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Different effects of dual task demands on the speech of young and older adults

Susan Kemper, **Ruth E. Herman**, and **Jennifer Nartowicz**

University of Kansas

Abstract

Young and older adults provided language samples in response to elicitation questions while concurrently performing 3 different tasks. The language samples were scored on three dimensions: fluency, grammatical complexity, and content. Previous research had suggested the hypothesis that the restricted speech register of older adults is buffered from the costs of dual task demands. This hypothesis was tested by comparing language samples collected during a baseline condition with those produced while the participants were performing the concurrent tasks. The results indicate that young and older adults adopt different strategies when confronted with dual task demands. Young adults shift to a restricted speech register when confronted with dual task demands. Older adults, who were already using a restricted speech register, became less fluent although the grammatical complexity and informational content of their speech was preserved. Hence, some but not all aspects of older adults' speech are buffered from dual task demands.

Different effects of dual task demands on the speech of young and older adults

As young adults, we take for granted the ability to walk and talk at the same time. But this ability is hard-won as toddlers and vulnerable to aging. Talking while walking has been shown to increase older adults' risk of falling (Lundin-Olsson, Nyberg, & Gustafson, 1998). This relationship between cognition and locomotion can be exploited in order to study how aging affects speech production by revealing the extent to which older adults can draw upon cognitive reserve capacity in order to maintain both the complexity and content of their speech.

Recently, dual task paradigms have been useful in the study of the effects of aging on cognition (Baddeley, Lewis, Eldridge, & Thomson, 1984; Camicioli, Howieson, Lehman, & Kaye, 1997; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Gupta & MacWhinney, 1995; Kinsbourne & Hicks, 1978; Kinsbourne & Hiscock, 1983; Kyllonen & Christal, 1990; Li, Lindenberger, Freund, & Baltes, 2001; Lindenberger, Marsiske, & Baltes, 2000; Maylor & Wing,1996; Maylor, Allison, & Wing, 2001; Murray, Holland, & Beeson, 1998; Navon & Gopher, 1979; Turner & Engle, 1989; Wright & Kemp, 1992). These dual task studies reveal how the performance of sensory-motor tasks may be affected by cognitive processing demands when two tasks are performed simultaneously. They confirm linkage between cognition and the sensory-motor control of behavior (Welford, 1958) and suggest that cognitive reserve capacity is affected by aging. Cognitive reserve capacity (Kinsbourne & Hicks, 1978; Satz, 1993; Staudinger, Marsiske, & Baltes, 1993, 1995) refers to the capacity to learn new tasks or

Correspondence to: Susan Kemper.

Address correspondence to: Susan Kemper Gerontology Center 3090 Dole 1000 Sunnyside Ave. University of Kansas Lawrence, KS 66045 785 864-4130 785 864-2666 (fax) SKEMPER@KU.EDU. This research was supported by grant RO1AG09952 from the National Institute on Aging. Requests for reprints may be addressed to: S. Kemper, 3090 Dole, Gerontology Center, University of Kansas, Lawrence, KS 66045 USA..

develop new strategies in response to new conditions or new task demands; cognitive reserve capacity, hence the learning new strategies such as those required by dual task demands, may be reduced across the life span as the maintenance of basic sensory-motor functions is compromised by aging. In general, it is assumed that older adults will experience greater dual task costs than young adults, reflecting age-related declines in cognitive reserve capacity (Verhaeghen, Steitz, Sliwinski, & Cerella, 2001).

Kemper, Herman, and Lian (2003) investigated whether the fluency, complexity, and content of the expressive speech of older adults are subject to reserve capacity limitations by assessed the effects of simple motor and selective ignoring tasks. Three motor tasks were compared: simple finger tapping, complex finger tapping, and walking. Two selective ignoring tasks were also compared: ignoring concurrent noise and ignoring concurrent speech. Surprisingly, Kemper et al. report that young adults exhibited *greater* dual tasks costs than the older adults. Analyses of young adults language sample revealed reduced sentence length, grammatical complexity, and propositional content when talking while performing the motor tasks or concurrent selective ignoring tasks. In contrast, the older adults spoke more slowly during the dual task conditions but their grammatical complexity and propositional content did not vary with dual task demands. However, the expressive language of older adults was less grammatically complex and less propositionally dense than the young adults' speech even under baseline, single-task conditions.

