Published in final edited form as:
*J Commun Disord*. 2010 ; 43(3): 212–224. doi:10.1016/j.jcomdis.2010.02.001.

# Discourse coherence and cognition after stroke: A dual task study

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## Abstract

Several researchers have suggested that the maintenance of global coherence (topic maintenance) and local coherence (maintenance between utterances) in discourse requires cognitive resources. This study directly tests this hypothesis by examining the relationship between cognitive variables and coherence in narrative discourse produced by mobility-impaired stroke survivors under single (talking) and dual (talking and walking) task conditions. Although there were no effects of the dual task on coherence, global coherence was significantly disrupted regardless of the single or dual task condition. Moreover, global coherence strongly correlated with cognitive function measures, whereas local coherence did not. Findings are consistent with two interpretations: (1) that global and local coherence may be subserved by different cognitive processes or (2) that maintaining global coherence is a more difficult task and thus will show effects of cognitive impairment before local coherence is impaired. These are both testable hypotheses for future research.

**Learning outcomes—**After reading the manuscript, the reader will be able to: (1) understand and differentiate between local and global measures of coherence; (2) discuss the effects of a dual task, walking and talking, on global coherence in a gait-impaired group of stroke survivors; (3) understand why the maintenance of global coherence in discourse might be more cognitively demanding than the maintenance of local coherence.

## 1. Introduction

Discourse production is a complex task that involves retrieving information from memory, deciding which elements to include or exclude, remembering what has already been said, planning upcoming utterances, accounting for what the listener may or may not know, all while maintaining topic over time. It is not surprising then that a variety of cognitive processes are hypothesized to be integral to maintaining the multilevel organization involved

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in telling a story (Glosser, Brownell, & Joanette, 1993). For example, Alexander (2006) suggests that discourse production is a complex, goal-directed task that requires memory, planning, and sustained attention. The cognitive elements required for linguistic and nonlinguistic knowledge integration in discourse can best be described as macrolinguistic functions which organize discourse beyond the sentence level (Kintsch & Van Dijk, 1978). Global coherence is a macrolinguistic measure of the higher-level conceptual maintenance of topic across the discourse as a whole, while local coherence is the continued maintenance of content from one utterance to the next (Glosser & Deser, 1991; Glosser, Deser, & Weisstein, 1992). The current study examined the relationship between global and local coherence and cognition in a nonaphasic, post-stroke population with mobility impairments during an attention-demanding task: talking while walking.

Studies examining the effects of dual tasks on walking have become increasingly common in the gait literature, with most studies focusing on older adults because of the potential for falls in this population under distracting conditions (e.g., Bootsma-van der Wiel et al., 2003; Liu-Ambrose, Katarynych, Ashe, Nagamatsu, & Hsu, 2009; Shumway-Cook et al., 2007; Woollacott & Shumway-Cook, 2002). In general, these studies have shown decreases in gait speed when a secondary cognitive task is performed. For example, Shumway-Cook et al. (2007) examined walking under dual task conditions in four age groups ranging from middle age to 85+. Although all groups decreased walking speed when performing a talking task, 20% of the 75–84 age group and over 50% of those over 85 stopped walking while talking (Shumway-Cook et al., 2007). Several researchers have investigated the utility of tasks which track whether individuals stop walking while talking as predictive measures for falls. The most common talking task employed in these studies is the verbal fluency task, which require participants to name as many items from a specified category as possible while walking a short distance (Bootsma-van der Wiel et al., 2003; Camicioli, Howieson, Lehman, & Kaye, 1997; Pettersson, Olsson, & Wahlund, 2007; Shumway-Cook et al., 2007; Williams, Hinton, Bories, & Kovacs, 2006). Verbal fluency tasks have traditionally been classified as executive function tasks (Lezak, Howiesson, & Loring, 2004), and thus, may be considered cognitive tasks rather than language tasks by some researchers. Other “talking” tasks in the gait literature include saying the alphabet or alternate letters of the alphabet (Verghese et al., 2007) or saying ‘yes’ to one color stimulus and ‘no’ to an alternate color (Bowen et al., 2001) both of which have attentional and/or executive function demands (Suchy, 2009). The majority of these studies focus on gait and balance changes and fail to report the reciprocal effects of gait on the talking task.

Only a few studies investigating the effects of walking while talking have used actual discourse generation as the dual task in either elderly populations or older adults with stroke (e.g., de Hoon et al., 2003; Hyndman & Ashburn, 2004); however, it is rare for researchers to actually analyze the discourse output. Notable exceptions to this trend come from Kemper and colleagues who focus on the effects of motor tasks on different elements of language use (Kemper, Herman, & Lian, 2003; Kemper, McDowd, Pohl, Herman, & Jackson, 2006; Kemper, Schmalzried, Herman, Leedahl, & Mohankumar, 2009). Kemper et al. (2003) elicited discourse from younger and older adults using rhetorical prompts while participants walked, tapped their fingers in a complex pattern, or ignored background noise. They compared the cost of performing these dual tasks on different aspects of language use (e.g., fluency, sentence complexity, content), as well as on rate and “time on task” (i.e., percentage of time spent walking or tapping while talking). They found that older adults decreased the rate of speech (number of words per minute) in dual task conditions. In contrast, younger adults produced shorter, less complex sentences in dual task conditions, so that their dual task discourse appeared more like that of the older adults in the single task. A more recent study has replicated these findings using a digital pursuit rotary tracking task in which participants produced language samples while using a touch pad or trackball to follow a target that moved along an elliptical track (Kemper et al., 2009).

