than those without MCI (M = 0.130, SD = 0.354). Those with MCI had shorter mean length of utterances (M = 12.323, SD = 1.993) than those without MCI (M = 18.190, SD= 5.968). Other composite and individual linguistic variables with medium to large effect sizes included empty utterances, phonemic errors, repetitions, filled pauses, indefinite terms, and number of correct informational units (See Table 9).

Table 9

Univariate ANOVAs Comparing Linguistic Features Among Those With and Without Mild Cognitive Impairment.

Sample Type/Variable Type	Linguistic Features	*F (1,14)*	*Effect Size* partial η^2	*p*
Story Narration - Composite	Empty Utterances, Phonemic Errors, and Repetitions	1.799	0.114	0.201
	Filled Pauses and Indefinite Terms	0.885	0.059	0.363
Free Conversation - Individual	Mean Length Utterances	2.173	0.134	0.163
Picture Description – Individual	Number of Correct Informational Units	0.758	0.051	0.399
	Repetitions	0.851	0.044	0.433
Story Narration - Individual	Agrammatic Deletions	6.831	0.328	*0.020
	Mean Length Utterances	6.952	0.332	*0.020

* $p < .05$

Results of a two (high versus low-density) x three (word, filler, pseudo) repeated measures ANOVA examining group performance on the Lexical Decision-Making task indicated no significant differences between those with and without MCI, Wilk's Λ = .992, F (3, 23) = .065, p = .978, partial η 2 = .008. There was a statistically significant effect of high versus low condition, Wilk's Λ = .358, F (3, 23) = 13.750, p < .001, partial η 2 = .642, but no significant interaction between high versus low condition and MCI group, Wilk's Λ = .950, F (3, 23) = .403, p = .752, partial η 2 = .050. Findings indicated that average accuracy rates were better in the low-density condition for the word and filler stimuli and better in the high-density condition for the pseudo stimuli. See Figure 1 in Appendix F.

Chapter 4: Discussion

The purpose of the current study was to (1) examine cognitive-linguistic features related to processing and production across a series of tasks that are representative of everyday discourse and related to (2) compare participants with and without MCI across linguistic features. Findings of this study provides information that not only guides clinicians in identifying key linguistic features associated with cognitive-linguistic impairment but is also critical to the development of assessment and treatment approaches with this population (Voleti et al., 2019).

Results of the current study indicated that key linguistic features were useful in identifying cognitive-linguistic performance that is correlated to MoCA and show group differences among persons with and without MCI. Specifically, the composite linguistic features correlated to MoCA score were related to (1) empty utterances, phonemic errors, repetitions and (2) filled pauses and indefinite terms. Individual linguistic variables correlated to MoCA included agrammatic deletions, repetitions, mean length of utterances, and correct informational units. The linguistic features found to significantly differ by MCI status were agrammatic deletions and mean length of utterances. These linguistic features affect the quality of our syntax and speech-language processing and production. For example, when a speaker internally detects difficulty in their speech output, they may produce output that is vague, lacking in syntax, and less cohesive. Their output may be represented with an increased number of extended pauses or they may attempt to fill their pauses with multiple “um” or “aah” resulting in a less fluent and connected meaningful speech output. This often results in increased communication breakdowns, losing their communicative turns, significantly impacts on interpersonal relationships, and as a result, increased social isolation (Christidi, Migliaccio, Santamaría-García, Santangelo, & Trojsi, 2018).

These findings are in agreement with previous studies (Boschi et al., 2017; Drummond et al., 2015) that indicate that discourse and pragmatic level analysis (e.g., correct informational units) are useful indicators of early impairment in people diagnosed with MCI and can contribute to the early detection of AD (Ahmed et al., 2013; Mueller, Hermann, et al., 2018). However, the current study also found that people with MCI demonstrated difficulty across cognitive-linguistic features at the phonetic and phonological, lexico-semantic, and morphosyntactic levels. Participants with MCI also indicated difficulty with lexical access and comprehension, linguistic planning, and difficulties with morphosyntax (i.e., meaning and arrangement of words) (Boschi et al., 2017) which are important elements of natural discourse in terms of speech-language production (i.e. empty utterances, phonemic errors, repetitions, indefinite terms, agrammatic deletions) and processing (i.e. filled pauses, hesitation ratio). Deficits in these areas result in communication breakdowns, social isolation, and affect quality of life (M. Johnson & Lin, 2014; Mueller, Hermann, et al., 2018).

Identifying linguistic features that have potential for differentiating cognitive status is of clinical utility because MCI is a risk factor for AD (Petersen, 2004; Petersen et al., 1999). For example, the linguistic features related to total number of words, indefinite terms, and repetitions, according to a number of studies (Ahmed et al., 2013; Boschi et al., 2017; Carlomagno, Santoro, Menditti, Pandolfi, & Marini, 2005; Drummond et al., 2015; Nicholas, Obler, Albert, & Helm-Estabrooks, 1985; Sajjadi, Patterson, Tomek, & Nestor, 2012) are especially impaired in patients with AD and often appear at the stage of MCI. In other words, people with MCI and AD present with less efficient and cohesive speech output. Therefore, assessing these cognitive-linguistic features linked to MCI from natural discourse samples as part of a comprehensive speech-language assessment provides an opportunity for early identification and treatment.