Kemper et al. (2003) hypothesized that speech may be an exception to the general hypothesis that older adults experience greater dual task costs than young adults. Older adults, in response to age-related loss of processing speed and working memory capacity, may develop a restricted speech register, that is grammatically less complexity and propositionally less dense than that used normally by young adults. This restricted speech register may be buffered from many of the costs associated dual task demands. Whereas young adults' faster, more complex speech is affected by simultaneously performing simple motor tasks, older adults are able to combine these tasks by reducing their speech rate without suffering further declines in grammatical complexity or propositional density. Under dual task conditions, young adults shift to a restricted speech register, reducing grammatical complexity in response to the demands of doing two things at once. Hence, both young and older adults can successfully adapt to dual task demands, albeit by using different strategies, as they are able to modifying their speech by reducing speech rate (older adults) or by reducing grammatical complexity (young adults).

Not all older adults may be able to avoid dual tasks costs to language. A second study (Kemper, McDowd, Pohl, Herman, & Jackson, in press) compared healthy older adults and older adults who were tested at least six months after a stroke. All stroke survivors had excellent recovery, as indicated by their performance on the Barthel Index (Collin, Wade, Davies, & Horne, 1988; Mahoney & Barthel, 1965) , the Fugl-Meyer Assessment (Duncan, Propst, & Nelson, 1983; Fugl-Meyer, 1980) , the Duke Mobility Scale (Hogue, Studenski, & Duncan, 1990), and the Berg Balance Scale (Berg, Wood-Dauphinee, & Williams, 1992; 1995) . They were matched to a group of healthy older adults in gender, education, age, and performance on the Short Portable Mental Status Questionnaire (Pfeiffer, 1975). A baseline language sample was compared to language samples collected while the participants were tapping their index finger, tapping four fingers in a complex pattern, or walking around an elliptical track as well as while they were ignoring noise or concurrent speech. Whereas the speech of the healthy older adults' showed few costs due to the concurrent task demands, the speech of the stroke survivors was disrupted by the demands of doing two things at once. The stroke survivors were unable to perform the two tasks simultaneously and alternated short walking segments with short segments of speech. Their speech was fragmented, repetitious, and marked by the use of many fillers and pauses. Their utterances were short and often ungrammatical. These dual task measures assessing the ability to talk while performing simple tasks revealed long-lasting effects of strokes that are not evident when stroke survivors were assessed using standard clinical tools.

The current study was designed to extend this line of investigation to determine how increasing the costs of walking will affect the speech of both young and older adults. Compared to the Kemper et al. (2003), the walking task was made more difficulty in two ways: participants were asked to carry a 10 lb bag of groceries while walking around an irregularly shaped track or flights of steps were introduced into the track so that the participants had to go up and down the steps. The first task increased the overall difficulty of the task while the second introduced a momentary challenge. These tasks were chosen because they are familiar, common, realistic challenges to older adults' communicative competence. (A task combining walking, talk, carrying groceries, and climbing stairs was not administered because pilot testing suggested older participants would be mute or otherwise unable to carry out all four elements simultaneously). We expected that their overall speech rate as well as walking rate and time on task may decline when they are asked to carry a bag of groceries, reflecting increased drain on their reserve capacity (Chen, Ashton-Miller, Alexander, & Schultz, 1994; Chen, Schultz, Ashton-Miller, Gioradani, Alexander, & Guire, 1996). We also expected that they older adults might stop talking entirely when they were confronted with a momentary challenge such as climbing steps in order to preserve sufficient reserve capacity for motor task. However, we also expected that the grammatical complexity and propositional content of older adults' speech would be unaffected by the task demands. Of interest will be determining whether or not the fluency, complexity, and content of the healthy older adults' speech comes to resemble that of the stroke survivors, showing greater dual tasks costs associated with the increase in walking difficulty, thus discrediting our hypothesis that these aspects of the restricted speech register of older adults are buffered from dual task costs.

METHOD

Participants

Twenty-six young adults, 18 to 28 years of age, and 37 older adults, 70 to 80 years of age, were tested. The young adults were recruited by posted signs and other announcements and paid $10 for participating. The older adults were recruited from a registry of previous research participants; all were living at home alone or with family. The participants were paid a modest honorarium; for the older adults, this honorarium also included compensation for their travel to campus to participate in this research. Two young adults and 16 older adults were excluded from full participation based on the screen tasks described below, leaving 24 young adults (M = 21.5, SD = 2.6) and 24 older adults (M = 74.8, SD = 7.2) who completed all tasks.