As discussed, the support for dual task interference from walking and talking is robust in healthy older adults. After a stroke however, even tasks such as walking or talking with no simultaneous distracting task can lose their automaticity and become more attentionally demanding (McCulloch, 2007). Doing two things at once then may be particularly challenging for stroke survivors who appear to have made functional recovery. Kemper et al. (2006) reported that when stroke survivors spoke on various topics while concurrently performing simple motor or selective ignoring tasks, performance on both tasks declined. Although the stroke survivors' speech was similar to that of the healthy older adults on standard clinical measures when tasks were performed one at a time, the content, grammatical complexity and fluency of the post-stroke group was impaired during concurrent walking or finger tapping (Kemper et al., 2006).

Recently, Plummer-D'Amato et al. (2008) examined the interaction of gait variables with two cognitive tasks and a language task in nonaphasic, mobility-impaired stroke survivors. Tasks included discourse production using prompts from Kemper et al. (2003), a 1-back task, and a clock task requiring participants to report whether, for a given time, both clock hands would be in a specified half of the clock face. Participants walked for about 3 min around an oval track with and without the concurrent tasks. Participants were significantly slower during all dual task conditions than during single task walking. Furthermore, the discourse task produced larger dual task effects on gait speed, stride length, and cadence (steps/min) than either of the other two tasks. Additionally, the effects were bidirectional; during the dual task, stroke survivors' narratives had more pauses and fewer words and utterances per narrative, but did not show the effects on grammaticality and complexity reported in Kemper et al. (2006).

Prior dual task studies examining walking while talking in post-stroke groups have analyzed discourse at the "microstructure" level, measuring variables such as content, grammaticality, and fluency (Kemper et al., 2006; Plummer-D'Amato et al., 2008). To our knowledge, no study has yet performed a macrolinguistic analysis of discourse performance during dual task in a post-stroke population. As stated above, a macrolinguistic analysis includes global coherence, the maintenance of each utterance's meaning to the discourse topic, and local coherence, the maintenance of one utterance's meaning to the preceding utterance (Glosser & Deser, 1991). The current study presents a secondary analysis of the narratives from the Plummer-D'Amato et al. (2008) study using macrolinguistic measures that investigate global and local coherence performance during single and dual task conditions.

Global and local coherence analyses have been performed in a variety of populations with neurogenic communication disorders (e.g., Ash et al., 2006; Coelho & Flewellyn, 2003; Dijkstra, Bourgeois, Petrie, Burgio, & Allen-Burge, 2002; Glosser & Deser, 1991; Hough & Barrow, 2003; Laine, Laakso, Vuorinen, & Rinne, 1998; Rogalski & Edmonds, 2008) and in normal aging (Glosser & Deser, 1992). Several studies have reported a connection between coherence and cognition. Glosser and Deser (1991) hypothesized that coherence was a function of cognitive processing based on findings that individuals with Alzheimer's disease and closed head injury, who had disrupted cognition, had degraded coherence compared with normal older adults and patients with fluent aphasia. Similarly, Ash et al. (2006) found that frontotemporal dementia patients with social comportment and executive function disorder were impaired in global coherence, which they attributed to impairments in organization, planning, and executive function. Though these studies have reported a link between cognition and coherence, none has directly tested the relationship between cognitive abilities and either local or global coherence.

In healthy older adults, Glosser and Deser (1992) postulated that cognitive processes such as executive function, working memory, and long-term memory are critical components of global coherence. A related line of research investigated “off-topic verbosity” in healthy older adults, and reported that older adults were more likely to produce more speech that was irrelevant to the topic than younger adults (e.g., Arbuckle & Gold, 1993; Arbuckle, Nohara-LeClair, & Pushkar, 2000; Arbuckle, Pushkar, Bourgeois, & Bonneville, 2004; Gold & Arbuckle, 1995). Gold and Arbuckle (1995) demonstrated that off-topic speech did not correlate with vocabulary, but did correlate with cognitive measures which they claimed examined inhibitory function (i.e., Wisconsin Card Sort, Verbal Fluency, Trail-Making Test). However, other research has shown that the presence and severity of off-topic verbosity in older adults may be dependent upon the elicitation method. James, Burke, Austin, and Hulme (1998) reported that older adults were more likely to produce off-topic discourse in autobiographical narratives than in picture descriptions; whereas, Trunk and Abrams (2009) demonstrated that older adults were comparable to younger adults when producing autobiographical narratives but were rated as more off-topic when producing procedural discourse. The discrepancy between these studies may be accounted for by differences in scoring methods. When Trunk and Abrams calculated the percentage of off-topic words in a story both procedural and autobiographical discourse received higher off-topic verbosity scores, but when listeners rated the discourse on holistic story dimensions, only the procedural discourse was perceived as having greater off-topic verbosity. Consequently, there are indications that in certain types of discourse, older adults may produce more off-topic speech and this off-topic speech may be related to measures of executive function. However, exactly how off-topic verbosity relates to measures of global and local coherence is unknown. Thus, the evidence suggesting that off-topic verbosity correlates with measures of cognitive function does not address the issue of whether global and local coherence are related to cognitive abilities.