Results indicated that the optimal cognitive-linguistic tasks that elicit the linguistic features with potential for differentiating cognitive status (i.e., MCI, Non-MCI) were the free conversation and story narration - wordless picture book tasks. This is further supported by previous research (Cannizzaro & Coelho, 2013; Snowdon et al., 1996; Voleti et al., 2019) indicating that higher-level cognitive tasks that examine the interactions of lexical units at the conversational discourse level require concurrent use of executive functions such as working memory, planning, inhibition, and self-regulation. Discourse tasks are considered the most elaborative linguistic activity and allow for assessment of various linguistic levels (i.e., phonetic, phonological, lexico-semantic, morpho-syntactic, and discourse/pragmatic processing) of language organization in comparison to other word level speech-language tasks (Kent, 2004). However, there are different types of discourse tasks. It should be noted that although the free conversation, picture description, and story narration are natural discourse tasks, the free conversation and picture description tasks impose a higher cognitive demand with little to no visual support. In contrast, the story narration - wordless picture book provides a series of pictures that serve as visual cues and provide a visual representation of a sequential story. Thus, allowing for a longer total locution time and greater number of total words but also including a greater number of pauses and a smaller number of mean length of utterances. Clinicians should use a combination of the free conversation and story narration – wordless picture book discourse tasks to fully assess connected speech-language processing and production with and without visual cues. However, the clinician must keep in mind that they must not only look at the length of the speech output as it may be longer due to the cueing but also look at the quality of the speech output as it relates to production (i.e. cohesiveness, mean length of utterances, total number of words) and processing (i.e., total number and length of pauses, hesitation ratio).

A limitation to the present study was the relatively small and homogenous sample size in terms of the number and diversity of people evaluated with and without MCI. Therefore, these findings warrant further investigation as they may not be generalizable to other study populations. For example, a person who is bilingual and cognitively impaired may present differently than a monolingual cognitively impaired English speaker. An additional limitation is that although manually extrapolating linguistic features from connected speech-language samples provide valuable information and serve as a promising tool in identifying cognitive-linguistic impairment (Voleti et al., 2019), it is difficult, time consuming, and requires expertise in manual and automated speech analysis procedures (Boschi et al., 2017).

A long-term goal of this line of research is to direct future study and advance clinical practice in relation to identifying specific linguistic features extrapolated from speech-language tasks that serve as predictors of MCI. This study further supports this long-term goal and enhances the existing literature regarding cognitive-linguistic features associated with MCI. It also calls attention to the necessary early detection of cognitive-linguistic changes that begin to occur at the stage of MCI and further escalate in AD (Berisha et al., 2015; Drummond et al., 2015; Snowdon et al., 1996; Toepper, 2017; Voleti et al., 2019). This study also highlights the importance of focusing on specific linguistic features that differentiate between people with and without MCI and the utilization of more efficient ways to extrapolate and analyze them from speech-language samples.

Future research should further explore the optimal cognitive-linguistic features to include as part of a comprehensive test battery that can best differentiate between persons with and without MCI. Future research should also explore the optimal manual and/or automated ways to extrapolate, measure, and analyze cognitive-linguistic features from speech-language samples (Voleti et al., 2019). Specifically, future research should investigate the clinical utility of utilizing complimentary automated speech-language analysis systems that provide outputs that can easily be visualized and interpreted by clinicians. Finally, future research should focus on developing a standardized protocol for extrapolating and measuring linguistic features that would further comparisons across studies and facilitate effective and efficient clinical application.

Although the current study examined 48 speech-language samples, future investigation of the current findings within a larger and more diverse sample statistically powered will provide more accurate values, reduce the margin of error, and elucidate interpretation and application of results. This will also provide an opportunity for making evidence-based conclusions regarding the optimal speech-language sample types and the most sensitive linguistic features to detect MCI. Future research should take into consideration that perhaps linguistic features may present differently in different types of MCI and in different populations. Therefore, future research should include a larger and more diverse sample of minority populations as they are at greater risk for MCI and AD (Alzheimer's Association, 2019).

Lastly, further interprofessional research between speech-language pathologists, neuroscientists, and neuropsychologists into the effectiveness of extrapolating linguistic features from speech-language samples will prove to be vital in caring for the cognitive health of older adults. This will aid in the development in more effective and comprehensive clinical assessment protocols in the early detection of MCI. With this added knowledge, future studies can be designed to enhance sensitivity for detecting and diagnosing MCI early and facilitate modifications to existing cognitive-linguistic assessment approaches. This is especially important in advancing clinical protocol and avoiding incorrect or delayed diagnosis of MCI. An incorrect diagnosis can lead to stress for the patient as well as the family and caregiver, hardships associated with the stigma of the diagnosis, and unnecessary medical and rehabilitative treatment (Hallowell, 2016). A delay in diagnosis can result in loss of valuable time to intervene and treat which can deter the progression of the disease. The clinical implication is that it could lead to early diagnosis, early treatment (V. B. Fleming, 2013) that targets abilities that are known to be susceptible to impairment in MCI, and thus, have considerable positive social and economic impact to the individual, the families and caregivers, as well as to the public health in general. Results from studies such as this one will not only help to further advance the fields of cognitive neuroscience and speech language pathology but will also inform objective ways to assess cognitive-linguistic deficits early, track the changes after diagnosis, and develop objective treatment approaches to improve patient outcomes.