Screening

All participants were screened for hearing acuity and those who had experienced clinically significant hearing loss were excluded from participation in this study. A hearing loss was defined as (i) a greater than 40 dB hearing loss at 500, 1000, 2000, or 4000 Hz using pure tone audiometrics or (ii) self-report of 6 or more problems on the Hearing Handicap Inventory (Ventry & Weinstein, 1982). Among participants who met these screening criteria, average pure tone hearing level, in dB, was 22.8 (SD = 2.3) for young adults and 31.0 (SD = 4.1) for the older adults for the 6 thresholds tested, $t(46) = 74.336$, $p < .001$. The younger adults (M_Y = 0.37, SD = 0.8) reported fewer problems on the Hearing Handicap Inventory than the older adults (M_O = 4.8, SD = 5.0), $t(46) = 18.07$, $p < .000$.

The participants were also screened for a variety of health conditions that might limit their performance on the walking and finger tapping tests. These exclusionary conditions included: failing 4 or more questions on the Short Portable Cognitive Status Questionnaire (Pfeiffer, 1975), any health condition that interfered “a great deal” with daily activities such as arthritis, high blood pressure, heart trouble, or diabetes; self-report of a history of stroke, polio, cerebral palsy, emphysema, or other disabling condition; or a history of taking any medication for angina, pain, seizure, vertigo, or any neurological or psychotropic medication. Two young adults and 13 older adults were excluded from further participation on the basis of these screening tests; all failed the pure tone hearing test.

Cognitive Tests—The 48 participants who passed the screening tests were given a battery of cognitive tests designed to assess individual and age-group differences in verbal ability, working memory, inhibition, and processing speed. The two groups had completed the same amount of formal education (M_Y = 15.1 years, SD = 2.7 years; M_O = 17.8 years, SD = 3.4), $t(46)$ = 1.075. The older adults scored somewhat higher on the Shipley (1940) vocabulary test (M_O = 36.5of 40 correct, SD = 2.9) than the young adults (M_Y = 32.6, SD = 3.2), $t(46)$ = 18.768. The young adults had higher scores on the Digits Forward and Digits Backwards tests (Wechsler, 1958) (M_Y = 10.9, SD = 2.0 and 10.0, SD= 2.6), respectively) than the older adults (M_O = 8.7, SD = 2.5 and 7.0, SD = 2.5 respectively), $t(46)$ = 11.465 and 16.888, respectively. The younger adults had higher scores on the Daneman and Carpenter (1980) Reading Span test, (M_Y = 4.1, SD = 1.1; M_O = 2.9, SD = 0.6), $t(46)$ = 20.208. The young adults also scored higher on the Digit Symbol test (Wechsler, 1958), (M_Y = 36.6, SD = 5.6; M_O = 22.4, SD = 5.9), $t(46)$ = 72.822. The Stroop test required participants to name the color of blocks of X's printed in colored inks or to name the color of color words printed in contrasting colored inks, e.g., RED printed in blue ink; participant were given 45 s to complete the tasks; the participant's score is the number of colors correctly named in 45 s. On this task, the young adults named the colors of the X's more rapidly than the older adults (M_Y = 94.8 SD = 13.9 years; M_O = 66.7, SD = 19.6), $t(46)$ = 32.736. They also named the colors of the color words more rapidly (M_Y = 68.6, SD = 9.6 years; M_O = 35.7, SD = 12.2), $t(46)$ = 107.247; the difference between these two conditions was smaller for young adults than for older adults, $t(46)$ = 63.206, indicating less interference from the words. An alpha level of .05 was set for these and all subsequent t and F tests.

Tasks

Each participant completed 5 tasks: talking alone, walking alone, walking while talking, walking and talking while carrying a 10 lb bag of groceries, and walking and talking while climbing steps. All tasks were administered in a random order and interspersed randomly with the cognitive tests. Rest breaks were provided after each walking task. The entire testing session lasted approximately 2 hours.

The Noldus Video Observer (Noldus, 1991) system was used to analyze all walking tasks. Participants were digitally video- and audio-recorded as they performed these tasks. The Noldus system enables the researcher to play back these recordings while inserting behavioral codes to mark critical behavioral events such as each foot step or tap of a finger. These codes are automatically time-locked to the recording. A hierarchical system of codes can be used so that critical events may be nested within larger behavioral segments. The Noldus system then computes rates, intervals, and durations for coded events based on the time-locked codes. Multiple coders can analyze each recording to establish reliability and reliability can be defined with msec accuracy if desired.