Participants in the current study were receiving or had completed therapy for gait impairments due to their stroke. We expected that the attentional demands of walking in this gait-impaired group would negatively impact discourse coherence in the dual task condition (walking and talking) more than in the single task condition (sitting and talking), because the dual task paradigm results in competition for cognitive resources (see Kahneman, 1973; McNeil, Odell, & Tseng, 1991), and coherence is hypothesized to involve cognitive processes. Furthermore, we predicted that global coherence would be more severely impaired by the dual task than local coherence, because global coherence requires the more attentionally demanding maintenance of topic over an extended period of discourse, while local coherence requires only maintenance between adjacent utterances.

In addition, we examined the correlation between different types of coherence, executive function measures, working memory measures, and vocabulary. While there is considerable face validity to the assertion that discourse coherence taps cognitive resources, it remains an empirical question. To our knowledge, this will be the first direct exploration of correlational relationships between different cognitive functions and measures of global and local coherence. Based on the literature, we made several predictions. First, we predicted that global coherence would correlate highly with measures of executive function, specifically those measuring inhibition and/or attention. The prediction regarding inhibition effects is based on studies of off-topic speech in normal aging which have suggested that inhibition of extraneous connections between ideas and events in memory is likely necessary for maintaining coherence throughout discourse (Arbuckle & Gold, 1993; Gold & Arbuckle, 1995). Additionally, it is possible that sustained attention may play an important role in maintaining a topic over an extended period of discourse (Alexander, 2006). With respect to local coherence, we predicted that it would correlate more highly with tests of working memory rather than executive function. Working memory requires holding and manipulating information for a short period of time (Baddeley, 1986); similarly, local coherence requires holding a preceding utterance in memory while constructing a subsequent utterance. Finally, we did not anticipate that there would be correlations between coherence and vocabulary measures. Vocabulary tasks require the access of declarative knowledge, that is, information that has been learned; in contrast, discourse coherence requires the continuous computation and updating of links to previous utterances as constrained by the global topic. Thus, there is little overlap in task demands between vocabulary tasks and the construction and maintenance of discourse coherence. Consistent with this reasoning, researchers have not found significant correlations between vocabulary and discourse measures in studies of off-topic speech (Arbuckle & Gold, 1993; Gold & Arbuckle, 1995).

## 2. Methods

### 2.1. Participants

Participants were 13 patients (11 males, mean age 60.46 years, range: 33–86) recruited from a homogenous community-dwelling stroke population (12 ischemic). All participants were within 2 years of having a stroke with the mean time post-onset being 8.69 months (*SD*: 4.79, range: 2.5–17 months). All were able to walk 10 m without physical assistance and could follow a three-step command. Participants did not have any pre-existing neurological disorders, severe hearing or visual impairments, orthopedic conditions affecting their walking ability, or severe dysarthria or aphasia affecting verbal responses to auditory stimuli. All participants were screened by certified speech-language pathologists at the Brain Rehabilitation and Research Center in Gainesville Florida and none met the clinical criteria for aphasia. This study was approved by the University of Florida Institutional Review Board, and all participants signed consent forms.

### 2.2. Cognitive measures

Table 1 presents the scores of the study participants on the cognitive tests below. Also included for comparison are means from older adults who have participated in other language and memory studies at the University of Florida in Gainesville and Northeastern University in Boston. Participants scored 1 to 2 standard deviations below local norms on all cognitive tests.

The Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) is a brief screen for cognitive impairment that assesses orientation, calculation, language, and immediate and delayed memory. A score lower than 25/30 is indicative of cognitive impairment.

The Stroop test (Stroop, 1935) is considered an executive function test that requires inhibition of habitual responses. It consists of two tasks. For the Color XXX task, participants see 100 sets of X's printed in different color inks. Participants are scored on how many of the colored X sets they can name correctly in 45 s. For the Color Word Interference task, participants have 45 seconds to name aloud the ink color of a series of Color Words (e.g., the word *BLUE* is presented in red ink so the participant must say "red"). This test was included because the inhibition of extraneous information may positively contribute to maintaining global coherence.

The Digit Symbols Test (Wechsler, 1987) is thought to assess attention and processing speed. It consists of two tasks. In the Digit Symbol Copy task, participants are presented with abstract symbols paired with blank boxes and are asked to copy each symbol into the empty box as quickly as they can. The time to complete the page is the outcome measure. In the Digit Symbol Substitution task, the numbers 1 through 9 are paired with abstract symbols in a coding key at the top of the page. In the test space beneath, the numbers are presented randomly in upper panels with empty panels below them. Participants are given 90 s to write the symbol that corresponds with each number, in order, without skipping any panels. The number of correctly written symbols in 90 s is the outcome measure. This measure was included because the ability to sustain attention might be crucial to the maintenance of global coherence in discourse.

