PHONOLOGICAL AND SEMANTIC WORKING MEMORY AND DISCOURSE COHERENCE IN FLUENT APHASIA

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ABSTRACT

Studies have found that people with aphasia demonstrate reduced nonverbal and verbal short-term memory (STM) and working memory (WM) and discourse measures related to topic maintenance such as global and local coherence. Research also suggests that STM capacity and WM abilities may influence discourse measures such as global and local coherence in people with aphasia and acquired brain injuries (ABI). The purpose of this study was to determine how differences in the domain (nonverbal or verbal) or linguistic level (phonological or semantic) of information held and manipulated in STM may influence global and local coherence in people with mild-moderate fluent aphasia. A forward Corsi block and subtests from the Temple University Assessment of Language and Verbal Short-term Memory in Aphasia (TALSA) were used to assess nonverbal, phonological, and semantic WM. 13 participants with mild-moderate fluent aphasia and 4 neurotypical adults completed the forward Corsi block and phonological and semantic WM subtests from the TALSA. These included various probe spans and pointing tasks (rhyming and synonymy triplets subtests), which required the participant to maintain a number of words and make different semantic and phonological decisions about these words (e.g. making judgements related to the rhyme (phonological) or the categorization (semantic) of the words). Pointing tasks (rhyming and synonymy triplets) involved participants pointing to words on a screen that shared a similar phonological (rhyme of the words) or semantic (meaning of the word) relationship in a high and low WM condition. All participants with aphasia and neurotypical adults completed 10 discourse samples from the Nicholas and Brookshire narratives. Global and local coherence were assessed by rating each C-unit from participants' discourse samples on a 1-5-point global and local coherence rating scale. This study determined if there was a relationship between the nonverbal, phonological, and semantic WM tasks and global and local coherence in the people with mild-moderate fluent aphasia. This study found that only the synonymy triplets change score (difference between the low WM condition and the high WM conditions), a semantic WM task, from the TALSA demonstrated a trend towards significance with local coherence in the participants with aphasia group. Additionally, a similar relationship was found when the same correlations were run on a group that combined the neurotypical adults and participants with aphasia group. Similarly, this study found that only the synonymy triplets change score had a significant correlation with local coherence in the combined group. None of the other WM tasks were significantly correlated with global and local coherence. Based on these results, this study provides some evidence that the integrity of the cognitive resources used for the maintenance and manipulation of semantic information held in verbal STM may be important for maintaining the topic or semantic coherence between adjacent utterances (measured by local coherence) in participants with mild-moderate fluent aphasia and neurotypical adults. More research is needed to determine if this relationship exists in other populations with aphasia and in an independent sample of neurotypical adults.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS LIST

STM…..Short-term Memory

WM…..Working Memory

AD…..Alzheimer's Disease

ABI…..Acquired Brain Injury

TBI…..Traumatic Brain Injury

Dell's IA Model…..Dell's Interactive Activation Model

TALSA…..Temple University Assessment of Language and Verbal Short-term Memory in Aphasia

Noun-Verb-Concrete-Abstract Synonym Triplets Subtest…..N-V-C-A Synonymy Triplets Subtest

WAB-R…..Western Aphasia Battery – Revised

MoCA…..Montreal Cognitive Assessment

ISO…..In Serial Order

IAO…..In Any Order

CHAPTER 1

INTRODUCTION

Aphasia is a complex neurological disorder that impairs a person's comprehension and production of verbal and written language. It is most often acquired by an injury to the language dominant hemisphere (typically the left hemisphere) of the brain. Most researchers have moved towards describing aphasia not as a loss of language knowledge, but an impairment that impedes access to language representations needed for communication (McNeil, 1982; McNeil & Pratt, 2001; Murray, 2000; Schuell et al., 1964). Speech-language pathologists have traditionally treated aphasia at the word and sentence level using common interventions such as Verb Network Strengthening Treatment (VNeST) and Semantic Feature Analysis (SFA) (Linnik et al.,2016; Edmonds, 2014; Efstratiadou et al., 2018). Although significant improvements can be obtained from these therapies, everyday conversation requires more complex linguistic and cognitive skills that go beyond the sentence and word level (Linnik et al., 2016). Worrall and colleagues (2011) found that people with aphasia were interested in improving their communication across a wide range of communicative activities including expressing their own opinion, which typically occurs at the discourse level. Discourse can be defined as a unit of connected speech that is longer than a sentence organized sequentially and logically to communicate a group of ideas to the listener (Kong, 2016). This form of communication requires longer and more complex language functions than language tasks that require a one word or sentence response (e.g. naming, syntactic priming, etc.). The need to evaluate more functional language performance has been addressed by an increasing interest in studying discourse in aphasia over the past 40 years (Bryant et al., 2016). Additionally, discourse analysis is an important part of the diagnostic process for individuals with acquired neurological disorders because language batteries are frequently not able to capture specific disruptions in discourse production (Marini et al., 2011).

Theoretical Model of Discourse Production

Researchers have developed models to better understand how discourse is produced. These models traditionally involve a prelinguistic conceptualization stage, a linguistic formulation stage, and articulation and monitoring of the message (Frederiksen et al., 1990; Indefrey & Levelt, 2000, 2004; Levelt, 1989, Levelt et al., 1999). (See Figure 1 for a model of discourse production.) Each stage is interactive and relies on both top-down and bottom-up processing to effectively produce discourse. The prelinguistic conceptualization stage involves generating a preverbal message before constructing the linguistic form. First, a communicative intent (a mental message of what the speaker wants to produce) is generated. To generate a communicative intent, the individual needs to retrieve an appropriate conceptual framework (i.e. select the appropriate discourse genre) from their explicit long-term memory. Then, semantic information is selected to fulfill the communicative intent. During this stage, the speaker constructs this intended message based on what has already been said, the general topic, and the extralinguistic content (e.g. pragmatic features, environment, situational stimuli). This preverbal conceptual representation results in the generation of propositions that must then be organized using cohesive and coherent links.

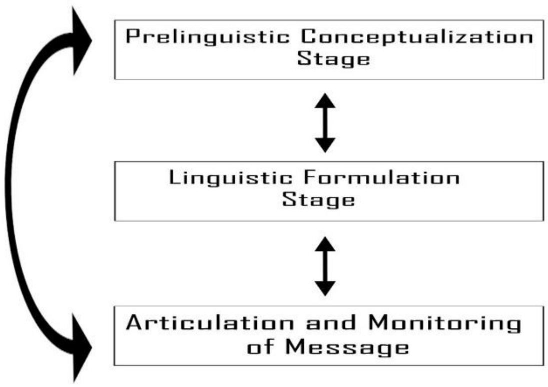

Figure 1. Model of Discourse Production. This figure represents each stage of discourse production proposed by discourse and language production models by Frederiksen and colleagues (1990) and Levelt and colleagues (1989, 1999). Bidirectional arrows indicate that each stage is interactive and is influenced by stages that follow and proceed it.

In the linguistic formulation stage, the preverbal message is mapped onto linguistic units stored in the individual's mental lexicon. This process is mediated by lexical access and selection. Each lexical representation's threshold is determined by the frequency of its use and the amount of time that elapsed since the last time it was activated. During the lexical selection stage, a mechanism is utilized to choose the lexical item with the strongest activation and simultaneously inhibit lexical items that may have a phonological or semantic relationship with the intended item. Once a single lexical item is selected, its morphosyntactic and morphological features are obtained, followed by the syllabic and phonological form. This information from the lexical items that are necessary for completing the sentence then serves as a guide to fill in the missing function words according to the intended message. In the final stage, the articulation and monitoring stage, the lexical items are mapped onto the corresponding phonological representations. These phonological representations are then sent to an output system where the message is coordinated by the speech articulators and mechanisms used for spoken production. The cycle repeats during conversation and discourse. As this cycle is repeated, during this prelinguistic conceptualization stage, the speaker attends to the current topic of focus, shifts their attention to new topics as the conversation changes, and monitors the discourse being produced.

Researchers have used microlinguistic and macrolinguistic measures to assess two different dimensions of linguistic processing (Caplan, 1992; Glosser & Deser, 1990). Microlinguistic measures (microstructure) assess linguistic variables within an utterance (Marini et al., 2011). These measures assess discourse production skills related to the formulation of lexical and syntactic structures. Examples include discourse measurements like lexical diversity and grammaticality. Macrolinguistic measures assess linguistic variables between/across utterances. These measures determine the contextual appropriateness of the words and sentences produced (pragmatic processing) and connect the utterances in discourse using coherent and cohesive devices to formulate a main theme (Kintsch, 1994; Kintsh & van Dijk, 1978). Examples include measures related to a narrative's story grammar or episodic complexity. Although these measures assess different aspects of discourse production, discourse is a complex interaction between both micro- and macrolinguistic processing and sometimes a breakdown in microlinguistic processing (formulation of lexical and syntactic structures) can influence performance on macrolinguistic measures (e.g. story grammar) and vice versa. For example, difficulties with retrieving the accurate words can influence clarity of story grammar elements (e.g. stating the setting or the people involved when producing a narrative).

Cognitive-Linguistic Constructs and Discourse

Models of discourse help clinicians and researchers understand discourse production, though more research is needed to refine these models, so they accurately represent discourse production across different populations. One aspect that can contribute to refining these models and to understanding discourse production is the determination of what cognitive-linguistic constructs are required to produce effective discourse. The role cognitive constructs, such as executive functioning and short-term memory (STM), have in discourse production can be better understood by investigating how these cognitive constructs influence discourse production. Better understanding their role in discourse production can also provide information on how breakdowns in these constructs can affect discourse production in populations with neurological impairments. This information can assist clinicians with choosing the most appropriate assessments and interventions to improve a target discourse skill related to a client's functional communication goal. This current study addresses how STM/WM may be related to the discourse measures global and local coherence. Coherence is a speaker's ability to maintain the unity related to a specific theme and it can be separated into two related concepts: global coherence and local coherence (Agar & Hobbs, 1982). Global coherence, which is similar to topic maintenance, is the speaker's ability to maintain an overall goal, plan, or topic during discourse production between their spoken utterances (Coelho & Flewellyn, 2003). Local coherence reflects the speaker's ability to provide a conceptual linkage between adjacent utterances. Deficits that affect global and local coherence may influence an individual's ability to communicate effectively and efficiently in everyday life. Tangential speech may also cause communication breakdowns if the listener cannot decipher the purpose or topic of conversation. Additionally, Rogalski and colleagues (2020) found that a measurement of topic maintenance (global coherence) correlated with the interest and attention of untrained listeners. This indicates that discourse that is off topic may lose the attention/interest of a listener and decrease communicative effectiveness.

Global and Local Coherence

Global and local coherence are typically measured using two main approaches: the first is rating scales, which assess how a topic is maintained for each utterance in a discourse sample, and the second is through analysis of a person's discourse sample for instances of errors associated with global and local coherence. One of the first attempts to quantify global coherence involved rating each utterance in a discourse sample on a 5-point scale based on the relationship to the overall topic (global coherence) or to the adjacent utterance (local coherence) (Glosser & Deser, 1990; 1992). Researchers rated each utterance on a 5-point scale and then averaged the ratings between all the utterances in the discourse sample. Many studies have adapted this rating scale to capture discourse coherence. (Van Leer & Turkstra, 1999; Coelho & Flewellyn 2003; Wright et al., 2013; Wright et al., 2014). Another approach that has been used involves counting the frequency and type of global and local coherence errors. Coherence errors are any error that causes an utterance to be tangentially or conceptually incongruent (Christiansen, 1995; Marini et al., 2005, 2011, 2014). Global coherence errors can include information gaps (missing information), filler utterances (utterances that do not provide additional information to the topic), repeated utterances, tangential utterances, and irrelevant or conceptually incongruent utterances (utterances that are not semantically related to the topic or picture in any way) (Christiansen, 1995; Andreetta et al., 2012; Andreetta & Marini, 2015). Local coherence errors can include missing referents (a referent of a pronoun is unclear or ambiguous) and a topic shift (the topic of utterance is not continued after previous utterance was abruptly stopped). An increase in errors would suggest poorer coherence. Researchers who have used measures that count the frequency of global and local coherence errors have also quantified difficulties with global and local coherence by calculating the percentage of coherence errors (Andreetta et al., 2012; Andreetta & Marini, 2015). This was accomplished by adding all the global coherence errors and dividing the number of errors by the total number of utterances. The same would be done for local coherence errors. A higher percentage would indicate poorer global or local coherence.