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Appendix A: Descriptive Statistics of Linguistic Features by Status

Table 1A - Descriptive Statistics of Linguistic Features by Status

	Linguistic Feature by Sample Type	Non-MCI			MCI			Total		
		M	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*Variance*
	Free Conversation									
1.	Agrammatic	1.000	1.414	8	1.000	1.927	8	1.000	1.633	1.278
2.	Complexity Index	2.069	0.352	8	1.848	0.305	8	1.958	0.338	0.581
3.	Correct Pronoun	99.58%	1.19%	8	99.44%	1.58%	8	99.51%	1.35%	0.116
4.	Efficiency	0.022	0.006	8	0.025	0.004	8	0.023	0.005	0.071
5.	Empty Utterances	5.250	3.284	8	4.880	2.748	8	5.060	2.932	1.712
6.	False Starts	1.130	1.246	8	1.130	1.458	8	1.130	1.310	1.145
7.	Filled Pauses	25.380	10.967	8	16.000	4.567	8	20.690	9.450	3.074
8.	Hesitation Ratio ≥ 30 ms	24.50%	2.78%	8	38.51%	13.06%	8	31.50%	11.64%	0.341
9.	Implausible or Irrelevant Details	0.000	0.000	8	0.250	0.463	8	0.130	0.342	0.585
10.	Incomplete Sentences	0.750	0.707	8	1.250	1.488	8	1.000	1.155	1.075
11.	Indefinite Terms	3.880	2.900	8	3.750	3.655	8	3.810	3.188	1.785
12.	Mean Length Utterances	17.496	5.876	8	14.006	3.211	8	15.751	4.916	2.217
13.	Number of correct Informational Units	4.880	0.354	8	4.880	0.354	8	4.880	0.342	0.585
14.	Number of pauses ≥ 250 ms	21.130	2.997	8	27.500	4.721	8	24.310	5.043	2.246
15.	Number of pauses ≥ 30 ms	165.880	83.535	8	151.130	32.180	8	158.500	61.626	7.850
16.	Number of pauses ≥ 50 ms	36.380	5.999	8	40.000	5.904	8	38.190	6.047	2.459
17.	Number of pauses Whole Sample ≥ 50 ms	150.880	73.554	8	135.380	24.640	8	143.130	53.592	7.321
18.	Perseverations	0.000	0.000	8	0.250	0.707	8	0.130	0.500	0.707
19.	Phonemic Errors	1.750	3.012	8	0.750	0.886	8	1.250	2.206	1.485
20.	Pronoun Rate	10.71%	2.09%	8	10.74%	3.90%	8	10.72%	3.02%	0.174
21.	Repetitions_Immediate	8.500	5.855	8	8.380	6.653	8	8.440	6.055	2.461
22.	Revisions	4.630	3.068	8	3.750	2.493	8	4.190	2.738	1.655
23.	Semantic Errors	0.130	0.354	8	0.000	0.000	8	0.060	0.250	0.500
24.	Speech Rate	155.880	20.326	8	146.153	24.576	8	151.016	22.358	4.728

Table 1A (Continued)

25.	Total Locution Time	241.880	114.121	8	205.000	38.859	8	223.440	84.528	9.194
26.	Total Number of Utterances	41.500	18.024	8	40.630	9.606	8	41.060	13.959	3.736
27.	Total Number of Words	661.000	392.796	8	505.750	152.516	8	583.370	298.804	17.286
28.	Word Finding Difficulties	26.99%	3.94%	8	30.44%	6.53%	8	28.71%	5.51%	0.235
	Picture Description									
29.	Agrammatic	0.380	0.744	8	0.380	0.744	8	0.370	0.719	0.848
30.	Complexity Index	1.953	0.670	8	1.895	0.706	8	1.924	0.665	0.815
31.	Correct Pronoun	98.43%	3.52%	8	99.04%	2.72%	8	98.73%	3.06%	0.175
32.	Efficiency	0.184	0.068	8	0.138	0.031	8	0.161	0.056	0.237
33.	Empty Utterances	2.880	2.748	8	3.000	2.330	8	2.940	2.462	1.569
34.	Errors in Content Elements	0.130	0.354	8	0.250	0.463	8	0.190	0.403	0.635
35.	False Starts	0.250	0.463	8	0.500	0.535	8	0.375	0.500	0.707
36.	Filled Pauses	6.750	5.036	8	6.000	2.390	8	6.370	3.828	1.957
37.	Hesitation Ratio ≥ 30 ms	27.01%	9.50%	8	44.68%	26.85%	8	35.84%	21.49%	0.464
38.	Implausible or Irrelevant Details	0.500	0.756	8	0.750	1.035	8	0.630	0.885	0.941
39.	Incomplete Sentences	0.130	0.354	8	0.630	1.768	8	0.370	1.258	1.122
40.	Indefinite Terms	2.380	2.446	8	2.880	1.642	8	2.630	2.029	1.424
41.	Information Content	7.250	3.770	8	8.500	3.546	8	7.870	3.594	1.896
42.	Mean Length Utterances	14.755	3.969	8	14.084	5.662	8	14.419	4.736	2.176
43.	Number of correct Informational Units	10.500	0.926	8	9.880	1.808	8	10.190	1.424	1.193
44.	Number of pauses ≥ 250 ms	19.250	8.242	8	21.750	4.559	8	20.500	6.563	2.562
45.	Number of pauses ≥ 30 ms	40.380	18.685	8	47.380	18.142	8	43.880	18.154	4.261
46.	Number of pauses ≥ 50 ms	32.250	10.925	8	33.250	4.528	8	32.750	8.095	2.845
47.	Number of pauses Whole Sample ≥ 50 ms	37.380	19.198	8	42.000	14.794	8	39.690	16.728	4.090
48.	Perseverations	0.000	0.000	8	0.380	0.744	8	0.190	0.544	0.738
49.	Phonemic Errors	0.000	0.000	8	0.130	0.354	8	0.060	0.250	0.500
50.	Pronoun Rate	9.02%	2.44%	8	8.40%	3.19%	8	8.71%	2.76%	0.166
51.	Repetitions_Immediate	2.500	2.507	8	1.630	1.768	8	2.060	2.144	1.464
52.	Revisions	2.380	2.560	8	1.250	1.488	8	1.810	2.105	1.451
53.	Semantic Errors	0.000	0.000	8	0.000	0.000	8	0.000	0.000	0.000
54.	Speech Rate	151.767	22.061	8	140.076	16.965	8	145.922	19.947	4.466