Working memory measures were included to test the possibility that working memory might be required to maintain local coherence in discourse. The Backward Digit Span Test (Wechsler, 1987) is considered a test of working memory. Participants hear increasingly longer lists of numbers and must repeat them back to the examiner in reverse order. The task includes 2 trials at each list length beginning with a two-item list. Scoring consists of the total number of digits recalled correctly, with a maximum score of 14. The Digit Ordering Test (Hoppe, Muller, Werheid, Thone, & von Cramon, 2000) is also considered a working memory test. Participants hear increasingly longer lists of numbers and must put them in order from smallest to largest. The test includes four trials at each list length and 24 trials total. Testing is discontinued when there are two or more errors at one list length. The score is the total number of correct trials. Finally, the vocabulary subtest from the Wechsler Abbreviated Scales of Intelligence (Wechsler, 1999) is a test of vocabulary knowledge. Participants hear a word and must provide a definition for it. Responses are scored 0, 1, or 2.

### 2.3. Procedure

In the single task condition, discourse was elicited while participants were seated. In the dual task condition, discourse was elicited while participants walked counterclockwise around an oval track for about 3 min, while using their assistive devices. A physical therapist was present but did not assist participants. Participants always performed tasks in the single condition prior to the dual condition in order to reduce the effects of fatigue and were not instructed to prioritize either walking or talking.

In each condition, participants were asked to speak for at least 2 min on topics chosen by the examiner from a list including topics from Kemper et al. (2003). Topics included people or events that had had a significant impact on their lives, as well as “Tell me what you like or dislike about the city you grew up in?” or “What sort of things would you consider important in a marriage partner?” Participants spoke on different topics for the single and dual task conditions. Examiners prompted participants (e.g., “Can you tell me more about…?”) when participants had lengthy pauses or stopped talking. Responses were digitally recorded using a wireless microphone.

### 2.4. Scoring

Discourse samples were transcribed verbatim orthographically, including examiner prompts and comments. Prior to analysis, a research assistant verified the transcripts for accuracy by listening to the recordings and checking the transcripts for any errors. Task information (single or dual) was removed and transcripts were randomized and coded so that the first author was blinded to the task condition during the analysis. Using the Systematic Analysis of Language Transcripts (Miller & Iglesias, 2008) the first author divided the transcripts into T-units (utterances) defined as the shortest allowable independent clause plus all related dependent clauses (Hunt, 1965). All 2 min worth of discourse was used in the analysis. On average, participants spoke a mean of 26.12 utterances per transcript (*SD*: 10.91), range: 9–56 utterances).

Coherence measures were based on published coding scales (Glosser & Deser, 1991; Van Leer & Turkstra, 1999). Each T-unit was coded for global and local coherence with a score of 5, 3, or 1 (5 = complete coherence, 1 = no coherence). Briefly, a global coherence score of 5 indicated that the utterance was highly related to the topic as a whole, a score of 3 meant that the utterance was possibly related to the topic, and a score of 1 indicated the utterance was off-topic. For local coherence, an utterance was scored 5 if it substantially related to the directly preceding utterance, 3 if it indicated a slight topic shift or was referentially vague, and 1 if it displayed a major topic shift or was unrelated. Samples of participant coherence scoring are provided in Tables 2 and 3.

### 2.5. Reliability

The first author coded all transcripts. To assess intra-rater reliability, a random 20% of transcripts were re-transcribed by the first author approximately 3 months after initial coding. Inter-rater reliability was performed by a research assistant who had been trained on the coherence rating scale. Based on point-to-point comparisons, intra-rater reliability was 88.49% for global coherence and 91.18% for local coherence; whereas, inter-rater reliability was 85.09% for global coherence and 87.47% for local coherence.

## 3. Results

All tests were considered statistically significant at $p < .05$. Global and local coherence scores were calculated as the sum of the coherence scores of each type for each T-unit divided by the number of T-units. A 2X2 within-subjects repeated measures ANOVA was conducted to determine the effects of task (single or dual) on coherence (global or local). No significant main effect was found for task [$F(1,12) = .25$, $p = .625$, partial $\eta^2 = .02$]. However, there was a significant main effect of type of coherence [$F(1,12) = 5.87$, $p = .03$, partial $\eta^2 = .33$] with global coherence scores being significantly lower than local coherence scores, regardless of task (see Table 4). There was no interaction between task and coherence type [$F(1,12) = .11$, $p = .75$, partial $\eta^2 = .01$].