Using these measures in research studies, populations that include people with Alzheimer’s disease (AD), dementia, traumatic brain injury (TBI), and aphasia have demonstrated lower global coherence when compared to neurotypical controls (Ellis et al., 2016). Older adults were also found to demonstrate significantly lower global coherence, but not significantly lower local coherence compared to young and middle-aged adults (Glosser & Deser, 1992; Marini et al., 2005; Wright et al., 2014). Researchers have investigated global coherence more extensively than local coherence. The majority of studies evaluating local coherence have found that there is no significant difference between neurotypical adults and adults with neurological impairments (people with aphasia, AD, and TBI) when using a 5-point rating scale and percentage of local coherence errors to measure local coherence (Glosser & Deser, 1990, 1992; Kurczek and Duff, 2012; Coelho et al., 2012; Andreetta et al., 2012). However, other studies have found people with TBI and mild-severe fluent aphasia exhibit significantly lower local coherence when compared to neurotypical controls using similar measures (Hough & Barrow, 2003; Glosser & Deser, 1990; Andreetta et al., 2015).

Most studies evaluating coherence in aphasia have found that people with aphasia exhibit significantly lower global coherence, but not significantly lower local coherence when compared to people without aphasia (Christiansen, 1994; Coelho & Flewellyn, 2003; Wright & Capilouto, 2012; Andreetta et al., 2012; Andreetta & Marini, 2015). To our knowledge only one study has found no differences in global coherence between people with and without aphasia (Glosser & Deser, 1990). This may be related to differences in discourse elicitation, type of discourse measures, or differences in aphasia population (differences in type and severity).

The consensus among researchers studying discourse in aphasia is that global coherence is affected by microlinguistic processing (e.g. lexical retrieval and syntactic processing) (Christiansen, 1995; Wright & Capilouto, 2012; Andreetta et al., 2012, Andreetta & Marini, 2015). Christiansen (1995) found that participants with mild-moderate anomic, conduction, and Wernicke’s aphasia made specific global coherence errors. She hypothesized that these participants may have used adaptive strategies to compensate for underlying microlinguistic impairment (e.g. word finding), which may have influenced their production of specific global coherence errors. For example, a participant with anomic aphasia may not produce obligatory propositions in discourse because of word finding difficulty (information gap). Wright and Capilouto (2012) and

Andreetta and colleagues (2012, 2015) investigated this further by determining if there was a relationship between micro- and macrolinguistic discourse measures using discourse samples from a group of people with aphasia and neurotypical controls. They both found that lexical informativeness (a microlinguistic measure) was correlated with global coherence in people with mild-severe fluent and nonfluent aphasia. Wright and Capilouto (2012) also found that global coherence correlated with lexical diversity, another microlinguistic measure. In terms of coherence errors, Andreetta and colleagues (2012) found that a group of people with anomic aphasia had more filler utterances and repeated utterances than their control group, but not more semantically incongruent or tangential utterances. The researchers indicated that specific global coherence errors, repeated and filler utterances, may be related to lexical difficulties and not a specific deficit related to sentence planning. Andreetta and Marini (2015) reported similar results in a group of participants with mild-severe fluent aphasia.

Other studies have suggested that microlinguistic processing is not the only contributor to global coherence errors in people with aphasia (Christiansen, 1995; Coelho & Flwellyn, 2003; Cahan-Amitay & Jenkins, 2018). Christiansen's (1995) study proposed that production of irrelevant propositions produced by the participants with Wernicke's, and to a lesser extent, conduction aphasia, may be related to deficits in formulating coherent macrostructure that would be processed at higher levels of discourse production or part of a larger semantic impairment affecting their comprehension and conceptual knowledge. Coelho and Flewellyn (2003) studied the recovery of a 1-month post-stroke participant with mild-moderate anomic aphasia and found microlinguistic improvements over a period of 12 months. However, global coherence was still well below a neurotypical control group after 12 months. However, specific information related to the microlinguistic improvements was not reported in the study. They concluded that macrolinguistic processes (sentence planning) may involve a dynamic interaction between the language dominant hemisphere and other cognitive processes that can be impacted by focal or diffuse brain pathology.

Differences between people with aphasia and neurotypical adults in terms of local coherence have been investigated in only a few studies (Glosser & Deser, 1990; Andreetta et al., 2012; Andreetta & Marini, 2015). In addition to global coherence, Glosser and Deser (1990) also found no significant difference in local coherence between neurotypical adults and people with fluent aphasia using their 5-point rating scale. Alternative global coherence rating scales have been adapted by other researchers by changing the number of ratings and criteria for each rating (e.g. Wright and colleagues' 4-point rating scale), though to our knowledge, there have not been any studies that have adapted the 5-point local coherence rating scale (Van Leer & Turkstra, 1999; Coelho & Flewellyn, 2003; Wright et al., 2013; Wright et al., 2014). Andreetta and colleagues (2012, 2015) evaluated local coherence errors that included missing referents (a referent of a pronoun is unclear or ambigious) and topic switches (the topic of utterance is not continued after previous utterance was abruptly stopped). They found no significant difference in the percentage of local coherence errors between a group of participants with anomic aphasia and neurotypical controls. However, in a follow up study, they found a significant difference in terms of local coherence between a group of participants with mild-severe fluent aphasia and neurotypical controls (Andreetta & Marini, 2015). Unlike global coherence, in both studies, Andreetta and colleagues (2012, 2015) did not find any microlinguistic measures that significantly correlated with percentage of local coherence errors.

From this research, people with aphasia appear to exhibit a lower global coherence compared to people without aphasia. However, there is not enough evidence to conclude that people with aphasia demonstrate a lower local coherence when compared to people without aphasia. Use of a rating scale to assess local coherence between people with aphasia and neurotypical adults has only been done in one study (Glosser & Deser, 1990) to our knowledge, and more research is needed to determine if people with aphasia will perform significantly lower on local coherence than neurotypical controls using a rating scale to measure local coherence.

Additionally, this research indicates that lower global coherence may or may not be related to deficits in sentence planning. Lower global coherence may be related to a linguistic breakdown at the microlinguistic level that influences the intended clarity of the message (e.g. word finding errors), response to a linguistic breakdown (e.g. commenting on difficulties with word finding), strategy to compensate for underlying impairments (e.g. information gap), or a breakdown related to higher levels of discourse production associated with sentence planning (e.g. producing off topic sentence) (Hazamy & Obermeyer, 2020). Since local coherence may be dependent on similar factors, these same factors mentioned above may also influence local coherence ratings. Though microlinguistic measures were not correlated with the percentage of local coherence errors in Andreetta and colleagues' studies (2012, 2015), it may be possible for microlinguistic measures to be related to local coherence using a local coherence rating scale. The local coherence rating scale may account for factors that influence local coherence beyond the two local coherence errors used in Andreetta and colleagues' studies (2012, 2015).

Despite differences in ways people with aphasia may have difficulty with global and local coherence, it is clear that people with aphasia demonstrate lower global coherence than people without aphasia. Investigating STM/WM influence on global and local coherence may contribute to better understanding these global and local coherence measures.

Short-Term and Working Memory (STM and WM)

Most studies have shown that people with aphasia demonstrate significantly lower global coherence than people without aphasia, and it is also true that people with aphasia perform significantly lower on STM/WM tasks (Martin, 2000). STM is the mental ability to temporarily store a limited amount of information that can be accessed for later use. It is traditionally measured by a forward digit or word span which consists of having a participant repeat an increasing span of digits or words (e.g. repeating back a sequence of two words, then three words, then four words, etc.). STM is a function that supports WM. WM involves the manipulation and organization of the information that is being temporarily stored in a person's STM (Martin et al., 2012). WM can be assessed by manipulating or organizing words or digits used in a STM task (e.g. arranging digits presented in ascending order). In the WM task, a person needs to use cognitive resources to make decisions about the information that they are holding in their STM so that this information can be organized or manipulated to successfully complete the task. WM tasks can have varying degrees of "work" which is related to how much a person may need to use their cognitive resources to manipulate information in their STM. For example, less “work” may be required to repeat a string of digits in the exact order they were presented than to repeat the strings of digits in a backwards order. The amount of “work” a STM/WM task requires can be thought of on a spectrum based on how much “work” is required to complete the task. This current study focuses on how WM, the ability to manipulate and organize information in STM, influences global and local coherence.

Limited research has investigated the relationship between STM/WM and global and local coherence in people with aphasia. One exception is the study by Cahana-Amity and Jenkins (2018). Given the limited research, an appropriate first step would be to understand how STM/WM impairments influence discourse production in other neurological populations such as traumatic brain injury (TBI).

A literature review by Hill and colleagues (2018) on the discourse production of participants with acquired brain injuries (ABI) found that STM/WM was related to reduced productivity, less complex syntax, reduced ability to use appropriate cohesive ties, reduced informativeness, and poorer global and local coherence. ABI was defined as any nonprogressive brain injury, excluding stroke, in participants that had no prior history of communication and/or cognitive deficits. The researchers hypothesized that difficulties using resources to hold, manipulate, and reproduce content held in STM may negatively affect coherence because the person may have difficulty monitoring what they previously said and the current topic of discourse. As a result, these individuals may produce tangential or repetitive utterances and may have difficulty with topic maintenance (Hill et al., 2018). Coelho and colleagues (2012) found that individuals with damage to the left dorsolateral prefrontal cortex had a lower global and local coherence that correlated with performance on a WM task from the Wechsler Memory Scale - 3rd edition (WMS-3; Wechsler, 1997). On the contrary, two studies (Lê et al., 2014; Marini et al., 2011) found that a lower performance on STM/WM tasks in a populations with severe TBI was not significantly correlated with lower local and global coherence despite their performance on STM/WM tasks being significantly lower than the people without TBI. Research has also found other cognitive constructs that are important for maintaining higher global and local coherence. Hill and colleagues (2018) and Rogalski and colleagues (2020) identified previous studies that found cognitive constructs such as executive function, declarative memory, sustained/selective attention, and processing speed to be related to global and local coherence (Lê et al., 2014, Marini et al., 2014; Marini et al., 2017; Galetto et al., 2013; Wright et al., 2014). Determining the interaction of these cognitive-linguistic constructs with each other and topic maintenance is beyond the scope of this study, though understanding these interactions may be important in future studies.

Similar to TBI and ABI, verbal STM/WM impairments have been ubiquitously found in people with aphasia and these impairments influence their language processing. Performance on verbal STM/WM tasks (forward and backward digit span) have been found to influence people with aphasia's performance on sentence comprehension tasks, naming, and production of complex sentences during sentence completion and syntactic priming tasks (Martin, 2000; Roach et al., 2018; Marin & Ayala, 2004; Martin & Gupta, 2004; Sung et al., 2018).

Only one study to date investigated the relationship between verbal STM/WM and discourse in people with aphasia (Cahana-Amitay & Jenkins, 2018). Researchers found that word span and sentence span predicted performance on macrolinguistic measures (episodic complexity, global, and local coherence) but not microlinguistic measures (grammatical complexity, lexical diversity, narrative length). The sentence span task involved having the participant repeat a sentence several times that increased in length by adding new nouns, prepositions, qualifiers, or verb phrases. They concluded that these STM/WM measures may predict global and local coherence in people with aphasia.