Table 1A (Continued)

55.	Topic Maintenance	2.000	4.036	8	5.500	3.635	8	3.750	4.127	2.032
56.	Total Locution Time	65.130	26.128	8	74.880	23.265	8	70.000	24.424	4.942
57.	Total Number of Utterances	13.880	7.200	8	15.000	4.899	8	14.440	5.977	2.445
58.	Total Number of Words	162.620	65.391	8	176.000	67.712	8	169.310	64.674	8.042
59.	Word Finding Difficulties	27.08%	5.99%	8	27.08%	6.62%	8	27.08%	6.09%	0.247
	Story Narration – Wordless Picture Book									
60.	Agrammatic	0.130	0.354	8	1.250	1.165	8	0.690	1.014	1.007
61.	Complexity Index	1.799	0.333	8	1.785	0.498	8	1.792	0.410	0.640
62.	Correct Pronoun	99.81%	0.54%	8	99.41%	1.31%	8	99.61%	0.99%	0.099
63.	Efficiency	0.135	0.182	8	0.156	0.289	8	0.145	0.233	0.483
64.	Empty Utterances	4.380	4.241	8	2.000	1.414	8	3.190	3.291	1.814
65.	Errors in Content Elements	0.130	0.354	8	0.250	0.463	8	0.190	0.403	0.635
66.	False Starts	0.500	0.756	8	2.380	1.408	8	1.440	1.459	1.208
67.	Filled Pauses	13.500	17.720	8	5.380	4.173	8	9.440	13.125	3.623
68.	Hesitation Ratio ≥ 30 ms	34.17%	11.22%	8	43.84%	16.80%	8	39.00%	14.68%	0.383
69.	Implausible or Irrelevant Details	0.750	1.035	8	1.250	2.765	8	1.000	2.033	1.426
70.	Incomplete Sentences	1.000	1.309	8	2.620	5.097	8	1.810	3.692	1.921
71.	Indefinite Terms	4.130	3.091	8	3.500	1.690	8	3.810	2.428	1.558
72.	Information Content	32.630	8.088	8	48.380	13.394	8	40.500	13.431	3.665
73.	Mean Length Utterances	18.190	5.969	8	12.324	1.994	8	15.257	5.259	2.293
74.	Number of correct Informational Units	14.620	1.188	8	15.380	0.916	8	15.000	1.095	1.046
75.	Number of pauses ≥ 250 ms	23.120	5.915	8	22.750	2.121	8	22.940	4.297	2.073
76.	Number of pauses ≥ 30 ms	153.880	41.461	8	203.630	79.986	8	178.750	66.692	8.167
77.	Number of pauses ≥ 50 ms	38.500	8.246	8	33.130	7.318	8	35.810	8.027	2.833
78.	Number of pauses Whole Sample ≥ 50 ms	140.880	39.909	8	181.500	71.986	8	161.190	60.014	7.747
79.	Perseverations	0.000	0.000	8	0.870	1.727	8	0.440	1.263	1.124
80.	Phonemic Errors	1.750	1.753	8	0.870	0.835	8	1.310	1.401	1.184
81.	Pronoun Rate	7.14%	2.04%	8	6.92%	1.61%	8	7.03%	1.78%	0.133
82.	Repetitions_Immediate	6.880	8.951	8	4.380	4.868	8	5.630	7.079	2.661
83.	Revisions	4.880	1.959	8	5.630	3.777	8	5.250	2.933	1.713
84.	Semantic Errors	0.630	1.061	8	0.870	1.727	8	0.750	1.390	1.179

Table 1A (Continued)

85.	Speech Rate	147.888	17.300	8	144.864	26.176	8	146.376	21.491	4.636
86.	Topic Maintenance	11.250	16.568	8	11.380	19.733	8	11.310	17.602	4.195
87.	Total Locution Time	229.500	54.209	8	293.380	102.352	8	261.440	85.721	9.259
88.	Total Number of Utterances	43.750	8.763	8	56.75	16.585	8	50.25	14.466	3.803
89.	Total Number of Words	573.000	165.214	8	691.75	216.413	8	632.38	195.843	13.994
90.	Word Finding Difficulties	31.61%	6.62%	8	27.08%	6.80%	8	29.35%	6.89%	0.262
	BDAE									
91.	BDAE Complexity Index	2.011	0.449	8	1.916	0.297	9	1.961	0.367	0.606
92.	BDAESEVR Severity Rating	5.000	0.000	8	4.667	0.433	9	4.824	0.351	0.592
	Lexical Decision Making									
93.	Low Neighborhood Density Filler	0.803	0.170	15	0.815	0.141	12	0.809	0.155	0.394
94.	Low Neighborhood Density Pseudo	0.676	0.244	15	0.697	0.218	12	0.685	0.229	0.478
95.	Low Neighborhood Density Word	0.785	0.166	15	0.798	0.134	12	0.791	0.150	0.388
96.	High Neighborhood Density Filler	0.725	0.137	15	0.713	0.077	12	0.719	0.113	0.336
97.	High Neighborhood Density Pseudo	0.701	0.216	15	0.721	0.195	12	0.710	0.204	0.451
98.	High Neighborhood Density Word	0.737	0.169	15	0.727	0.152	12	0.732	0.159	0.398