Correlations are summarized in Table 5. Scores on two cognitive tests, Stroop Color XXX and Stroop Color Words, were not normally distributed so we used nonparametric statistics to explore the relationship between coherence and cognitive function measures. Since we found no task effects on either local or global coherence in our prior analysis, the correlation analysis reflects mean local and mean global coherence across tasks. Using Spearman rho nonparametric correlations, neither age nor MMSE correlated with local or global coherence [both $r_s < .15$]. Local and global coherence did not correlate with each other [$r_s = .52$, $p = .07$], but this may have been due to low power. Additionally, none of the executive function, working memory or vocabulary measures correlated with mean local coherence. In contrast, strong positive correlations were found between global coherence scores and Digit Symbol Substitution [$r_s = .74$, $p < .01$], with higher global coherence scores being associated with a greater number of symbols transcribed. In addition, there were moderate negative correlations found between global coherence and Digit Symbol Copy [$r_s = -.69$, $p < .01$]; that is, higher global coherence scores were associated with faster times to copy all the symbols in the task. It should be noted that Digit Symbol Copy has been found to strongly correlate with Digit Symbol Substitution (Joy, Fein, Kaplan, & Freedman, 2000;Joy, Kaplan, & Fein, 2004). Indeed, we found that Digit Symbol Copy time was strongly negatively correlated with Digit Symbol Substitution [$r_s = -.81$, $p < .01$]; that is, faster symbol substitution scores correlated with faster symbol copy times. There were no other significant correlations between global coherence and other cognitive or vocabulary measures.

Finally, we calculated nonparametric correlations between the coherence scores and the microstructure language variables reported in Plummer-D’Amato et al. (2008), including number of words, number of utterances, several subtypes of dysfluencies, and various measures of sentence complexity. None of these correlations were significant.

## 4. Discussion

The present study used macrolinguistic measures, global and local coherence, to examine the effect of walking while talking in a gait-impaired group after stroke. Given the cognitive demands of discourse production and the attentional demands of walking, we predicted that coherence would be more affected during the dual task, walking and talking, than the single task, sitting and talking. We also predicted that global coherence would be more strongly correlated with cognitive measures, particularly attention and inhibition, since global coherence requires the cognitively demanding maintenance of a topic throughout the entire discourse. Our two primary findings were that (1) overall, global coherence was poorer than local coherence regardless of whether the narrative was produced under single or dual conditions, and (2) global coherence, but not local, correlated significantly with an executive function measure of attention and processing speed.

Our finding that global coherence performance was poorer than local coherence regardless of task condition is consistent with the literature in this area. Greater deficits in global coherence compared with local coherence have been observed in normal aging (Glosser & Deser, 1992) and a range of disorders, including fluent aphasia (Coelho & Flewellyn, 2003), traumatic brain injury (Glosser & Deser, 1991; Hough & Barrow, 2003), and dementia (Dijkstra et al., 2002; Dijkstra, Bourgeois, Allen, & Burgio, 2004; Glosser & Deser, 1991; Laine et al., 1998). To our knowledge, there have been no reported cases in which local coherence is significantly more impaired than global coherence, although several researchers have reported trends in this direction. Glosser et al. (1992) reported that the right hemisphere disorder patients in their study produced proportionately more "locally incoherent" utterances than non-brain-injured controls, although there were no between-group differences in the mean levels of global and local coherence. Similarly, Van Leer and Turkstra (1999) also found a trend for adolescents with traumatic brain injury to produce more instances of sporadic locally incoherent discourse than their non-impaired peers; however the groups did not differ significantly. In addition, there are reports of individuals with aphasia who have linguistic impairments that limit production of elements important for local coherence such as increased pronoun use without referents or with ambiguous referents (Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, & North, 1983; Ulatowska, North, & Macaluso-Haynes, 1981). These individuals may be considered to have poorer local than global coherence, although their discourse characteristics are likely due to lexical or morphosyntactic deficits. Therefore, the evidence supports the conclusion that global coherence is generally more compromised than local coherence (see Table 4) across impaired and healthy older populations. This is consistent with the hypothesis that global coherence draws more heavily on cognitive resources than local coherence.

Our prediction that cognitive tests would correlate with global more strongly than local coherence was supported. We found a moderate to strong relationship between global coherence and the Digit Symbol Test, which is thought to assess sustained attention, concentration, and processing speed (Sheridan et al., 2006; Smith, 1982). Symbol copy and substitution assessments are sensitive to age-related as well as neurogenic cognitive decline (Lezak et al., 2004). Participants with poorer scores on these attention-demanding tasks also performed poorly on global coherence, suggesting that global coherence taps some of the same cognitive processes required by the Digit Symbol Test, such as attention, concentration, and processing speed. In contrast, we found no relationship between global coherence and inhibition as measured by the Stroop task. Thus, we can provide no support for the hypothesis that inhibition deficits can lead to impaired global coherence.

Additionally, we found no support for our hypothesis that local coherencewould be related toworking memory. Smith, Heuerman, Wilson, and Proctor (2003) also found no correlation between working memory and local or global coherence in the discourse samples of younger adults. These authors used the Recognition Memory Subtest of the Goldman–Fristoe–Woodcock Auditory Memory Battery (Goldman, Fristoe, & Woodcock, 1974) as their working memory measure, a task that requires listening to different words and counting the number of different words that are repeated. Youse and Coelho (2005) contend that more complex measures of working memory may be necessary to establish a relationship between working memory and macrolinguistic language measures. Thus, the task used as working memory measures in Smith et al.'s (2003) study and those used in the current study (i.e., Backward Digit Span and Digit Ordering) may have been too simple. Even so, Backward Digit Span has been found to correlate with cohesion, a macrolinguistic measure of discourse production (Hartley & Jensen, 1991), while more complex measures of working memory such as the Daneman and Carpenter Reading Span Task (Daneman & Carpenter, 1980), have failed to correlate with discourse production measures (Caspari & Parkinson, 2000). Thus, consistent significant findings regarding the cognitive foundations of local coherence are lacking in the literature, and more research is needed in this area.