Domain and Linguistic Level (STM and WM)

Unlike the previous studies mentioned above, this study separates STM/WM based on domain (nonverbal and verbal) and linguistic level (phonological and semantic) since these variables are important for the lexical impairments associated with aphasia. Previous research has shown that people with aphasia have had significantly more difficulty with verbal STM/WM tasks than nonverbal STM/WM tasks (Martin & Saffran, 1999). Nonverbal STM/WM tasks typically involve the maintenance and manipulation of spatial information. Nonverbal STM is commonly assessed by having a participant watch the examiner point to an array of blocks in a particular sequence and then having them point to the same blocks in the same sequence that was presented by the examiner (Corsi Block-tapping task; De Renzi & Nichelli, 1975). The span or number of blocks in the sequence would then be increased (e.g. examiner would point to a sequence of two blocks, then three blocks, then four blocks, etc.). Nonverbal WM, the manipulation of the spatial information held in STM, would be then assessed by having the participant repeat the sequence in a backwards order. Nonverbal WM was chosen for this study because aphasia impacts language processing, so it may be appropriate to observe if difficulties in discourse management are more closely related to nonverbal or verbal WM.

Neuroanatomical models have traditionally described the language impairments demonstrated by people with aphasia based on performance at the task level (naming, repetition, and comprehension) (Martin et al., 2018). However, researchers have moved towards describing the linguistic impairments present in aphasia through psycholinguistic models that account for semantic and phonological processing in language tasks because this approach can more thoroughly describe a person with aphasia's language impairments (Martin et al., 2018; Dell, 1986). Dell's interactive activation (IA) model has been used to explain how language is processed when completing various language tasks (e.g. naming, repetition, comprehension, etc.) (See Figure 2). Additionally, researchers have also applied the IA model to verbal STM/WM and have proposed that verbal STM/WM is a specific process that supports language processing (Martin & Saffran, 1997). The IA model is consistent with Cowan's more general embedded processes STM model (Cowan, 1999). This model states that STM representations are retrieved from long-term memory as temporarily activated codes (e.g. semantic, visuospatial) for the function that the activated knowledge supports. Related to the verbal domain of STM/WM, verbal information is retrieved from long-term memory (from the mental lexicon) and is temporally stored in a person's verbal STM. A person then uses processes associated with their WM to manipulate this information so they can complete a task that involves some form of language processing. Dell's IA model includes a semantic, lexical, and phonological linguistic level that is mediated by two stages (the lexical and phonological access stages). During lexical retrieval (naming), activated semantic concepts send their activation to the corresponding lexical representation (the word) and only the most highly activated lexical item is selected (completed via lexical access stage). Once the target lexical representation is activated, it spreads to the phonological representations and the sounds used to produce the word (completed via phonological access stage). The model suggests this process is completed via bidirectional activation such that later levels of representations can influence earlier activated representations. During this spreading activation, the target word and words that are phonologically or semantically similar are primed. The target word is then chosen to be retrieved based on having the strongest activation.

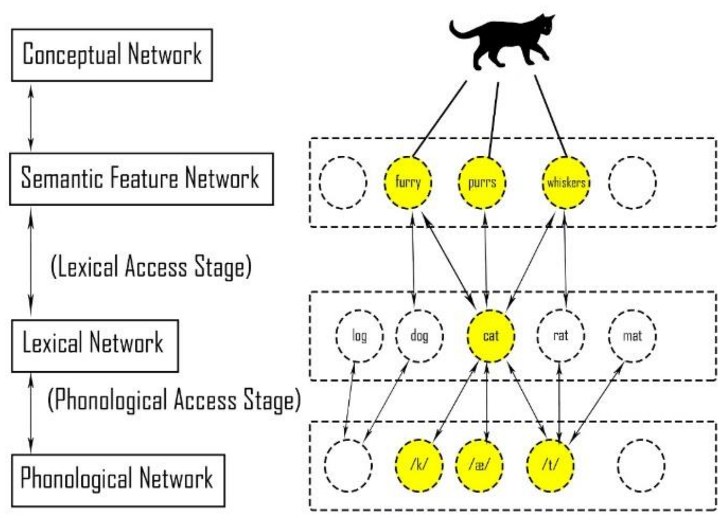

Figure 2. <u>Dell's IA Model.</u> Depiction of how retrieval of the word "cat" would be represented using Dell's IA model.

In terms of the maintenance of this verbal information, as time progresses, the activation of the target word will begin to decay towards baseline immediately after the word is retrieved. This activation strength is dependent on the overall word's connection strength and decay rate. If connection strength is weak, activation will be spread too slowly. If the decay rate of a representation is too fast, the representation's activation will decrease towards baseline too quickly. In terms of naming, if the activation of a target word is weak or if it decays too quickly by the time the person produces the word, a more highly activated related word (semantic or phonological), unrelated word, nonword, or an omission (no response) can occur.

Based on this IA model, output (e.g. naming), input (e.g. comprehension), and a combination of input and output (e.g. repetition) can be described. In naming, the person would move from the conceptual level and advance through the semantic, lexical, and phonological level. During related input processes (e.g. comprehension), processing would occur in a reverse order (phonological→lexical→semantic→conceptual). Finally, repetition would begin at the phonological level and then spread to the lexical and semantic networks with bidirectional feedback activation spreading between the levels of representations (phonological, lexical, semantic).

In terms of a verbal STM/WM task, a sequence of words is heard and recalled in the same order they were originally heard. The spreading activation of the phonological-lexical-semantic network of a word is then held in temporary storage until the person is required to reproduce the sequence. Impairments in aphasia are characterized by a combination of impairments in specific domains of linguistic representations (semantic and phonological) and processing these representations expressed by the decay rate and connection strength of the word's representations.

Using the IA model, researchers have found that people with aphasia can have language impairments related to the semantic representation (overall meaning and semantic features associated with words) or the phonological representation (sequence of phonemes associated with words) of a word (Martin et al., 2018). For example, a participant may demonstrate difficulties with a rhyming judgement task (processing phonological representations by determining if words rhyme) but perform within normal limits on a category judgement task (processing semantic representations by determining if words share the same semantic category). In addition, researchers have moved beyond describing the access and retrieval of these linguistic representations (semantic and phonological) towards describing also how these linguistic representations are maintained and manipulated in verbal STM to process single and multiple word utterances (Martin & Gupta, 2004; Saffran & Dell, 1996; R, Martin et al., 1994). Researchers hypothesized that individuals use verbal STM and WM to maintain and manipulate the semantic and phonological representations of words within an utterance. Successful language production and comprehension then requires the person's ability to access and retrieve, maintain, and manipulate the words' phonological and semantic representations within an utterance. A compromised ability to do so can contribute to a person with aphasia's language impairments (Martin et al., 2018).

Researchers have created WM tasks that are sensitive to identifying disruptions in a person with aphasia's ability to maintain and manipulate semantic and phonological representations (Martin et al., 2018). Semantic WM tasks can include having a participant temporarily store words and make decisions (thus requiring manipulation of the information) about the semantic representation of words (e.g., meanings, semantic category, semantic features.). An example of this would be having a participant hold three words in their STM and having them indicate if any of the words have a similar meaning (e.g. pier and dock) (see “current study” and “methods” section for more information about the specific tasks used). Phonological WM tasks include having a participant temporarily store words and make decisions (thus requiring manipulation of the information) about the phonological representation of words (e.g., rhyming, first consonant vowel (CV) in the word). An example of this would be having a participant hold three words in their STM and having them indicate if any of the words rhyme (see “current study” and “methods” section for more information about the specific tasks used). Semantic and phonological WM tasks may provide information on an individual’s ability to maintain and manipulate semantic and phonological representations of words. Given that people with aphasia can have differences in accessing and retrieving, maintaining, and manipulating semantic and phonological representations, exploring semantic and phonological WM may be informative in determining which one is more important for global and local coherence.

Current Study

The previous literature review demonstrates that there is evidence that performance on STM/WM tasks may influence global and local coherence (Cahana-Amitay & Jenkins, Coelho et al., 2012). However, more research is needed to understand this relationship in people with aphasia. This current study investigated how STM/WM may influence discourse production in people with aphasia by investigating the influence of nonverbal, phonological, and semantic WM on global and local coherence.

Specific semantic and phonological WM tasks from a recent battery, developed to assess phonological and semantic language processing, STM, and WM in people with aphasia, called the Temple Assessment of Language and Short-term Memory in Aphasia

(TALSA, Martin et al., 2018) were used to assess semantic and phonological WM (Martin et al., 2018). The current study utilized semantic WM tasks from the TALSA that include the Noun-Verb Concrete-Abstract (N-V-C-A) Synonymy Triplets subtest and three semantic probe span subtests (see methods for specific semantic probe spans). The semantic WM tasks all involve making semantic judgements (related to word meaning or category membership) between words under high and low WM conditions. The phonological WM subtests include the Rhyming Triplets subtest and two Phonological Probe Span subtests (see methods for specific phonological probe spans) from the TALSA. The phonological WM tasks all involve making phonological judgements (related to rhyming and initial consonant vowel (CV)) between words under high and low WM conditions.

Research Questions and Predictions

This study investigated the relationship between nonverbal, phonological, and semantic WM and global and local coherence in people with aphasia. More specifically this research study aimed to answer three research questions below.

1. *Is there a relationship between performance on nonverbal WM tasks and/or global or local coherence ratings?*

This study hypothesized that nonverbal WM abilities would not be correlated with global and local coherence scores because discourse production is verbal in nature. Successful coherence requires a person to make decisions about the verbal information within the utterances they are producing during discourse. Difficulties with the maintenance and the manipulation of verbal information will result in difficulties maintaining successful global and local coherence.

2. Is there a relationship between performance on phonological WM tasks and global and/or local coherence ratings in people with aphasia?

This study hypothesized that phonological WM abilities would not have a relationship with global and local coherence. Since coherence is a semantic construct based on the meaning of utterances and their thematic unity, we hypothesized that phonological WM abilities would not be correlated with global or local coherence scores. The maintenance and manipulation of phonological representations will have less of an influence on making decisions about the semantic content between utterances that is accomplished to maintain a high global and local coherence.

3. Is there a relationship between performance on semantic WM tasks and global and/or local coherence ratings in people with aphasia?

This study hypothesized that semantic WM abilities would be correlated with global and local coherence. Maintaining a coherent semantic theme between utterances in discourse should require semantic STM/WM. A person may be maintaining and manipulating the semantic information related to what the person has already said, the topic of conversation, and what the person is going to say in their verbal STM during discourse production. If there are deficits in the person's semantic STM and WM system during this stage of processing, the person's ability to maintain and manipulate these semantic representations would be compromised and they would have more difficulty maintaining semantic connections between utterances that would be important for maintaining global and local coherence.

CHAPTER 2

METHODS

Participants

A total of 13 participants with aphasia (7 males and 6 females) and neurotypical adults (4 females) were included in this study through the Eleanor M. Saffran Center for Cognitive Neuroscience. Participants were all required to pass hearing and vision screening and had no prior history of neurological disorder (other than stroke) or learning disability. See Table 1 for group demographic information. See Tables 2 and 3 for individual demographic information for both participants with aphasia and neurotypical adults.

Table 1

Descriptive Statistics of Demographic Information

Participants with Aphasia (n = 13)				Neurotypical Adults (n = 4)			
	Mean	SD	Range		Mean	SD	Range
Education	13.00	2.48	7.00 - 16.00	Education	13.00	1.15	12.00 - 14.00
Age (Years)	56.06	7.78	38.40 - 72.11	Age (Years)	64.28	4.61	60.68 - 70.76
Time Post Onset (Months)	58.62	52.13	12.00 - 173.00	MoCA	24.75	1.50	23.00 - 26.00
WAB AQ	81.96	6.75	73.19 - 93.50				

Data from participants with aphasia was taken from existing data from the Eleanor M. Saffran Center for Cognitive Neuroscience. To be included in the study, participants were required to be a minimum of six months post-onset of aphasia, diagnosed with mild-moderate fluent aphasia based on the Western Aphasia Battery - Revised (WAB-R; Kertesz, 2007), and to have completed testing related to this study within one calendar year. Participants with severe aphasia were excluded due to severity possibly skewing discourse data if participants made too many lexical errors during discourse production. Fluency was considered because previous research has demonstrated that participants with nonfluent aphasia have lower global coherence than participants with fluent aphasia since sentence completeness influences global coherence ratings (Hazamy & Obermeyer, 2020). Participants with aphasia were classified as fluent if they scored a 5 or above on the 10-point fluency, grammatical competence, and paraphasia scale in the spontaneous speech section of the WAB-R. Mild-moderate aphasia was classified based on the aphasia quotient (AQ) from the WAB-R. Mild aphasia was determined if the AQ fell between 75 and 95 and moderate aphasia if AQ fell between 51 and 74. Eleven of the 13 participants were classified as mild (11/13 participants with aphasia; range of 75.9 - 93.5), and two were classified as moderate (TU-XH46 AQ: 73.1; TU-BQ58 AQ: 74.8). In terms of aphasia type, anomic aphasia accounted for 10/13 participants, one participant with aphasia was classified with transcortical sensory and two were classified with conduction aphasia. Time post onset had ranged between 12 months (1 year) and 173 months (14 years and 5 months) (mean = 58.62, SD = 52.13).