Note. Non-MCI = No mild cognitive impairment; MCI = mild cognitive impairment.

Appendix B: Correlation Analysis of Linguistic Variables in Free Conversation

Table 1B - Correlation Analysis of Linguistic Variables in Free Conversation Sample

	Linguistic Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Agrammatic Deletions	-	.390	-.125	-.251	.283	.218	-.148	-0.17	.168	.122	.141	.093	.013	.492	.045	.096	.319	.078
2	Empty Utterances		-	-.488	-.117	0.315	.087	-.135	.089	-.034	.229	-.053	.008	.269	-.143	.168	-.103	.212	-.042
3	False Starts			-	.036	.088	-.074	-.236	-.329	.178	-.045	.225	.242	-.100	-.063	.134	.287	.284	.301
4	Filled Pauses				-	-.397	.248	.38	-.199	.683**	-.271	.689**	.746**	.057	.255	.306	.700**	.398	.678**
5	Incomplete Sentences					-	.453	.290	-.263	-.094	-.143	-.085	-.105	.114	.021	.559*	-.005	.256	.120
6	Indefinite Terms						-	.412	-.286	.427	-.593*	.454	.396	.384	.486	.609*	.500*	.444	.528*
7	Mean Length Utterances							-	-.356	0.100	-.456	.085	.127	.162	.206	.406	.223	.002	.278
8	# of pauses ≥ 250 ms								-	-.027	.468	-.075	-.151	.209	-.096	-.327	-.253	-.186	-.305
9	# of pauses ≥ 30 ms									-	.075	.994**	.960**	.288	.633**	.471	.953**	.852**	.923**
10	# of pauses ≥ 50 ms										-	.036	-.019	.005	-.099	-.164	-.068	.164	-.073
11	# of pauses Whole Sample ≥ 50 ms											-	.966**	.265	.617*	.518*	.960**	.849**	.939**
12	Phonemic Errors												-	.286	.522*	.457	.954**	.829**	.929**
13	Repetitions													-	.300	.122	.255	.270	.241
14	Revisions														-	.330	.553*	.427	.525*
15	Speech Rate															-	.530*	.550*	.677**
16	Total Locution Time																-	.873**	.981**
17	Total # of Utterances																	-	.881**
18	Total # of Words																		-

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Appendix C: Correlation Analysis of Linguistic Variables in Picture Description

Table 1C - Correlation Analysis of Linguistic Variables in Picture Description Sample

	Linguistic Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Empty Utterances	-	.569*	-.358	.369	.059	-.767**	-.187	.505*	.131	.283	.33	.215	.319	-.542*	.346	.275	.586*	0.007
2	Filled Pauses		-	-.031	.320	.236	-.237	.060	.398	.290	.139	.495	.525*	.282	-.435	.504*	.491	.633**	.220
3	Incomplete Sentences			-	.033	.527*	.520*	.367	-.016	.484	.075	.465	.065	-.148	.191	.032	.573*	.349	.651**
4	Indefinite Terms				-	-.089	-.305	.303	.531*	.022	.010	.067	-.239	-.267	-.312	-.052	.184	.317	.034
5	Information Content					-	.099	.174	.257	.654**	.453	.697**	.356	.376	.006	.474	.721**	.772**	.706**
6	Mean Length Utterances						-	.320	-.375	.286	-.148	.127	.132	-.030	.602*	.012	.181	-.228	.432
7	# of correct Informational Units							-	-.039	.009	-.123	.050	.018	-.076	.323	-.145	.270	.162	.392
8	# of pauses > 250 ms								-	.349	.734**	.498*	.036	.171	-.429	.329	.453	.585*	.228
9	# of pauses > 30 ms									-	.616*	.942**	.643**	.488	.065	.495	.874**	.684**	.871**
10	# of pauses > 50 ms										-	.670**	.385	.353	-.084	.374	.509*	.525*	.449
11	# of pauses Whole Sample > 50 ms											-	.646**	.540*	-.073	.591*	.945**	.837**	.862**
12	Repetitions												-	.446	-.146	.405	.550*	.450	.452
13	Revisions													-	.176	.328	.431	.442	.465
14	Speech Rate														-	-.168	-.108	-.263	.320
15	Topic Maintenance															-	.545*	.528*	.418
16	Total Locution Time																-	.851**	.902**
17	Total # of Utterances																	-	.675**
18	Total # of Words																		-

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Appendix D: Correlation Analysis of Linguistic Variables in Story-Narration

Table 1D - Correlation Analysis of Linguistic Variables in Story Narration-Wordless Picture Book Sample