Participants were asked to walk at a “brisk but comfortable” pace around an irregular elliptical pathway, approximately 25 ft in diameter, for 3 to 5 min. The participants were permitted to walk clockwise or counter-clockwise, as preferred. During the walking and carrying grocery tasks, they were permitted to carry the bag of groceries suspended by handles from either hand or braced against their body using either arm. For the step climbing task, short flights of steps were placed periodically around the walking pathway so that the participants had to alternative climbing steps with walking along the flat pathway; hand rails were provided flanking the steps and participants were encouraged to use the hand rails when climbing the steps (only 1 did so). During the concurrent walking and talking segments, the participants were handed a prompt card with an elicitation question and asked to complete 1 “lap” or about 30 s of walking before beginning to respond orally.

The walking or walking + talking segments were coded using the Noldus system and then analyzed to determine the average walking rate, in steps per s, starting 30 s after the participant began walking. Walking “errors” such as stumbles and footsteps outside of or inside of the boundaries of the path were coded separately. The walking “errors” were of extremely low frequency and were not analyzed further. During the concurrent walking + talking tasks, codes were inserted to mark the onset of speech and all discernable speech interruptions or pauses; additional codes marked the onset of walking and all pauses or interruptions of walking as well as the onset and termination of step climbing. Speech interruptions and pauses while walking or step climbing were rare and were not analyzed further. The percentage of time each participant was actually walking or walking while talking simultaneously was computed as a measure of “time-on-task.”

Two coders independently coded video recordings from 5 young and 5 older participants; they agreed at better than 90% accuracy on all walking measures. The two coders had better than 95% agreement on coding all pauses and walking errors; they were required to agree within ± 10 ms on the onset and offset of all speech or walking pauses.

The total duration of the walking segments varied unsystematically across participants and tasks. For example, young adults walked for an average of 4 min 5 s (range: 250 - 320 s) in the walking baseline segment and for an average of 4 min 18 s (range: 200 - 300 s) in the walking, talking and climbing steps segment, $t(23) < 1.0$. Older adults walked for an average of 4 min 20 s (range: 200 - 360 s) in the baseline segment and for an average of 4 min 40 s (range: 200 - 380 s) in the walking, talking and carrying groceries segment, $t(23) < 1.0$. There were no significant age differences in the duration of any walking segments. The first minute and last minute of each walking segment were compared; there was no indication that walking rates or time-on-task declined across these segments for young or older adults in any condition.

Language Sample Elicitation

A baseline line sample was collected from each participant and additional language samples were collected while the participants were performing each of the 3 concurrent walking tasks. Each language sample was approximately 5 min duration and included at least 50 utterances. Language samples were elicited using a variety of questions requiring participants to describe people or events that have influenced their lives, recent vacations, significant inventions of the 20th C, individuals they admire, and so forth. Different elicitation questions were counter-balanced across conditions. Each elicitation question was printed on a card which was shown to the participant. During concurrent walking tasks, participants were first instructed to start walking and after a 30-s start-up interval, the participant was shown the elicitation question and asked to respond without interrupting their walking. Participants were instructed that they were to respond to the elicitation question without disrupting their performance on the current task. When a participant first paused or stopped responding, a standard prompt such as “can you tell me more about….?” or ““would you like to add anything?” was used to ensure that an adequate language sample of at least 50 utterances was obtained from each participant in each condition.

The samples were analyzed following the procedures described by Kemper et al. (1989) and Kemper et al. (2003). The samples were transcribed and coded by first segmenting each into utterances and then coding each utterance. Utterances were defined by discernable pauses in the participant's flow of speech; therefore, utterances did not necessarily correspond to grammatically defined sentences but included interjections, fillers, and sentence fragments. “Fillers,” defined as speech serving to fill gaps in the speech flow, included both lexical and non-lexical fillers. Non-lexical fillers, such as “uh,” “umm,” “duh,” etc., were excluded from the transcript. Lexical fillers, such as “and,” “you know,” “yeah,” “well,” etc. were retained in the transcript. Also excluded from the transcript were utterances that repeated or echoed those of the examiner.

Eight measures were then obtained from each language sample. Four measures of fluency were computed: (i) The percentage of utterances containing lexical fillers was determined; (ii) All grammatical sentences were identified and the percentage of grammatical sentences was computed for the entire language sample; (iii) Mean Length of Utterance (MLU) was obtained automatically using the Systematic Analysis of Language Transcripts (SALT) software (Chapman & Miller, 1984); (iv) A word-per-minute (WPM) speaking rate was also computed by timing the duration of 10 different segments of 5 to 10 words and computing an average. Two measures of grammatical complexity were obtained from each language sample: (i) Mean Clauses per Utterance (MC) was obtained by identifying each main and embedded or subordinate clause in each utterance; (ii) Developmental Level (D-Level), an index of grammatical complexity, was scoring based on a scale originally developed by Rosenberg and Abbeduto (1987). Grammatical complexity ranged from simple one-clause sentences to complex utterances without multiple forms of embedding and subordination. Each complete sentence was scored and the average D-Level for each language sample was then calculated.