Four neurotypical adults were included in this study to establish a reference point to compare to the participants with aphasia. All subtests and discourse procedures were completed during the completion of the thesis by research assistants and a graduate student through the Eleanor M. Saffran Center for Cognitive Neuroscience. Similar to the participants with aphasia, all neurotypical adult data was completed within one calendar year.

Table 2

Demographic Information (Participants with Aphasia)

Participant ID	Education	Sex	Age (Years + Months)	Time Post Onset (Months)	WAB AQ	WAB Aphasia Classification	Handness
TU-BQ58	16	F	38; 5	78.00	74.8	Conduction	R
TU-CM5	10	M	53; 6	55.00	90.3	Anomic	R
TU-DC44	14	F	56; 8	31.00	93.5	Anomic	R
TU-DE79	11	F	55; 7	19.00	75.9	Anomic	R
TU-DS68	12	F	72; 1	12.00	82.7	Anomic	R
TU-GN73	16	M	59; 11	16.00	87.9	Anomic	R
TU-HI28	13	M	61; 9	123.00	77.5	Conduction	R
TU-KC3	14	M	56; 0	173.00	76.1	Transcortical Sensory	R (Left prior to seizure)
TU-MN56	14	M	60; 4	114.00	81.1	Anomic	R
TU-NF54	14	F	55; 9	32.00	81.1	Anomic	R
TU-UP35	14	M	53; 2	84.00	80.4	Anomic	R
TU-XH46	7	M	47; 7	13.00	73.1	Anomic	R
TU-ZK87	14	F	58; 1	12.00	91.1	Anomic	R

Table 3

Demographic Information (Neurotypical Adults)

Participant ID	Education	Sex	Age (Years + Months)	MoCA Score	Handness
TU-CTT51	12	F	64.36	26.00	R
TU-CHD50	14	F	61.32	23.00	R
TU-CQK48	14	F	60.68	26.00	L
TU-CHN44	12	F	70.76	24.00	R

All neurotypical adults completed the Montreal Cognitive Assessment (MoCA) to screen for language or cognitive impairments that may influence their performance on the study tasks (Nasreddine et al., 2005). Neurotypical adults had to obtain a cutoff score of 23 or higher on the MoCA to be categorized as having no language or cognitive impairments.Similar to the participants with aphasia, all neurotypical adult data was completed within one calendar year. All neurotypical adults completed the Montreal Cognitive Assessment (MoCA) to screen for language or cognitive impairments that may influence their performance on the study tasks (Nasreddine et al., 2005). Neurotypical adults had to obtain a cutoff score of 23 or higher on the MoCA to be categorized as having no language or cognitive impairments. Studies have found that reducing the MoCA's typical cutoff score of 26/30 to 23/30 lowers the presence of false positives and establishes an overall better diagnostic accuracy (Carson et al., 2018; Rossetti et al., 2011).

All 17 participants were right-handed with exception of one of the neurotypical adults (TU-CQK48), between 38 and 72 years of age, and had achieved an education level between 7 and 16 years. Educational level for the neurotypical adults (mean =13, SD = 1.15) were similar to the participants with aphasia (mean = 13.00, SD = 2.48), though participants with aphasia had more variability and a larger range (education of participants with aphasia ranged from 7-16 and neurotypical adults ranged from 12-14). The mean age for the participants with aphasia (mean = 56.06, SD = 7.78) was lower than the mean age of the neurotypical adults (mean = 64.28, SD = 4.61).

WM Tasks

Fifteen out of the 17 participants completed the forward Corsi Block Task (De Renzi & Nichelli, 1975) to assess nonverbal WM. Two participants with aphasia did not complete the forward Corsi block when they completed study related testing. All participants completed the Rhyming Triplets subtest (TALSA) and two phonological probe spans (rhyming, initial CV; TALSA) to assess phonological WM. Finally, all participants completed the Noun-Verb-Concrete (N-V-C-A) Synonymy Triplets subtest and three semantic probe spans (category coordinate, synonymy, and superordinate) to assess semantic WM. Each WM task will be described below. See Table 4 for a list of the WM subtests administered, an example of each, and the variable of interest for each WM task.

Table 4

List of all WM tasks

WM Domain (WM Linguistic Level)	Task	Example
Nonverbal WM	Forward Corsi Block	Examiner points to three blocks in a 3x3 array of blocks. Participant points the same blocks in the same order.
Verbal WM (Phonological)	Rhyming Triplets Subtest (TALSA)	*Low WM Condition:* A picture of a “rat,” “cat,” and a “bug” are presented on the screen and each word is presented verbally. “Cat” is surrounded by a black box. Participant points to the word that rhymes with “cat” out of the two choices (correct answer is “rat”). *High WM Condition:* A picture of a “rat,” “cat,” and a “bug” are presented on the screen and each word is presented verbally. Participant points to the two words that rhyme (“cat” and “rat”).
Verbal WM (Phonological)	Rhyming Probe Span (TALSA)	Words “rat,” “dog,” and “bug” are presented verbally in a sequence. The probe word “mat” is then presented. Participant answers "yes" or "no" if “mat” rhymes with any of the words in the sequence (correct answer is “yes” because “mat” rhymes with “cat” and “rat”).

Table 4

List of All WM Tasks (continued)

Verbal WM (Phonological)	Initial CV Probe Span (TALSA)	Words “rat,” “cat,” and “bug” are presented verbally in a sequence. The probe word “cake” is then presented. Participant answers "yes" or "no" if “cake” has the same initial CV with any of the words in the sequence (correct answer is “yes” because “cat” and "cake" have same initial CV).
Verbal WM (Semantic)	N-V-C-A Synonymy Triplets Subtest (TALSA)	*Low WM Condition:* Words "chair,” "man," and "boy" are presented verbally and in writing on the screen. “Man” is surrounded by black box. Participants points to the word that has a similar meaning to "man" out of the two choices (correct answer is "boy"). *High WM Condition*: Words "chair," "man," and "boy" are presented verbally and in writing on the screen. Participant points to the two words that have a similar meaning (correct answer is "boy" and "man").
Verbal WM (Semantic)	Category Coordinate Probe Span (TALSA)	Words “rat,” “dog,” and “strawberry” are presented verbally in a sequence. The probe word "banana” is then presented. Participant answers "yes" or "no" if there are any words that share the same category with "banana" (correct answer is “yes” because “banana" and "strawberry" are fruits).

Table 4

List of All WM Tasks (continued)

Verbal WM (Semantic)	Synonymy Probe Span (TALSA)	Words “rat,” “dock,” and “bug” are presented verbally in a sequence. The probe word “pier” is then presented. Participant answers "yes" or "no" if “pier” has a similar meaning to any words in the sequence (correct answer is “yes” because “dock” and "pier" have a similar meaning).
Verbal WM (Semantic)	Superordinate Probe Span (TALSA)	Words “rat,” “banana,” and “chair” are presented verbally in a sequence. The probe word “fruit” is then presented. Participant answers "yes" or "no" if any of the words in the sequence belong to the category of "fruit" (correct answer is “yes” because a "strawberry" is a fruit).

Nonverbal WM Task

Forward Corsi Block Task

Forward Corsi block task was used to assess nonverbal WM (De Renzi & Nichelli, 1975). Forward Corsi block had been administered during background testing for participants with aphasia before administration of the TALSA subtests. When this project was being completed, the neurotypical adults were in the process of completing TALSA subtests relevant to this study. The graduate student completing this project administered the forward Corsi block to all neurotypical adults. Forward Corsi block was set up by placing a 3x3 pattern of blocks (total of nine blocks) between the participant and the examiner. Participants were asked to observe the examiner point to a sequence of blocks, then the participant was asked to imitate the same sequence. Sequence length ranged from 1-9 blocks with six trials for each sequence length. Sequence length continued to increase until the participant incorrectly performed four out of the six trials in a sequence length (they would fail this sequence length) at which point the participant would not proceed to the next sequence length. For example, if a participant was at sequence length 5, pointing to a sequence of five blocks, they would fail sequence length 5 if they incorrectly performed four out of the six trials in sequence length 5. Nonverbal span was then calculated by adding together the last span they passed (e.g. if they failed sequence length 5, this would be 4) and how many sequences they correctly performed in serial order (ISO) out of three (the number of trials they needed to pass) on the list length they failed. Nonverbal span was the variable of interest to determine participants' performance in terms of nonverbal WM.

Forward Corsi block provides information about each participant's nonverbal WM because the task involves maintaining and manipulating visuo-spatial information. Manipulation and increased WM load is achieved by repeating the sequence in the exact order it was presented. Instructing participants to complete the sequence in any order (IAO) would isolate the individual's maintenance of the items. Increasing the sequence length increases the amount of information the participant needs to maintain in their STM and increases WM load.

Triplets WM Tasks (Phonological and Semantic WM)

Rhyming Triplets (Phonological WM)

The Rhyming Triplets subtest was administered to assess phonological WM (Martin et al., 2012; Martin et al., 2018). The assessment was administered using E-Prime software and had a low WM condition and high WM condition. In the low WM condition, three words were presented verbally and visually (with a picture) in a diagonal pattern from the top left corner of the screen to the bottom right corner of screen. A black box surrounded the word in the middle. The participant was instructed to point to the word that rhymes with the word surrounded by the black box. In the high WM condition, three words were presented in a similar pattern, but there was no black box surrounding the middle word. The participant was then instructed to point to the two words that rhyme. Removing the black box increases WM difficulty because it increases the number of comparisons the participant has to make (three comparisons instead of two). See Figure 3 for example of both the high and low WM condition. The variable of interest for this task is the difference between the low and high WM conditions (change score).

Noun-Verb Concrete-Abstract (N-V-C-A) Synonymy Triplets (Semantic WM)

The N-V-C-A Synonymy Triplets subtest was administered to assess semantic WM (Martin et al., 2012; Martin et al., 2018) using E-Prime software. The stimuli presented in this task had an equal number of abstract and concrete nouns and verbs. Procedures were identical to the rhyming triplets' procedure except each word was only presented in writing and participants were instructed to make decisions about which two words had a similar meaning. Similar to the rhyming triplets, the variable of interest for this task is the difference between the low and high WM conditions (change score).

Based on previous research using this subtest, people without aphasia tend to perform at ceiling on both high and low WM conditions and participants with aphasia's performance is more distributed (Martin et al., 2018). The change score is the variable of interest since the difference between the high and low WM conditions isolate the influence of WM on the task and excludes other variables that may influence performance on task (retrieval, decoding, etc.) (Martin et al., 2012).