	Linguistic Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Agrammatic	-	-.201	.099	-.204	-.291	.144	-.052	-.061	-.359	0.060	-.051	-.187	-.253	-.207	-.042	-.396	-.240	-.062
2	Empty Utterances		-	-.213	.827**	.149	.020	.564*	-.456	.429	.092	.529*	.128	.524*	.235	-.021	.377	.827**	.161
3	False Starts			-	-.286	.607*	.090	-.258	.662**	-.421	.042	-.185	-.147	-.050	-.112	.483	-.111	-.184	-.324
4	Filled Pauses				-	.050	.029	.722**	-.461	.678**	.139	.372	.122	.263	.223	-.205	.242	.628**	.356
5	Implausible or Irrelevant Details					-	-.080	.068	.273	.016	.329	-.053	.520*	-.118	.523*	-.156	.375	.454	.347
6	Incomplete Sentences						-	.152	.524*	-.103	.082	.230	.566*	.329	.568*	.205	.141	.255	.602*
7	Indefinite Terms							-	-.165	.518*	.175	.044	.316	-.111	.381	-.254	.195	.496	.569*
8	Information Content								-	-.433	.213	-.047	.753**	-.145	.690**	.367	.030	-.063	.437
9	Mean Length Utterances									-	-.095	.010	-.035	.064	-.003	-.403	.487	.340	.212
10	# of correct Informational Units										-	.184	.409	-.334	.419	-.145	.003	.292	.166
11	# of pauses ≥ 250 ms											-	.118	.707**	.178	.140	-.196	.383	-.004
12	# of pauses ≥ 30 ms												-	-.004	.991**	.222	.378	.494	.760**
13	# of pauses ≥ 50 ms													-	.055	.344	.118	.357	-.120
14	# of pauses Whole Sample ≥ 50 ms														-	.212	.390	.573*	.770**
15	Perseverations															-	-.045	-.092	-.211
16	Phonemic Errors																-	.678**	.272
17	Repetitions																	-	.442
18	Revisions																		-

Table 1D (Continued)

	Linguistic Variables	19	20	21	22	23	24
1	Agrammatic	-.106	.203	-.147	-.184	-.131	-.138
2	Empty Utterances	-.106	.125	-.161	-.015	.059	.059
3	False Starts	.565*	.125	-.319	-.180	.003	-.138
4	Filled Pauses	.083	-.009	-.252	.151	.011	.159
5	Implausible or Irrelevant Details	-.094	.071	.013	.506*	.394	.536*
6	Incomplete Sentences	.107	-.015	.267	.445	.649**	.454
7	Indefinite Terms	-.114	-.005	-.137	.410	.248	.392
8	Information Content	.050	-.214	.372	.702**	.835**	.608*
9	Mean Length Utterances	.132	.182	-.287	.145	-.152	.220
10	# of correct Informational Units	-.044	.243	.460	.385	.282	.474
11	# of pauses ≥ 250 ms	.198	.135	.216	-.077	.140	-.004
12	# of pauses ≥ 30 ms	-.178	-.166	.315	.917**	.936**	.853**
13	# of pauses ≥ 50 ms	.127	.035	.064	-.228	.050	-.172
14	# of pauses Whole Sample ≥ 50 ms	-.142	-.141	.295	.897**	.929**	.847**
15	Perseverations	.028	-.185	-.132	-.017	.285	-.102
16	Phonemic Errors	-.094	.287	-.137	.354	.348	.495
17	Repetitions	-.085	.240	-.038	.359	.459	.483
18	Revisions	-.147	-.254	.094	.794**	.699**	.696**
19	Semantic Errors	-	.418	-.274	-.096	.013	.070
20	Speech Rate		-	-.073	-.185	-.116	.214
21	Topic Maintenance			-	.258	.244	.265
22	Total Locution Time				-	.849**	.917**
23	Total Number of Utterances					-	.805**
24	Total Number of Words						-

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Appendix E: Individual and Composite Linguistic Variables Correlated to MoCA

Table 1E - Individual and Composite Linguistic Variables Correlated to MoCA

Task Type and Individual or Composite Variable	Linguistic Variable	Correlation Coefficient *r* *(n = 16)*
Free Conversation – Individual		
	Agrammatic Deletions	.039
	Free Conversation – Empty Utterances	.112
	Free Conversation – False Starts	-.208
	Free Conversation – Incomplete Sentences	.028
	Free Conversation – Mean Length of Utterances	.453
	Free Conversation – 250 ms	-.443
	Free Conversation – 50 ms	-.330
	Repetitions	.406
	Revisions	.102
Picture Description – Individual		
	Indefinite Terms	-.197
	Number of Correct Informational Units	.511*
	Repetitions	.497
	Revisions	.171
	Speech Rate	.088
	Topic Maintenance	-.105
Story Narration – Individual		
	Agrammatic Deletions	-.576*
	Mean Length of Utterances	.686**
	Number of Correct Informational Units	-.146
	Perseverations	-.133

Table 1E (Continued)