The results of our study suggest at least two hypotheses; the first is that global coherence, a higher-order measure of topic maintenance throughout discourse, is potentially dissociable from local coherence, a lower-order measure of sentence to sentence maintenance. Glosser and Deser (1991) hypothesized that global and local coherence were at two different ends of a macrolinguistic continuum, and were subserved by different cognitive mechanisms. This argument was based on findings that individuals with Alzheimer's disease and closed head injury had poorer global than local coherence, while participants with fluent aphasia did not differ from non-brain-injured controls on either global or local coherence. According to this hypothesis, it should be possible to identify individuals with isolated deficits of either global or local coherence, as well as individuals with impairments to both. However, as previously discussed, there is little evidence for isolated deficits of local coherence in the literature.

Our findings are also consistent with an alternative hypothesis, that maintaining global coherence is just, in general, more cognitively demanding than maintaining local coherence. Consequently, global coherence will break down first when cognition declines, and local coherence will only be impaired when cognitive impairment is severe. Considering more than half of the participants in the current study were adults over 60 years of age and the majority of all participants performed cognitive tasks below local norms, it is likely that the combined effects of age and cognition account for poorer global coherence in this group. That global coherence is more cognitively demanding is consistent with studies of normal aging and dementia. In healthy aging, older adults have been found to produce more off-topic speech than younger adults (e.g., Arbuckle & Gold, 1993; Arbuckle et al., 2000, 2004; Gold & Arbuckle, 1995), which may be indicative of global coherence breakdowns. Similar to our findings with global coherence, off-topic speech has been found to correlate with cognitive measures (Arbuckle & Gold, 1993; Gold & Arbuckle, 1995). Along these lines, Dijkstra et al. (2002) found that global coherence impairments, but not local, were evident in the middle stages of dementia, and local coherence impairments only became significant in the late-stage dementia group. These authors stated that the discourse impairments of their participants were most likely attributed to the high cognitive demands of formulating global coherence. Similarly in a later study, Dijkstra et al. (2004) reported that the conversations of individuals with dementia exhibited preserved local coherence in contrast to global coherence when compared to those of healthy older adults, most likely because local coherence was less difficult to maintain. This hypothesis would predict that it would be possible to find individuals with impaired global coherence and individuals with both local and global coherence deficits, but not isolated deficits affecting only local coherence. Considering that there is little evidence in the literature for poorer local compared to global coherence, the hypothesis that global coherence is more cognitively demanding than local coherence is currently supported; however, the issue deserves further study.

The association between global coherence and attention has implications for rehabilitation in populations with neurogenic communication disorders. Patients with impaired global coherence may benefit from a top-down treatment approach that stimulates cognitive functions, such as attention and memory, in the context of a discourse task. For example, Attentive Reading and Constrained Summarization (ARCS) is a discourse treatment that is designed to combine cognitive and linguistic elements (Rogalski & Edmonds, 2008). The treatment requires that one read then summarize from memory consecutive portions of a text, while refraining from using pronouns and other nondescript words (e.g., "thing" or "stuff"). In the case study of a gentleman with primary progressive aphasia and concomitant attention impairments, the authors found that the ARCS treatment demonstrated greater gains in global compared with local coherence (Rogalski & Edmonds, 2008). Alternatively, if there are patients who show relatively preserved topic maintenance but evince more difficulty maintaining connections between contiguous utterances, they may need a different approach to rehabilitation. Indeed, studies have demonstrated that people with aphasia include and organize macrolinguistic story elements in a coherent manner despite errors of reference that may potentially detract from local coherence (Ulatowska et al., 1983, 1981). Patients such as these may benefit more from a treatment with a morphosyntactic emphasis on the words and phrases that efficiently link one utterance to another (local coherence), rather than a treatment emphasizing topic maintenance (global coherence).

The prediction that coherence, particularly global, would decline in the dual task compared with the single task was not supported. There are several possible explanations for this finding. First, there may have been a task order effect, as the single task was always performed prior to the dual task. This could have lowered the coherence scores for the single task condition and inflated them for the dual task condition, thus masking any dual task effects. Second, perhaps the lack of homogeneity in the topics discussed masked dual task effects. In particular, some of the topics used to elicit discourse may have inadvertently elicited a listing effect (see Table 3), such as describing what one likes or dislikes about the city one lives in or describing a person who has had a significant impact on one's life, resulting in narratives that were globally related but less locally integrated. Indeed, during the dual task condition this type of descriptive discourse was elicited more often (9 times) than during the single task condition (6 times) and of the 6 participants whose coherence improved during the dual task, 4 spoke on topics considered descriptive, possibly inflating global coherence. However, since topics were not balanced for type or order across participants, we cannot make any concrete assertions at this time regarding potential effects of topic type on discourse coherence.