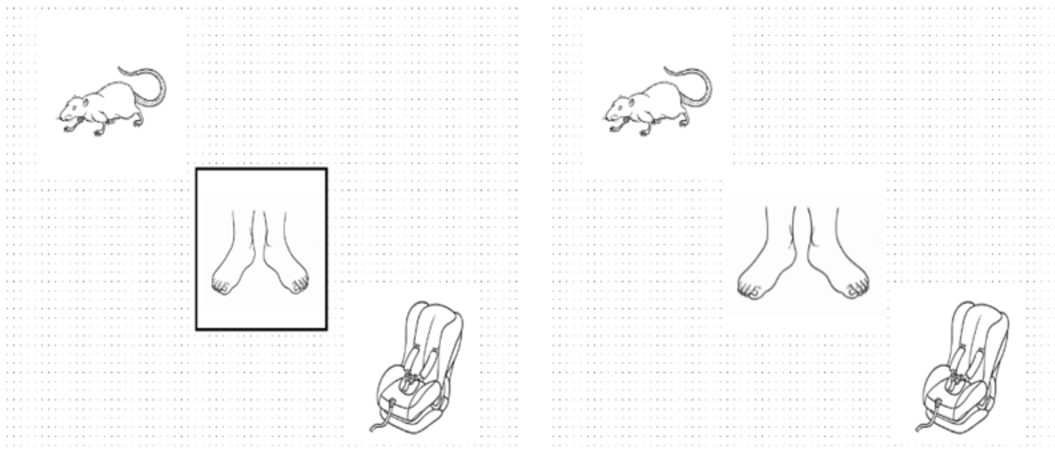

Figure 3. The left side is an example of an item from the rhyming triplets low WM condition and the right side is example of an item from the high WM condition

Probe Spans (Phonological and Semantic WM)

Phonological Probe Spans (Rhyming, Initial CV, and Nonword Identity; Phonological WM)

Two phonological probe span subtests were also administered to assess phonological WM using E-Prime software (Steinberg 1969; 1975; Martin et al., 2018). There were two different types of probe spans, which assessed different information associated with phonological WM. In all probe spans, participants heard a sequence of words followed by a two second delay. A probe word was then presented, and participants were asked if the probe word shared a phonological relationship with any of the words presented in the sequence. For the rhyming probe span, the participant judged if any of the words in the sequence rhymed with the probe word. For the initial CV probe span, the participant judged if any of the words in the sequence shared the same initial CV syllable with the probe word. All probe spans started at a span of one (also called list length 1; one word is presented and then the probe word) and proceeded to next span based on the pass and fail criteria determined by administration instructions from the TALSA (Martin et al., 2018). If the participant started at list length 1 (one word is presented and then the probe word), the next span would be list length 2 (sequence of two words are presented and then the probe word). The highest list length would be list length 7 (sequence of seven words and then the probe word). For each probe span, a span would be calculated based on administration instructions from the TALSA (Martin et al., 2018). A phonological composite span was calculated as the variable interest to provide information about overall performance on phonological probe spans. This was calculated by transforming raw scores to z-scores and then averaging the z-scores of the rhyming probe span and initial CV probe span.

Semantic Probe Span (Category Coordinate Probe Span, Synonymy Probe Span, and Superordinate Probe Span)

The semantic probe spans were administered to assess semantic WM (Steinberg 1969; 1975; Martin et al., 2018) using E-Prime software. Procedures were identical to the phonological probe spans except participants made judgments related to the semantic representation of words. The semantic probe spans consisted of the category coordinate, synonymy, and superordinate probe span. The category coordinate probe span required the participant to decide if any of the words in the sequence shared a similar category with the probe word. (For examples of each semantic probe span see Table 4.) The synonymy probe span required participants to decide if any of the words in the sequence shared a similar meaning to the probe word. Finally, the superordinate probe span required the participant to decide if any of the words in the sequence belonged to a category that was presented as the probe word. A semantic composite span was calculated to provide information about overall performance on semantic probe spans. This was calculated by transforming raw scores to a z-scores and then averaging the z-scores of the category coordinate probe span, synonymy probe span. and the superordinate probe span.

For all probe spans, each word that is added to list length increases information held in STM (Martin et al., 2018). In comparison to the triplets, the probe spans require an increased STM capacity. Performance on the probe spans is more variable for both the neurotypical adults and participants with aphasia. Probe spans "test the limits" of the person's STM/WM by increasing list length until they fail to accurately perform the task. If participants perform at ceiling on triplets, probe spans can provide information on when a participant's STM/WM might break down when making comparisons beyond three items. Averaging the performance on the probe spans for each linguistic level (semantic and phonological) was selected to provide a more comprehensive understanding of the participant's semantic and phonological WM.

Each phonological probe span assessed the participant's judgement of phonological representations in terms of the maintaining and manipulating of the initial phonemes associated with a word's phonological representation (initial CV) and the ending phonemes associated with a word's phonological representations (rhyme). Similarly, each semantic probe span assessed the participant's judgement of semantic representations in terms of maintaining and manipulating the meaning of the words (synonymy) and the superordinate category the word belongs to (category coordinate and superordinate). Participants may perform differently on these types of probe spans because they require maintaining and manipulating different information associated with the representations of the words.

Discourse Elicitation

Similar to the forward Corsi block, the discourse samples for the participants with aphasia were elicited as background testing prior to completing TALSA testing in the lab. The graduate student completing this project administered discourse samples to neurotypical adults when they were completing relevant TALSA subtests for this study. Discourse samples were obtained using the 10 discourse stimuli and elicitation procedures described by Nicholas and Brookshire (1993). Discourse stimuli consist of four single pictures (e.g. picnic scene, cookie theft, cat rescue, birthday), 2 picture sequences (e.g. argument, directions), two requests for personal information (e.g. "tell me where you live and describe it to me"; "tell me what you usually do on Sundays"), and two procedural narratives (e.g. "tell me how you do the dishes by hand"; "tell me how you write and mail a letter").

The 10 discourse stimuli were administered in random order to the participants. During the elicitation procedure involving pictures, the picture was placed in front of the participant and they were asked to describe what was happening in the picture(s). During the elicitation procedure involving the prompts, a piece of paper with the prompt written in black type was placed in front of the participant and the prompt was read verbatim by the examiner. Participants were asked to talk about each stimulus for about one minute. If the participant stopped talking before at least 15 seconds of speech, the examiner cued the participant to provide more information by saying “can you tell me more?”. No other prompts or feedback were given. These 10 discourse stimuli were included to obtain an adequate number of utterances to analyze for global and local coherence.

Discourse Transcription and Analysis

Discourse Transcription

Discourse samples were transcribed orthographically by the graduate student or research personnel in the Eleanor M. Saffran Center for Cognitive Neuroscience. Transcriptions were segmented into C-units, which is defined as a syntactic unit that consists of an independent clause with all its modifiers or dependent clauses (Hunt, 1965). Unintelligible utterances were excluded (if majority of words could not be interpreted due to paraphasic errors), though unintelligible utterances were rare. Procedural narratives and the Sunday transcript contained imperative utterances with an understood subject (e.g. “get the peanut butter from the cabinet”) and these imperative utterances were segmented as a separate C-unit (e.g. “I turn on the water and then wash the dishes” is counted as 2 C-units). This was done because understood subjects are grammatically acceptable in imperative utterances which are common in procedural narratives. Researchers noted that the Sunday transcript contained imperative utterances (e.g. “first, I get up and go for a walk”) similar to a procedural narrative and determined this was grammatically acceptable for the Sunday transcript.

Discourse Analysis

Discourse samples were analyzed for global and local coherence using a 5-point Likert scale used by Van Leer and Turkstra (1999).

Global Coherence

Global coherence was evaluated using the 5-point Likert scale described by Van Leer and Turkstra (1999) adapted from Glosser and Deser's 5-point scale (1987). Global coherence was rated by assessing how well each C-unit related to the overall topic of discourse. For the pictures(s), this would mean how well each C-unit related to the picture being described or story generated from the picture sequence. For the procedural narratives or request for personal information, this included how well each C-unit related to the topic of the prompts. C-units were rated on a scale from (least relevant to overall topic of discourse) to 5 (most relevant to overall topic of discourse) based on how well the meaning of the current utterance relates to the overall topic of discourse. See Table 5 for each rating with a description about each rating. See examples of ratings and rationales for each rating in Appendix A.

Table 5

Global Coherence Rating Scale

Scores	Description
5	The utterance provides substantive information related to the general topic.
4	The utterance contains multiple clauses, wherein one clause relates directly to the topic and the other relates indirectly.
3	The utterance provides information possibly related to the general topic or is an evaluative statement without providing substantive information, or the topic must be inferred from the statement.
2	The utterance contains multiple clauses, wherein one clause possibly relates the general topic and one does not.
1	The utterance is unrelated to the general topic or is a comment on the discourse.

Local Coherence

Local coherence was evaluated using a 5-point Likert scale also described by Van Leer and Turkstra (1999) adapted from Glosser and Deser's 5-point scale (1987). Local coherence ratings were measured based on evaluating the relationship between the meaning of a C-unit with the meaning of the preceding C-unit. C-units were rated on a scale ranging from 1 (least relevant to topic of preceding utterance) to 5 (most relevant to topic of preceding utterance) based on how well the meaning of the current C-unit related to the topic or meaning of the C-unit that was immediately preceding it. See Table 6 for a description of each rating and criteria for each rating. All intelligible C-units were rated using the local coherence rating scale with exclusion of any utterances immediately following responses to examiner. See examples of ratings and rationales for each rating in Appendix B.

Table 6

Local Coherence Rating Scale

Score	Description
5	The topic of the preceding utterance is continued by elaboration; temporal sequencing; enumeration of related examples; or maintaining the same actor, subject, action or argument as the focus.
4	The utterance contains multiple clauses, wherein one clause definitely relates to the content in the preceding utterance, but another may not.
3	The utterance topic generally relates to that of the preceding utterance, but with a shift in focus from the subject or activity of the preceding utterance; or the utterance is referentially vague or ambiguous so that the relation to the preceding utterance must be inferred.
2	The utterance contains multiple clauses, wherein one possibly relates to the content of the preceding utterance, but the other (s) may not.

1	The utterance has no relationship to the content of the immediately preceding utterance. It may be a radical topic shift, a comment on the discourse, or an unintelligible utterance.

Exclusion Criteria for Global and Local Coherence

All intelligible C-units were rated using a global and local coherence rating scale, which included incomplete or unclear utterances. C-units related to ending commentary (e.g. “that’s it”, “the end”, “that’s the story”) stated at the end of the discourse sample were excluded. If the participant continued to describe the picture after producing ending commentary, then the commentary was included in the analysis. For example, if a participant said, “that’s it” and continued to describe the picture, the C-unit, “that’s it” would be rated using both scales and not excluded. Other C-units that were excluded were initial questions to clarify task instructions (e.g. “Do you want me to describe this picture?”). If the examiner provided any other feedback, cuing, or questions that differed from the discourse elicitation protocol, all utterances after examiner’s utterance were excluded. These specific rules for coding, although not originally used in this 5-point-scale, were adapted from a 4-point-scale in the study completed by Wright and colleagues (2013). Researchers for this study felt these exclusion rules ensured that utterances included in the discourse samples were not related to clarification of test instructions, that discourse administration was as consistent as possible, and that utterances that were irrelevant to coding global and local coherence were excluded (e.g. conclusive statements like “that’s it”).

Calculation of Average Global/Local Coherence

Participant's average global and local coherence scores were calculated by adding all the scores for each rated C-units from all 10 discourse samples and then dividing this by the total number of coded C-units. This was done to control the effects of the discourse sample's length on the participants overall global and local coherence.

Reliability

Inter- and intrarater reliability was calculated to ensure global and local coherence ratings were reliable. The graduate student completing this project and a licensed speech language pathologist that had experience working with people with aphasia initially completed a training period to establish consistency using global and local coherence rating scales. Cohen's kappa was utilized to establish strong reliability since this statistical test controls for the influence of chance in terms of agreement within and between raters. During the reliability training phase, raters decided to omit ratings 2 and 4 from both global and local coherence scales due to difficulties maintaining strong agreement when considering the global coherence scores of C-units with multiple clauses. Van Leer and Turkstra (1999) similarly omitted ratings of 2 and 4 when using the same scale due to ratings of 2s and 4s rarely being assigned and the fact that rating of 2s and 4s differed only in the presence of a second clause and not if the utterance as a whole was linked to the topic of discourse or the preceding utterance. For global coherence, 7/17 transcripts were coded together during the reliability training phase. After the reliability training phase for global coherence, interrater reliability was calculated for 50% of the remaining transcripts and Cohen's kappa of 0.654 (substantial agreement) was obtained. Intrarater reliability was calculated for 5/18 (28%) of transcripts one month after these transcripts were coded, and a Cohen's kappa of 0.655 (substantial agreement) was obtained. In terms of local coherence, all transcripts were coded together with both raters due to difficulty maintaining consistent interrater reliability. Due to difficulty maintaining intrarater reliability, the graduate student completing this project looked through all transcripts to ensure that he agreed with all ratings based on the local coherence rating scale's criteria. If the graduate student disagreed with any ratings, these ratings were recoded together with other raters. Following recoding procedure, 29% of the transcripts were coded again one week later to establish intrarater reliability and a Cohen's kappa of 0.609 was obtained.