Task Type and Individual or Composite Variable	Linguistic Variable	Correlation Coefficient *r* *(n = 16)*
	Semantic Errors	.345
	Speech Rate	.104
	Topic Maintenance	-.194
Free Conversation - Composite Variables		
	Filled Pauses and Phonemic Errors	.204
	Indefinite Terms and Speech Rate	.145
	# of Pauses ≥ 30 ms and # of Pauses ≥ 50 ms in whole sample	.084
	Total # of Words, Total # of Utterances, and Total Locution Time	.179
Picture Description - Composite Variables		
	Empty Utterances and Mean Length of Utterances	.240
	Filled Pauses and Total # of Utterances	.261
	Information Content and Total Locution Time	.206
	Incomplete Sentences and Total # of Words	.265
	# of Pauses ≥ 250 ms and # of Pauses ≥ 50 ms	.119
	# of Pauses ≥ 30 ms and # of Pauses ≥ 50 ms in whole sample	.199
Story Narration - Composite Variables		
	Empty Utterances, Phonemic Errors, and Repetitions	.508*
	False Starts and Implausible Irrelevant Details	-.166
	Filled Pauses and Indefinite Terms	.529*
	Incomplete Sentences and Revisions	.213
	Information Content and Total # of Utterances	.021
	# of Pauses ≥ 250 ms and # of Pauses ≥ 50 ms	-0.05
	# of Pauses ≥ 30 ms and # of Pauses ≥ 50 ms in whole sample	.127
	Total Locution Time and Total # of Words	.251

Note. MoCA = Montreal Cognitive Assessment.

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed)

Appendix F: Lexical Decision-Making Mean Accuracy Rates

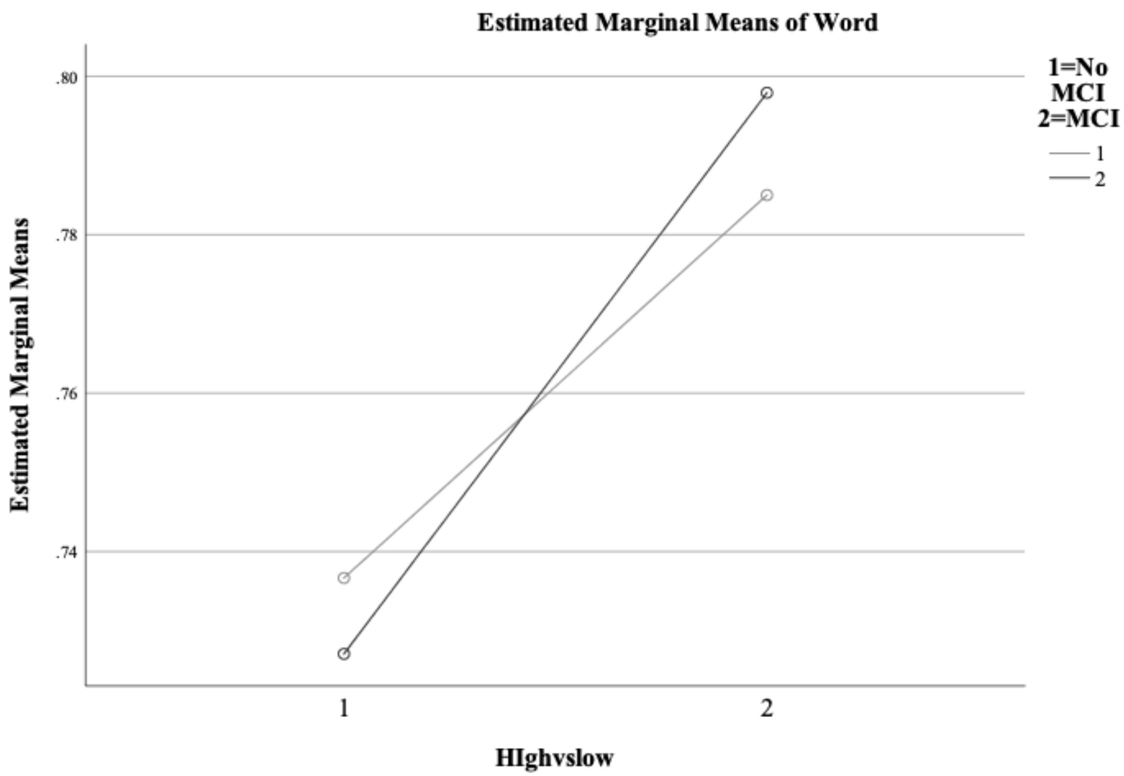

Figure 1A - Lexical Decision-Making Mean Accuracy Rates in High Versus Low-Density Word Condition by Mild Cognitive Impairment (MCI) Status.