Finally, two measures of propositional content were obtained from each language sample: (i) Propositional Density (P-Density) was calculated according to the procedures described by Turner and Greene (1977). Each utterance was decomposed into its constituent propositions, which represent propositional elements and relations between them. The P-Density for each speaker was defined as the average number of propositions per 100 words. (ii) A Type-Token Ratio (TTR) was also computed for each language sample based on the ratio of the number of different words in the sample to the total number of words in the sample. TTR was automatically computed by the SALT program. Two trained coders independently scored 10% of the language samples to establish reliability. Agreement exceeded r (15) > .90 for all measures.

RESULTS

The analysis was designed to compare baseline performance to performance during in the concurrent walking and talking tasks. The initial analysis, summarized in Table 1, examined age group differences in baseline performance. Baseline age group differences were expected on the language sample measures and for the baseline walking performance measures. Second, Dual Task Costs (DTCs) were computed for the language sample measures and for the performance measures (walking rates and time-on-task measures). These DTCs compared the baseline tasks to the walking and talking task. The analysis examined whether DTCs for the language sample and performance measures were significantly different than zero. Third, multivariate ANOVAs were used to examine age group and task differences in DTCs for the measures of fluency (MLU, WPM speech rate, the percentage of grammatical sentences, and the percentage of utterances without fillers), complexity (MCU and D-Level), and content (TTR and P-Density) and for the two performance measures, walking rate and time-on-task.

Baseline Differences in Walking and Talking

Baseline language sample measures are presented in Table 1 along with the results of a one-way ANOVA comparing the age groups on these measures. Consistent with prior observations (Kemper et al., 2003), the older adults used a restricted speech style: they were less fluent than young adults, on 2 of 4 measures (MLU, and WPM speech rate); older adults' speech was less complex than the young adults', differing in MCU; and the older adults' speech had reduced the propositional content, affecting the P-Density measure.

Baseline performance measures for the young and older adults are given in Table 1. Walking rates, in steps per s, were the same for young and older adults. Both young and older adults were able to sustain their performance on this baseline task as indicated by the time-on-task measure.

Dual Task Costs of Walking and Talking

Following Lindenberger et al. (2000), DTCs were computed for each language sample measure and the performance measures using the formula:

$$\text{DTCs} = (\text{Walking \& Talking} - \text{Baseline}) / \text{Baseline} * 100. \quad (1)$$

Figures 1 and 2 report DTCs for the language sample measures of fluency, grammatical complexity, and content and the performance measures (rate and time-on-task) for young and older adults, respectively.

The analysis tested whether DTCs for the language sample and performance measures were significantly different than zero, using a series of *t*-tests on the DTCs for young and older adults separately. These results are indicated on Figures 1 - 2. DTCs that were significantly different than zero are indicated by an asterisk (*). These tests indicated that young adults experienced DTCs significantly greater than zero for 1 of 4 fluency measures (percentage of utterances without fillers) and 1 complexity measure (D-Level). Older adults experienced DTCs significantly greater than zero for WPM speech rates and for the time-on-task and walking rate performance measures.

DTCs of Carrying Groceries and Climbing Steps

DTCs for the other two tasks, walking, talking and carrying groceries and walking, talking and climbing steps, were computed using the same baseline measures. Figures 1 and 2 also summarize these findings. Asterisks mark DTCs significantly greater than zero. In general DTCs for carrying groceries and climbing steps tasks were comparable; however, two tasks affected young and older adults differently. Young adults experienced significant DTCs for only 1 fluency measure (the percentage of utterances without fillers) but for both complexity measures (D-Level and MCU) and for P-Density. Older adults experienced significant DTCs for 3 fluency measures (MLU, WPM, and the percentage of utterances without fillers), as well as both performance measures (walking rate and time-on-task) but did not exhibit significant DTCs for either complexity measure or for P-Density.