Data Analysis

Nonverbal WM variable of interest included the forward Corsi block's span. Phonological WM variable of interests included the phonological composite span (average z-scores of both the rhyming and initial CV probe spans) and the rhyming triplets change score (proportion of correct responses for low WM condition – high WM condition). Semantic WM variables of interests included the semantic composite span (average z-scores of category coordinate, synonymy, and superordinate probe span) and the synonymy triplets change score (proportion of correct responses for low WM condition – high WM condition). Correlations between the nonverbal, phonological, and semantic WM tasks and global and local coherence (scores for each C-unit of all 10 transcripts divided into the total C-units) were used to answer all research questions. The same correlations were also run on a combined group ($n = 17$) of the neurotypical adults and participants with aphasia to determine if a similar relationship could be found with the neurotypical adults.

CHAPTER 3

RESULTS

Outliers were identified and a Shapiro-Wilk test was completed to assess each relevant variable's normality. Based on the results, nonparametric statistics were chosen due to skewness and outliers presented in some variables. Spearman Rho correlation with $\alpha = .05$ was chosen to evaluate the relationships between variables of interests and to answer all proposed research questions.

Participants with aphasia (n = 13) were compared to the neurotypical adult's reference point (n = 4). The mean for all WM measures (nonverbal, phonological, and semantic) and discourse measures were lower for the participants with aphasia than the neurotypical adults. See Tables 7 and 8 for descriptive statistics. Participants with aphasia had a similar range and standard deviation in terms of forward Corsi block performance compared to the neurotypical adults (participants with aphasia SD = 0.79, range = 4 – 6.67; neurotypical adults SD = 0.72, range = 4.33 – 6.00). Neurotypical adults appeared to perform at ceiling on all rhyming and synonymy triplets measures (proportion of correct in high and low WM condition and change score) compared to the participants with aphasia who had more variability in their performance on the rhyming and synonymy triplets tasks, demonstrated by a higher standard deviation and wider range of performance (see Tables 7 and 8). On both rhyming and initial CV probe spans, participants with aphasia had a wider and lower range of performance compared to the neurotypical adults (participants with aphasia rhyming probe span range = 0.80 – 6.04; neurotypical adults rhyming probe span range = 3.60 – 7.00; participants with aphasia initial CV probe span range = 0.53 – 5.80; neurotypical adults initial CV probe span range = 4.96 – 6.84). Neurotypical adults had similar variability on the rhyming probe span compared to participants with aphasia demonstrated by a similar standard deviation (participants with aphasia SD = 1.55; neurotypical adults SD = 1.59). However, neurotypical adults had less variability on the initial CV probe span than the neurotypical adults demonstrated by a different standard deviation (participants with aphasia SD = 1.55; neurotypical adults SD = 0.78). Both participants with aphasia and neurotypical adults performed lower on initial CV probe span than rhyming, though participants with aphasia had a larger difference between average performance on rhyming and initial CV probe span compared to neurotypical adults (participants with aphasia rhyming probe span mean = 3.39; participants with aphasia initial CV probe span mean = 2.02; neurotypical adults rhyming probe span mean = 5.88; neurotypical adults initial CV probe span mean = 5.81). Neurotypical adults appeared to have a higher standard deviation on all semantic probe spans (see Tables 8 and 9*)*. Neurotypical adults had high variability in their performance on all semantic probe spans with participants performing at the highest level possible (span length of 7.00) and similar or lower when compared to the performance of some of the participants with aphasia (1.98 – 4.91), which may account for a higher standard deviation. Unlike neurotypical adults, participants with aphasia had a lower range on all semantic probe spans with a minimum value ranging from 0.53 – 0.80 and a maximum value ranging from 4.80 – 4.91. Both the participants with aphasia and the neurotypical adults appeared to perform better on the synonymy and superordinate probe span than the category coordinate probe span (see Tables 7 and 8 for means). On average, neurotypical adults produced more C-units than participants with aphasia, though both had a similar standard deviation (similar distribution) (participants with aphasia mean = 127.00, SD = 39.34; neurotypical adults mean = 166.50, SD = 44.94). Participants with aphasia had a wider range in number of C-units produced than the neurotypical adults (participants with aphasia range = 68.00 – 218.00; neurotypical adults range = 132.00 – 232.00). Some of the participants with aphasia had lower global coherence scores compared to neurotypical adults (participants with aphasia range = 2.25 – 4.00; neurotypical adults range = 3.43 – 4.24). Participants with aphasia had a bigger difference between their average local and global coherence compared to neurotypical adults (participants with aphasia global coherence mean = 3.24, local coherence mean = 2.81; neurotypical adults global coherence mean = 3.67, local coherence mean = 3.46). A larger sample size of neurotypical adults is needed to determine if there is a significant difference between the means of the WM tasks and discourse measures of the participants with aphasia and neurotypical adult.

Answers to Research Questions

1. *Is there a relationship between performance on nonverbal WM tasks and/or global or local coherence ratings?*

Forward Corsi block span was not significantly correlated with global ($r_s(9) = -.18$, $p = .600$) or local coherence ($r_s(9) = .14$, $p = .680$). See Table 9 for correlation coefficients and *p* values.

2. Is there a relationship between performance on phonological WM tasks and global and/or local coherence ratings in people with aphasia?

Rhyming triplets change score was not significantly correlated with global ($r_s(11) = -.21$, $p = .492$) or local coherence ($r_s(11) = -.31$, $p = .295$).

Table 7

Participants with Aphasia WM tasks and Discourse Descriptive Statistics

	Measure	N	Mean	SD	Range
Nonverbal WM	Forward Corsi Block	11	4.61	0.79	4.00 - 6.67
Phonological WM	Rhyming Triplets (High WM Condition)	13	0.82	0.09	0.70 - 0.97
Phonological WM	Rhyming Triplets (Low WM Condition)	13	0.92	0.06	0.83 - 1.00
Phonological WM	Rhyming Triplets Change Score	13	0.10	0.10	-0.07 - 0.30
Semantic WM	Synonymy Triplets (High WM Condition)	13	0.76	0.17	0.53 - 1.00
Semantic WM	Synonymy Triplets (Low WM Condition)	13	0.87	0.12	0.70 - 1.00
Semantic WM	Synonymy Triplets Change Score	13	0.11	0.10	0.00 - 0.30
Phonological WM	Rhyming Probe Span	13	3.39	1.53	0.80 - 6.04
Phonological WM	Initial CV Probe Span	13	2.02	1.55	0.53 - 5.80
Phonological WM	Phonological Composite Span	13	0.00	0.91	-1.09 - 2.35
Semantic WM	Category Coordinate Probe Span	13	2.49	1.10	0.80 - 4.80
Semantic WM	Synonymy Probe Span	13	3.12	1.48	0.53 - 4.91
Semantic WM	Superordinate Probe Span	13	2.97	1.26	0.53 - 4.91
Semantic WM	Semantic Composite Span	13	0.00	0.89	-1.52 - 1.54
Discourse	Global Coherence	13	3.24	0.51	2.25 - 4.00
Discourse	Local Coherence	13	2.81	0.35	2.05 - 3.26
Discourse	Total Utterances	13	127.00	39.34	68.00 - 218.00

Table 8

Neurotypical Adults WM Tasks and Discourse Descriptive Statistics

	Measures	Mean	SD	Range
Nonverbal WM	Forward Corsi Block	5.33	0.72	4.33 - 6.00
Phonological WM	Rhyming Triplets (High WM Condition)	0.97	0.03	0.93 - 1.00
Phonological WM	Rhyming Triplets (Low WM Condition)	0.98	0.02	0.97 - 1.00
Phonological WM	Rhyming Triplets Change Score	0.02	0.02	0.00 - 0.03
Semantic WM	Synonymy Triplets (High WM Condition)	0.98	0.04	0.93 - 1.00
Semantic WM	Synonymy Triplets (Low WM Condition)	0.98	0.05	0.90 - 1.00
Semantic WM	Synonymy Triplets Change Score	0.00	0.02	-0.03 - 0.03
Phonological WM	Rhyming Probe Span	5.88	1.59	3.60 - 7.00
Phonological WM	Initial CV Probe Span	5.81	0.78	4.96 - 6.84
Semantic WM	Category Coordinate Probe Span	3.81	1.51	1.98 - 5.67
Semantic WM	Synonymy Probe Span	5.46	2.38	1.98 - 7.00
Semantic WM	Superordinate Probe Span	5.69	1.51	3.94 - 7.00
Discourse	Global Coherence	3.67	0.38	3.43 - 4.24
Discourse	Local Coherence	3.46	0.33	3.15 - 3.85
Discourse	Total Utterances	166.50	44.94	132.00 - 232.00

Phonological composite span was also not significantly correlated with global ($r_s(11) = -.12$, $p = .707$) or local coherence ($r_s(11) = -.02$, $p = .957$).

3. Is there a relationship between performance on semantic WM tasks and global and/or local coherence ratings in people with aphasia?

When determining the relationship between global and local coherence and the N-V-C-A (synonymy) triplets change score, we expected to obtain a significantly negative correlation given that a higher triplets change score should reflect a lower global and local coherence. N-V-C-A (synonymy) triplets change score was not significantly correlated with global coherence ($r_s(11) = -.157$, $p = .608$).

Synonymy triplets change score and local coherence demonstrated a trend towards a significant correlation ($r_s(11) = -.538$, $p = .058$). Based on appearance of the scatter plot of the synonymy triplets change score and local coherence, it appears that the people with aphasia who had a synonymy triplets change score between 0.00 and 0.20 had a clear negative linear relationship consistent with our prediction (higher local coherence will correlate with bigger change score) See Figure 4 for scatter plot. Semantic composite span was not significantly correlated with global ($r_s(11) = .17$, $p = .590$) or local coherence ($r_s(11) = .14$, $p = .655$).

Table 9

Spearman Rho Correlations Between WM Measures and Discourse (People with Aphasia Group)

	Forward Corsi Block (n = 11)	Rhyming Triplets Change Score (n = 13)	Synonymy Triplets Chane Score (n = 13)	Phonological Composite Span (n = 13)	Semantic Composite Span (n = 13)
Global Coherence	-.18 (.600)	-.21 (.492)	-.157 (.608)	-.071 (.817)	.17 (.590)
Local Coherence	.14 (.680)	-.31 (.295)	-.537 (.058)	-.25 (.415)	.14 (.655)

p value represented in parentheses.
** represents significant correlation*

Results of Spearman Rho Correlation run on Combined Group (n = 17)

We conducted a second correlational analysis that combined the neurotypical participants and participants with aphasia (total n = 17) because we predicted a similar relationship between the WM measures and global and local coherence would exist in both the people with aphasia and the neurotypical adults.

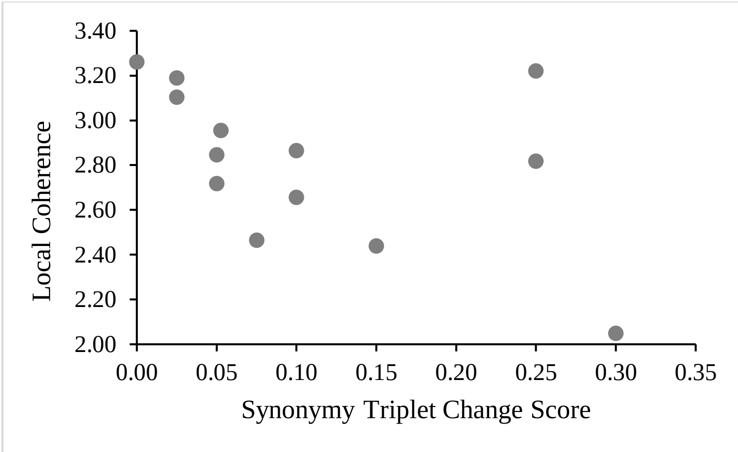

Figure 4. Scatter Plot of Synonymy Triplets Change Score and Local Coherence.