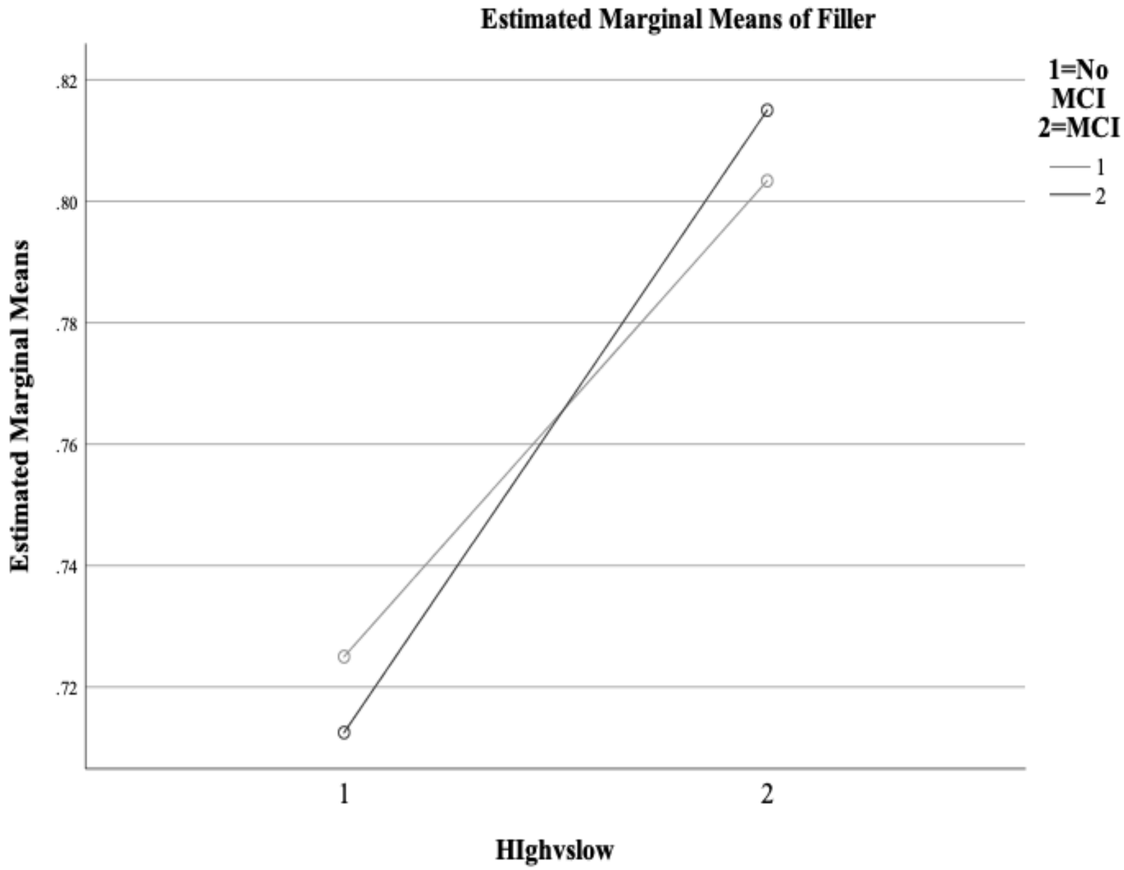

Figure 1A.1 - Lexical Decision-Making Mean Accuracy Rates in High Versus Low-Density Filler Condition by Mild Cognitive Impairment (MCI) Status

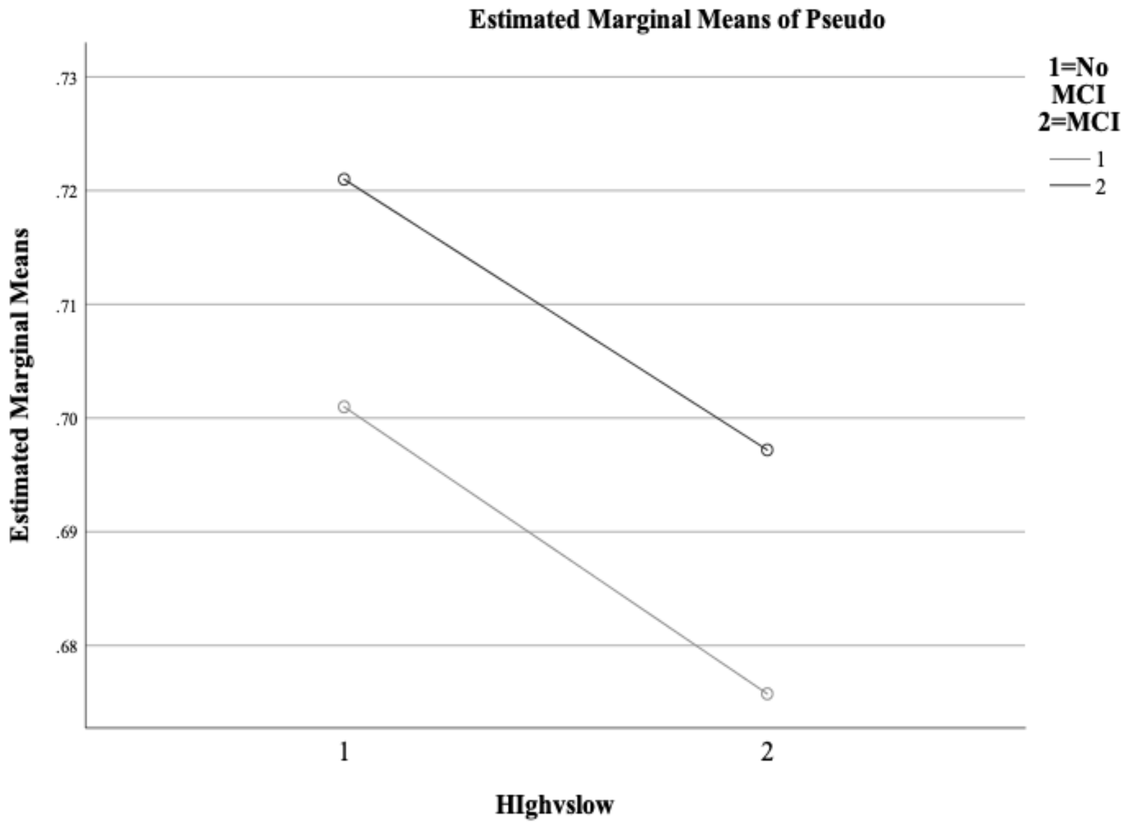

Figure 1A.2 - Lexical Decision-Making Mean Accuracy Rates in High Versus Low-Density Pseudoword Condition by Mild Cognitive Impairment (MCI) Status