This leads us to another alternative: participants were paying more attention to maintaining discourse coherence than to walking in the dual task condition. This explanation is supported by the Plummer-D'Amato et al. (2008) finding that participants experienced significant disruptions in gait when they were concurrently speaking. Indeed, participants' gait was more impaired during speech than during any of the other cognitive tasks reported in the original study (Plummer-D'Amato et al., 2008). Similarly in healthy older adults, Verghese et al. (2007) reported that walking speed and cadence were significantly slowed when participants were asked to prioritize talking as opposed to giving equal attention to walking and talking. Another possible explanation is that participants made accommodations in their speech at the microstructure level in lieu of disrupting coherence. Healthy younger and older adults have been found to accommodate their speech during concurrent walking and talking by slowing speech rate (Kemper et al., 2003; Williams et al., 2006). Indeed, in the original study, Plummer-D'Amato et al. (2008) reported that stroke survivors demonstrated increased numbers of pauses and produced fewer words and utterances during the dual task condition than during the single task condition. This suggests that participants may have been focusing more on telling a good story and maintaining coherence at the expense of discourse speed and length. However, there were no significant correlations between microstructure measures and coherence measures to suggest such a trade-off. On the other hand, it is also possible that the microstructure level of discourse is more vulnerable to dual task demands than is coherence. Disentangling these possibilities should provide fertile ground for future research.

On a final note, although the 5-point coherence scale has been used in a number of different studies (Coelho & Flewellyn, 2003; Glosser & Deser, 1991; Rogalski & Edmonds, 2008; Van Leer & Turkstra, 1999), what represents a clinically meaningful change in coherence scores has not yet been tested. In our study for example, global coherence was statistically different from local coherence (see Table 4), however, the actual difference on the scale is quite small. Therefore, future research should also consider incorporating qualitative measures of discourse (e.g., listener evaluations of discourse adequacy as in Trunk & Abrams, 2009) as a complementary comparison measure for the global and local coherence scale. This would contribute to the validation and refinement of the coherence scales commonly used in discourse studies.

## 5. Conclusions

In summary, we examined the relationship between coherence and cognition during a dual task, walking and talking, in a post-stroke population. Participants' global coherence was poorer than local coherence regardless of single or dual task, and global coherence correlated with tests of sustained attention and speed of processing while local coherence did not. Findings suggest that global coherence may be more difficult to maintain than local coherence and that global and local coherence are potentially subserved by different cognitive mechanisms. We note, however, that our participants were below local norms on cognitive measures and that most of our participants were older adults, factors which may negatively affect global coherence. As there was no control group we cannot generalize these findings to the normal population. Additionally, it is possible that the variability in the topics used and the lack of balance between topic type and order across participants may have masked subtle differences between global and local coherence. The representation of clinically significant change on the coherence scale also deserves further study.

Finally, the question of the relationship between global and local coherence remains open. We have added to the evidence that global coherence can be significantly more impaired than local coherence; however, the other pattern, more impaired local than global coherence, has not been verified. The question remains: do local and global coherence depend on two distinct types of processing with separate cognitive and cortical demands, or is global coherence a more cognitively demanding manifestation of the same processes underlying local coherence? Future studies combining linguistic and neuropsychological approaches with different types of neuroimaging (e.g., electroencephalography, functional magnetic resonance imaging) or longitudinal studies in dementing populations may help us address this question.

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## Appendix A. Continuing education questions

1. Global coherence is defined as a:
    - **a.** microlinguistic measure targeting information at the sentence level.
    - **b.** microlinguistic measure of unconnected speech.
    - **c.** macrolinguistic measure of topic maintenance throughout discourse.
    - **d.** macrolinguistic measure of the continued maintenance of themes between sentences.
2. Local coherence is defined as a:
    - **a.** macrolinguistic measure of topic maintenance throughout discourse.
    - **b.** macrolinguistic measure of the continued maintenance of themes between sentences.
    - **c.** microlinguistic measure targeting information at the word level.
    - **d.** microlinguistic measure of unconnected speech.
3. Why might global coherence be more difficult to maintain than local coherence?

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   - **a.** Global coherence requires the attentionally demanding maintenance of adjacent sentences; whereas local coherence only requires maintenance between adjacent words.
   - **b.** Global coherence, generally, is not as difficult to maintain as local coherence.
   - **c.** Local coherence requires the attentionally demanding maintenance of topic over a number of utterances; whereas, global coherence only requires maintenance between adjacent utterances.
   - **d.** Global coherence requires the attentionally demanding maintenance of topic over a number of utterances; whereas, local coherence only requires maintenance between adjacent utterances.

4. In the present study:
   - **a.** No differences between the single and dual task conditions were found for global and local coherence but global coherence was poorer than local coherence regardless of task.
   - **b.** No differences between the single and dual task conditions were found for global and local coherence but local coherence was poorer than global coherence regardless of task.
   - **c.** Global and local coherence were poorer in the dual task condition (walking and talking) than in the single task condition (talking alone).
   - **d.** Global and local coherence were poorer in the single task condition (talking alone) than in the dual task condition (walking and talking).