A Spearman Rho correlation was completed with $\alpha = .05$ to determine if there was a correlation between the same nonverbal, phonological, and semantic variables of interest and global and local coherence scores in the combined group. The forward Corsi block span was not significantly correlated with global ($r_s(13) = .105$, $p = .709$) or local coherence ($r_s(13) = .417$, $p = .122$). Rhyming triplets change score was not significantly correlated with global ($r_s(15) = -.321$, $p = .209$) or local coherence ($r_s(15) = -.445$, $p = .074$). Phonological composite span was not significantly correlated with global ($r_s(15) = .088$, $p = .736$) or local coherence ($r_s(15) = .039$, $p = .881$). Synonymy triplets change score was significantly correlated with local coherence ($r_s(15) = -.673$, $p = .003$). Semantic composite span was not significantly correlated with global ($r_s(15) = .201$, $p = .439$) or local coherence ($r_s(15) = .150$, $p = .567$).

CHAPTER 4

DISCUSSION

The purpose of this study was to determine the relationship between semantic and phonological WM and global and local coherence in people with aphasia. The research questions addressed in this study aimed to further investigate how a cognitive-linguistic construct like verbal WM may influence global and local coherence during discourse production. Based on theoretical models of verbal processing and STM/WM and discourse, this study investigated if maintenance and manipulation of information based on domain (verbal and nonverbal) and linguistic level (phonological and semantic) had different influences on global (relevance of utterance to topic of discourse) and local coherence (relevance of utterance to preceding utterance) scores. This study was exploratory in nature given the limited research investigating the influence of cognitive-linguistic constructs and discourse in people with aphasia.

Consistent with our first prediction, nonverbal WM did not have a relationship with global and local coherence in both the participants with aphasia group and the combined group. This finding is also consistent with previous research that has shown people with aphasia perform lower on verbal STM/WM tasks than nonverbal STM/WM tasks (Martin & Saffran, 1999). Furthermore, this finding contributes to the claim that people with aphasia perform differently on STM/WM tasks that differ in domain (verbal or nonverbal). Additionally, this evidence supports the view that nonverbal STM/WM, at least in this group of people with aphasia and neurotypical adults, may not be related to maintaining the topic of discourse or the preceding utterance (global and local coherence). Despite this finding, there is a possibility that this relationship may be different across different aphasia types and severities. Additionally, more research is needed to confirm that there is no relationship between nonverbal STM/WM and global and local coherence in a large sample of neurotypical adults. Forward Corsi block does not engage working memory as much as other nonverbal WM tasks (e.g. backward Corsi block). Thus, it may also be informative to determine if these findings are consistent when using nonverbal WM tasks that have a higher WM load like a backward Corsi block. The backward Corsi block may be a nonverbal WM task that can better analyze a participant’s ability to manipulate nonverbal information held in STM. The backward Corsi block task requires participants to repeat the sequence in a backwards order and requires more manipulation of information held in STM than the forward Corsi block.

Consistent with our second prediction, phonological WM did not have a relationship with global and local coherence in the participants with aphasia group or the combined group. We hypothesized that maintaining coherence requires making decisions about the semantic content of utterances. Therefore, maintenance and manipulation of words/utterances’ phonological representations (the word’s sounds) may have less of an influence on global and local coherence. Further research is needed to determine if this finding is consistent across different aphasia types and severities and in a larger group of neurotypical adults.

Inconsistent with our third prediction, semantic WM did not show a significant relationship with global coherence. In terms of local coherence, only the synonymy triplets change score had a trend towards significance for local coherence ($p = .058$) in the people with aphasia group. With the exception of the trend found between synonymy triplets change score and local coherence, these results contrast with the results found in the Cahana-Amitay and Jenkins study (2018) which found that both a reduced word and sentence span (repeating a sentence with increased number of nouns, prepositions, qualifiers, or verb phrases) (verbal STM/WM tasks) predicted reduced global and local coherence in people with aphasia.

Differences in results may be related to several factors. First, differences in aphasia type and severity between both studies may have influenced the results. Cahana-Amitay and Jenkins (2018) included participants with more severe aphasia (WAB AQ 45.5 – 93.4) and more aphasia types (included anomic, Wernicke's, and Broca's based on WAB classification). In terms of severity, participants with more severe aphasia may perform lower on word and sentence span tasks and may have lower global and local coherence scores. Even though Cahana-Amitay and Jenkins (2018) did not find differences in performance in terms of aphasia type, other research studies have found that participants with fluent aphasia had higher global coherence than participants with nonfluent aphasia (Hazamy & Obermeyer, 2020).

Second, differences between STM/WM measures may have influenced the results in this study and Cahana-Amitay and Jenkins (2018). The STM/WM measures of the present study were less reliant on output processing (participant pointed or selected a "yes" or "no" button on a keyboard). Difficulties with repetition/output processing may have influenced the performance on word and sentence span and global and local coherence scores in the Cahana-Amitay and Jenkins study (2018). Additionally, this study addressed differences in semantic and phonological maintenance and manipulation between the participants with aphasia that was not addressed in the Cahana-Amitay and

Jenkins study. Differences in these measures may have influenced the results between both studies (2018).

Third, this study and the Cahana-Amitay and Jenkins study (2018) used different discourse genres and elicitation procedures. This study combined the global and local coherence scores of multiple genres from the Nicholas and Brookshire narratives. The Cahana-Amitay and Jenkin' study (2018) utilized a Cinderella retell from a 36-paged picture book. Since this current study included many different discourse genres averaged together, individual performance on specific discourse genres may have influenced the results. Studies have found significant differences in global coherence between different discourse genres in adolescents with and without a brain injury and young and old neurotypical adults (Van Leer & Turkstra, 1999; Marini et al., 2005; Wright et al., 2014). Marini and colleagues (2005) found that neurotypical adults had better global coherence scores when describing sequential pictures than describing a single picture. Wright and colleagues (2014) found that young and older neurotypical adults had statistically significant lower global coherence scores when producing recounts (e.g. "tell me what you did last weekend") in comparison to the global coherence scores of the single and sequential picture descriptions and procedural narratives. In this current study, discourse genres could not be separated due to some participants producing relatively short discourse samples (e.g. 2-3-utterances). These shorter discourse samples would not be able to be compared to longer discourse samples due to the influence of the discourse's length on the participants' overall global and local coherence scores.

Despite the finding that the synonymy triplets change score did not correlate significantly with local coherence (demonstrated a trend; $p = 0.058$) in the participants with aphasia group, the scatter plot demonstrated a clear linear relationship with the exception of two participants with aphasia. Further research with a greater sample size is needed to determine if this trend reflects a true relationship between the performance on the synonymy triplets change score and local coherence in people with aphasia. However, we also examined the relationship between the synonymy triplets change score and local coherence when the neurotypical adults and the participants with aphasia group were combined (n = 17), assuming that local coherence should be related to integrity of semantic STM/WM in neurotypical adults. This correlation was significant ($p = 0.003$) providing some support for the hypothesis that the maintenance and manipulation of the semantic representations of words is important for maintaining global and local coherence. Compared to the participants with aphasia, the neurotypical adults tended to have higher local coherence scores and had a smaller difference between the synonymy triplets low and high WM conditions (synonymy triplets change score). The neurotypical adults may have performed on the higher end of the continuum due to not having any language or cognitive impairments. More research is needed to determine if the relationship between local coherence and the synonymy triplets change score exists in a larger group of healthy neurotypical adults that is independent of any participants with neurological impairments.

Whereas a trend of a relationship was observed between local coherence and the synonymy triplets change score, no relationship was found between the semantic composite span and local coherence. This may reflect differences in the tasks used to tap into semantic representations and WM. Specifically the integrity of the cognitive resources used to maintain and manipulate semantic representations in verbal STM may be independent of processes that access and retrieve words. Both low and high WM conditions of each triplets task included the same words and the same procedure and differed only in terms of WM load. Familiarity of the test items were controlled for by having participants complete different parts of the low and high WM conditions at different times. This design is intended to isolate the effect of the WM load (maintenance and manipulation of words) between both tasks and exclude any other variables that may be related to linguistic processing (e.g. access-retrieval of the words). Importantly though, variations in performance may occur due to the influence of time (e.g. a participant may perform better or worse on any specific day). On the contrary, lexical access-retrieval processing cannot be excluded during the semantic probe spans, and difficulties with access-retrieval of words could affect a participant's performance on this task. Additionally, the triplets are a more active task than the probe spans and this may explain differences in results. The probe spans are judgement tasks that require the participant to judge whether or not the target word shares a semantic or phonological relationship with any of the words in a previously presented list. The triplets are identification tasks because the participant needs to identify the two word(s) that share a phonological or semantic relationship. Although further investigation is needed, these results suggest that specifically the integrity of the cognitive resources used to maintain and manipulate semantic information in verbal STM may be important for maintaining a topic between adjacent utterances measured by local coherence during discourse production. Although other executive function measures were not specifically investigated, it is important to also consider that cognitive constructs like executive function, selective and sustained attention, processing speed, and declarative memory are related to global coherence and may also be related to verbal WM and local coherence as well (Hill et al., 2018; Le et al., 2014; Marini et al., 2014; Marini et al., 2017; Galetto et al., 2013; Wright, Koutsoftas, Capilouto, & Fegadiotis, 2014; Rogalski et al., 2010).

Limitations and Future Direction

Sample Size

One limitation related to this study is the relatively small sample size for the participants with aphasia. However, it may be challenging to obtain a large enough sample size for a specific aphasia type and severity. Increasing the sample size or range of aphasia types and severities may or may not strengthen the relationships found in this study. Another limitation is the small sample size used for the neurotypical adults. Although the data from neurotypical adults was useful as a reference point to evaluate the performance of the participants with aphasia, a larger sample size could be used to identify differences between means of both groups, since both had high variability in terms of performance on the probe span tasks. Additionally, studies investigating the relationship between cognitive-linguistic constructs and discourse of individuals without aphasia is needed to understand how these constructs are related to aspects of discourse production and how breakdowns in populations with neurological impairments may affect these relationships. Also, our neurotypical adult reference point may not have been as representative of the participants with aphasia since the neurotypical adults were all females (participants with aphasia had 7 males and 6 females) and had an average age about 8 years older than the participants with aphasia.

Use of Both Rating Scales

Another limitation is related to the measurements used to assess global and local coherence. The measurements used in this study had limitations in terms of the published information related to using them, difficulty with maintaining reliability, and the varied reasons that individuals may demonstrate a lower global and local coherence score (e.g. tangential utterance, incomplete utterance, repetition, commentary, etc.) that cannot be accounted for with these scales.

Information about the global and local coherence scales used in this study included a description of them in the appendix from Van Leer & Turkstra (1999) study adapted from Glosser and Deser (1987) and examples from various papers that used the same scale (Cahana-Amitay & Jenkins, 2018; Van Leer & Turkstra, 1999; Glosser & Deser, 1990. 1992; Laine et al., 1998). We felt the need for a more explicit protocol when utilizing these scales, though we acknowledged that creating explicit rules for measurements related to global and local coherence is challenging because there is more variability in terms of the ways in which participants can maintain or not maintain a specific topic, and it is difficult to account for each individual situation. On the contrary, if the rules are not explicit enough, raters may be more lenient or strict in terms of their ratings, which makes it challenging to compare results of global and local coherence between studies. This may explain differences in results between Glosser and Deser's (1990) study and the other studies investigating whether there were differences in global coherence between people with aphasia and neurotypical adults (Christiansen, 1994; Coelho & Flewellyn, 2003; Wright & Capilouto, 2012; Andreetta et al., 2012; Andreetta & Marini, 2015).