5. In the present study:
   - **a.** Global and local coherence correlated with a cognitive measure of sustained attention, processing speed, and concentration.
   - **b.** Only local coherence was correlated with a cognitive measure of sustained attention, processing speed, and concentration.
   - **c.** Only global coherence was correlated with a cognitive measure of sustained attention, processing speed, and concentration.
   - **d.** Neither global nor local coherence correlated with any of the cognitive measures.

**Table 1**

Test score means (*M*) and standard deviations (*SD*) for participants compared with healthy older adults (HOA) from the University of Florida and Northeastern University.

| Test | Participants *M* (*SD*) | HOA *M* (*SD*) | |
|---|---|---|---|
| MMSE[a] (out of 30) | 26.69 (2.69) | 29.22 (1.40)[b] | *n* = 105 |
| Stroop (number in 45 s) | | | |
| Color XXX | 50.85 (17.37) | 70.79 (13.49)[b] | *n* = 58 |
| Color Word | 24.69 (11.14) | 36.53 (11.09)[b] | *n* = 58 |
| Digit symbol | | | |
| Copy (seconds to complete) | 139.77 (45.03) | 99.48 (18.44)[c] | *n* = 21 |
| Substitution (number in 90 s) | 33.00 (8.27) | 41.86 (9.34)[c] | *n* = 21 |
| Backward digit span (out of 14) | 5.15 (1.57) | 6.95 (2.28)[b] | *n* = 205 |
| Digit ordering (out of 24) | 12.23 (3.86) | 17.09 (3.50)[b] | *n* = 207 |
| WASI[d] vocabulary (out of 70) | 53.08 (10.67) | 61.44 (7.43)[b] | *n* = 207 |

[a]MMSE = mini-mental state exam.

[b]Local means for adults age 60+ collected at the University of Florida.

[c]Local means for adults age 60+ collected at Northeastern University.

[d]Wechsler Abbreviated Scale of Intelligence.

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**Table 2**

An example of impaired global relative to local coherence.

| Line | Topic: Talk about a person who has had a significant impact on your life | Global | Local |
|---|---|---|---|
| 1–5 | Talks about stepfather | – | – |
| 6 | …When I hit twelfth grade, I… started, ah… I would leave home | 3 | 3 |
| 7 | And I talked with my stepfather | 5 | 3 |
| 8 | And he said that, ah, maybe a good place would be the air force… | 5 | 5 |
| 11 | … I went into the air force… and started off in… Austin, Texas… | 1 | 5 |
| 12 | Ahh, it was cold | 1 | 5 |
| 13 | But, made it through Texas and went to Illinois | 1 | 5 |
| 14 | From Illinois I… went to… what's it, McCoy air force base | 1 | 5 |
| 15 | From McCoy air force base I went to Guam… | 1 | 5 |

**Table 3**

An example of impaired local relative to global coherence.

| Line | Topic: Describe what you like or don't like about Jacksonville | Global | Local |
|---|---|---|---|
| 1 | Well, one thing I don't, um, it's awfully big | 5 | – |
| 2 | And they keep, they keep, um, building things and gets everybody confused | 5 | 5 |
| 3 | I'm not fond of the beach | 5 | 1 |
| 4 | Um …and the weather of course, it's just much too hot | 5 | 1 |
| 5 | There's just too many people | 5 | 1 |
| 6 | When we moved here 30 years ago, well, it was pretty good | 5 | 3 |
| 7 | But, it's sure grown in 30 years… | 5 | 5 |

**Table 4**

Coherence means (M) and standard deviations (*SD*) by task.

| | **Local coherence *M* (*SD*)** | **Global coherence *M* (*SD*)** |
|---|---|---|
| Single task | 3.78 (.58) | 3.47 (.69) |
| Dual task | 3.93 (.69) | 3.53 (1.13) |

## Table 5

Correlations among coherence, demographic, and cognitive variables.

| Variable | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Mean global coherence | .52 | −.11 | −.09 | .35 | .14 | −.69** | .741** | .17 | .06 | .28 |
| 2. Mean local coherence | | −.12 | .12 | .39 | .21 | −.25 | .26 | .22 | .22 | .17 |
| 3. Age | | | −.45 | .12 | −.45 | .29 | −.34 | −.13 | −.26 | .21 |
| 4. MMSE[a] | | | | −.01 | .38 | −.20 | .22 | .39 | .59* | .45 |
| 5. Stroop color XXX | | | | | .66* | −.57* | .53 | .26 | .01 | .08 |
| 6. Stroop Color Words | | | | | | −.35 | .46 | .34 | .33 | .12 |
| 7. Digit symbol copy | | | | | | | −.81** | −.02 | .00 | −.06 |
| 8. Digit symbol substitution | | | | | | | | .28 | .10 | .10 |
| 9. Backward digit span | | | | | | | | | .76** | .54 |
| 10. Digit ordering | | | | | | | | | | .66* |
| 11. WASI[b] vocabulary | | | | | | | | | | |

[a] MMSE = Mini-Mental State Exam.

[b] Wechsler Abbreviated Scale of Intelligence.

* Correlation is significant at: $p \leq .05$.

** Correlation is significant at: $p \leq .01$.