In terms of reliability, previous studies have demonstrated point-to-point reliability of 80% or higher using both scales. Difficulty in maintaining reliability in this study may be related to using Cohen's kappa, which considers the influence of chance. Other reasons could be that our study had 10 different samples while most studies using this scale utilized one or two discourse samples. It may be more challenging to maintain reliability between more discourse samples because raters need to be aware of differences in genre and content that varied across stimuli, which may affect the use of the scale. Maintaining reliability was most challenging using the local coherence rating scale. This may be related to inherent challenges using this rating scale with certain stimuli. For example, individual events in the picnic scene from the WAB-R contain events that do not explicitly relate to each other (e.g. a person is fishing by the lake and a family is having a picnic). In certain situations it seemed unnatural for every utterance to be explicitly connected if the participant was describing a picture that contained several unrelated events. Also, switches in topics between utterances naturally occur in discourse, and participants both with and without aphasia do not always need to reference the preceding utterance for the listener to understand the speaker's message. Only a few studies have used local coherence in people with aphasia and more research is needed to ensure that this scale can be used effectively across different discourse genres and stimuli with a strong reliability (Glosser & Deser, 1990; Andreetta et al., 2012; Andreetta & Marini, 2015; Cahana-Amitay & Jenkins, 2018). Additionally, research is needed to determine if there are any microlinquistic measures that may correlate with local coherence scores using a local coherence rating scale. Despite difficulties with reliability, participants with aphasia in this study (primarily anomic aphasia; n = 13) had a comparable severity and local coherence score to the participants with anomic aphasia used in Cahana-Amitay and Jenkins' study (2018) (n = 15) utilizing the same measures. This may indicate that local coherence scores are reliable between studies. See Table 10 for comparisons of means between both studies.

Table 10

Comparison of Local Coherence Scores and Aphasia Severity Average Between This Study and the Cahana-Amitay and Jenkins study (2018)

Measure	Mean of participants used in this study	Mean of the participants with anomic aphasia used in the Cahana-Amitay and Jenkins' study (2018)
Local Coherence (Utilizing Van Leer and Turkstra's 5-point scale) (1999)	2.81	2.71
Aphasia Severity (WAB-R AQ)	81.96	82.75

A final limitation related to the use of the rating scales in this study is that the rating scales provided information on overall performance in terms of maintaining discourse topic or the topic of the preceding utterance, however, they did not consider why the utterance may be off topic. Differentiating why an utterance may be off topic may be important diagnostically given that many other neurological populations have impairments related to maintaining global coherence for a variety of reasons (Ellis et al., 2016). We suggest that using both the rating scales and identifying the errors that may contribute to a lower rating may be effective in identifying how well a participant maintains a topic overall, and if there are difficulties, what is contributing to them. Hazamy and Obermeyer (2020) attempted this approach and concluded that participants with nonfluent aphasia had a lower global coherence than participants with fluent aphasia when using Wright and colleague's 4-point rating scale (2013). They also identified types of errors that were differentiated between the group of fluent and nonfluent aphasia.

Access-Retrieval, Maintenance, and Manipulation

A final limitation is that this study did not utilize measures that considered the isolated influence of phonological and semantic access-retrieval. Severity and access-retrieval skills may have a strong influence on the performance of STM/WM tasks and global and local coherence. It may be important to determine the person with aphasia's phonological and semantic access-retrieval skills since these skills and severity could be a confounding variable that influences both verbal STM/WM and global and local coherence scores. Depending on the WM task used, it would be recommended to include a language task that requires minimal maintenance and manipulation so that access-retrieval skills can be observed independently. For example, if a researcher planned to use the synonymy triplets task to investigate a relationship between semantic STM/WM and another variable, they could use a synonym pair judgement task to observe the participant's semantic access-retrieval skills. This task requires the participant to listen to list of verbally presented word pairs and judge if they have a similar meaning (answer "yes" or "no"). The synonym pair judgement task requires minimal maintenance and manipulation and can assist with understanding the participant's semantic access-retrieval skills independently. Our study did not specifically include an isolated phonological or semantic access-retrieval task that could be used to compare to the STM/WM tasks, though it is recommended to include such tasks that isolate access-retrieval skills for future studies.

Clinical Application

More research is needed to determine which cognitive linguistic constructs may influence successful discourse production. To our knowledge, local coherence has not been as thoroughly investigated as global coherence, and more research is needed to create a more reliable scale that can be effectively used in clinical practice. Based on the clinical implications recommended by Hazamy and Obermeyers (2020) and Rogalski and colleagues (2020), using both global coherence rating scales and an error analysis, analyzing a discourse sample for global coherence errors that may contribute to a lower rated utterance, can be useful tools for assessing global coherence. These tools may provide insight into functional communication skills that clients need to communicate in their everyday lives. Rogalski and colleagues (2020) found that Wright and colleagues' 4-point scale correlated with ratings of topic maintenance, inclusion of unnecessary information, and interest and attention by untrained listeners. Ratings of the 4-point scale were broken up between low global coherence ratings (less than 2 out of 4), medium (between 2.5 and 3), and high (between 3.8 and 4). Unfortunately, they did not have a control group so there could be no comparison with neurotypical adults. Wright and colleagues (2014) used the 4-point rating scale on a group of younger and older neurotypical adults. If clinician's use Wright and colleagues' 4-point scale, clinicians may be able to compare the global coherence ratings of their clients to the neurotypical adults global coherence ratings in Wright and colleagues' study (2014). In addition to using the 4-point rating scale, Hazamy and Obermeyer found that using the same 4-point rating scale and identifying errors associated with low rated utterances (utterances rated as 1 or 2) assisted with determining differences in errors between participants with fluent and nonfluent aphasia. They concluded that using both measures can assist with clinical decision making because clinicians can use the global coherence rating scale to determine overall performance in terms of maintaining discourse topic (4-point global coherence scale) and the error analysis to determine specific treatments that can improve overall topic maintenance (e.g. incomplete sentences, nonspecific wording, etc.).

Conclusion

This exploratory study contributed to a better understanding of how cognitive-linguistic constructs affect discourse production in aphasia. This study provided some evidence that the integrity of the cognitive resources used for the maintenance and manipulation of semantic information held in verbal STM is important for successful maintenance of the topic between adjacent utterances (local coherence) in people with aphasia and neurotypical adults. Successful maintenance and manipulation of semantic information may influence local coherence because local coherence is a semantic construct that maintains the semantic and thematic unity between adjacent utterances. Deficits that affect the cognitive resource abilities to maintain and manipulate the semantic representations of words in verbal STM may influence a person’s ability to maintain the semantic theme of the proceeding utterance thus resulting in a lower local coherence. More information is needed to determine if this same relationship exists in other aphasia types and severities, in an independent sample of young and old neurotypical adults, and in separate discourse genres.

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APPENDIX A

EXAMPLES OF GLOBAL COHERENCE RATINGS

Transcript	Utterance	Rating	Explanation
Cookie Theft	her (m* th*) her mom is in the the faucet in the sink	3	Missing Information Requires inference
Cookie Theft	(um :04) the lady is standing in water at the sink (um) washing or drying dishes	5	
Cookie Theft	at the same time the sink is running over	5	
Cookie Theft	(um) she’s (uh uh) there’s a window (:02 uh) next to the uh sink behind the sink showing showing the (um) garden area	3	Somewhat off topic to event occurring in picture
Cookie Theft	(um) there’s pots on the sink cover	3	Somewhat off topic to event occurring in picture
Cookie Theft	curtains on the window	3	Somewhat off topic to event occurring in picture
Picnic	dad or mom are sitting on the blanket	5	
Picnic	and her dad is reading	3	Unclear referent ("her")
Picnic	it's a flag to the left of us	3	Describes picture though contains egocentric information (“to the left of us”).

Argument	(um) and of course the (uh) the (uh) the man is a little sad about the whole the whole the (descript*) the (uh) the (uh) the whole all the are>	3	Incomplete utterance.
Argument	(uh) prolly [EW:probably] (uh) the man is just a little sad	1	Repeated information from previous utterance
Live	and Rich is probably watching tv	1	Off topic
Live	and we have doors, steps	5	
Live	it’s a flat we walk (s*) flat level	3	Nonspecific word/unclear referent (“it”)
Live	and (um) we have (um) we have (uh) a school around the corner from from my house called Park Lane Elementary	3	Somewhat off topic
Live	I used to work there	1	Off topic
Directions	a man is reading newspaper	1	There is no man reading newspaper in picture Man is reading the map Misleading information is rated as a 1

Argument	and she she was crying because she got in a car	3	Woman crashed car in picture Incorrect verb usage (“got”), though provided relevant nouns for topic
Sunday	I (uh) will get myself together	3	Nonspecific verb (“get”)
Sunday	and she if she’s there, she’ll then ride her bike in the back of the house while I’m (uh) messing around in the garage	5	
Sunday	(um) usually usually, I have some stuff that I have to (uh) shift around that I don’t put in the right place all the time	3	Nonspecific noun (“stuff”)
Birthday	and all the dogs paw paw prints are following him underneath the couch and that’s why the lady has a broom	5	
Birthday	has a (mea*) looking sayin’ she gonna kill it	3	Unclear referent (“it”) Missing noun “___ has”
Dishes	just wash ‘em	3	Unclear referent (“’em”)
Dishes	(th*) put the put the water in the sink first	5	
Dishes	and put the dishes good in there	3	Nonspecific word (“there”)

Dishes	and then start washin	1	Repetition

APPENDIX B

EXAMPLES OF LOCAL COHERENCE RATINGS

Transcript	Utterance	Rating	Explanation
Cookie Theft	okay, okay they was (um) washing dishes		
Cookie Theft	and the water ran over	3	Missing information (needed to mention sink)
Cookie Theft	and the kids was the kids was the cookie jar	1	Radical shift from topic of preceding utterance
Cookie Theft	and they washin	1	Repetition of previously stated information
Picnic	and his dog was walkin’		
Picnic	and the (um) the girl the boy was the boy was the same man>	1	Incomplete and not topic not related to previous utterance
Picnic	and (uh) and (uh) guy is fishin’	1	Radical shift from topic of preceding utterance
Picnic	and they have a sail boat		
Picnic	and and they enjoyin’ the moment	3	Maintained actor (“he”), though shift in activity of previous utterance
Letter	I sign it		
Letter	and then I fold it up	5	Topic continued via temporal sequencing Provided clear and relevant next step in procedure

Letter	put it in the envelope	5	Topic continued via temporal sequencing Provided clear and relevant next step in procedure
Argument	she's arguing		
Argument	and the man was reading the paper	1	Radical shift in subject/activity from previous utterance
Argument	and he was reading the paper	1	Repetition of previous utterance
Argument	he's depressed		
Argument	and then (um) he looked back	3	Maintained same actor ("he"), though shift in activity of previous utterance
Directions	(:02) (um) lady and man in a car (um) greeted by a man outside the man outside the man with a shovel and a tree		
Directions	(um) the couple in the car seems to (:02) looking for directions from a map	5	Continuation of activity ("lady and man are driving and asking for directions")
Directions	the (:02) man is giving directions with his hands while they're listening to him	5	Continuation of activity ("lady and man are driving and asking for directions")
Directions	the car is driving forward while the man looks off at a couple	5	Continuation of activity ("couple gets directions and drives off")

Directions	he’s (:02) planting>	3	Maintained same actor, though shift in activity of previous utterance
Directions	he’s he has a shovel that he’s digging for the tree that he looks like he’s about to (:02) plant	5	Elaboration of previous utterance (i.e. what he is planting and what he is using to plant the tree)
Directions	there’s no road	1	Radical shift from topic of preceding utterance
Directions	but now there’s a>	1	Incomplete utterance
Birthday	the little boy is upset		
Birthday	and there’s two couples there’s two people a boy and a little girl little boy carrying a gift	1	Radical shift from topic of preceding utterance
Birthday	looks like the chunk was taken out of a a a a (par*) a party or birthday party		
Birthday	people are coming in with gifts	3	Somewhat related to topic of preceding utterance due to lexical tie (“birthday party and gifts are related”) Slight shift in actor and activity
Cat in Tree	there’s a cat and there is a man		
Cat in Tree	both are in the (curt*) in the tree	5	Continuation of previous utterance (i.e. describes where cat and man are)