A series of MANOVAs was conducted to compare DTCs for the two age groups and three tasks; the multivariate analyses examined: (i) fluency, measured by MLU, WPM speech rate, the percentage of grammatical sentences, and the percentage of utterances without fillers; (ii) complexity, measured by MCU and D-Level; (iii) content, measured by TTR and P-Density; and (iv) walking performance, measured by walking rate and time-on-task. The overall main effects for age group and task were significant but qualified by significant age group x task interactions for all 4 fluency measures, both complexity measures, and P-Density. Table 2 reports these age group x task interactions. These interactions were decomposed into a series of age group comparisons for each task, as reported in Table 3. On the walking and talking task, these analyses showed that young and older adults experienced equivalent DTCs for 2 fluency measures (percentage of grammatical sentences and percentage of utterances without fillers); however, young adults experienced greater DTCs than older adults for MLU whereas older adults experienced greater DTCs than young adults for WPM. Young adults also experienced greater DTCs for both complexity measures, D-Level and MCU. In contrast, older adults experienced greater DTCs for the walking rate measure.

These two patterns were amplified by the additional task demands imposed by carrying groceries or climbing steps tasks. On these more demanding two tasks, older adults experienced greater DTCs for 3 of 4 fluency measures (the exception was the percentage of grammatical sentences) and for walking rate whereas young adults experienced greater DTCs for both complexity measures and for P-Density. Older adults also experienced greater DTCs for the time on task measure for the walking, talking, and climbing steps task. In general, DTCs on the carrying groceries and climbing steps tasks were equivalent and greater than those on the walking and talking task. An exception to this pattern occurred for the time on task measure for older adults; older adults' DTCs on the climbing steps task were greater than their DTCs on the other two tasks.

DISCUSSION

These results confirm previous findings that young and older adults adopt different strategies when confronted with dual task demands. In order to accommodate to the demands of walking and talking simultaneously, young adults adopt a restricted speech register, resembling that of older adults. This restricted speech register is composed of shorter and less complex sentences than young adults' normal speech register. These simplifications are first evident when the young adults were walking and talking simultaneously as reductions in MLU and grammatical complexity. Their speech was further restricted when additional task demands were imposed by the requirements to carry a bag of groceries or climb steps. These additional task demands resulted in further declines in grammatical complexity and information content, measured by propositional density. As a result, their speech under these more demanding task requirements was significantly shorter, less complex, and less informative than their baseline speech style.

In contrast, older adults who are already using a restricted speech register respond to the demands of walking and talking simultaneously by walking more slowly, and by speaking more slowly. When additional task demands are imposed, older adults become disfluent, experiencing further reductions in sentence length and speech rate; they also use more fillers such as “well” or “you know” to break up their speech. And when confronted with obstacles, such as short flights of steps to climb, they begin to alternate speaking and walking, affecting the time on task measure. However, even under demanding dual task requirements, the grammatical complexity and propositional density of older adults' speech is unaffected.

A similar “floor” effect for grammatical complexity and propositional content was observed in the longitudinal analysis of language samples collected from healthy older adults over a 15 year interval by Kemper, Thompson, and Marquis (2001). They considered whether the use of language sample methodology contributed to the “floor’ effect. The measures of grammatical complexity and propositional content are computed from a language sample; the grammatical complexity measure, D-Level, is computed for complete sentences whereas the content measure, P-Density, is computed for complete sentences as well as sentence fragments. The D-level measure reaches an actual floor of 0.0 for grammatical complexity (a language sample composed of single clause sentences) and the P-Density measure reaches an actual floor of 0.0 propositions per 10 words (a language sample containing only fragments and nonlexical or lexical fillers that do contribute any information). In the present study, the grammatical complexity of young adults declined from 2.65 at baseline by 30% to 1.85 on the carrying groceries or climbing steps tasks while that of older adults declined from 2.05 at baseline by 4% in the carrying groceries task and 3% on the climbing steps task. Propositional density for young adults at baseline was 3.93; it declined by 13% to 3.41 on the carrying groceries or climbing steps tasks. Propositional density for older adults was 3.81 at baseline, declining by

4% on the climbing steps task. Hence, it does not appear that the language sample methodology contributed to the apparent floor observed for the complexity and content of older adults' speech.

Rather, it appears that older adults are able to preserve the complexity and content of their speech while sacrificing fluency and walking rate. They are able to do so because they already use a reduced speech register in response to age-related changes to working memory and processing speed and efficiency (Kemper et al., 2001; Kemper & Sumner, 2001). This restricted speech register is characterized by reduced grammatical complexity and propositional content. Working memory limitations may affect the ability of older adults to produce complex grammatical constructions by limiting how many sentence relations, particularly hierarchical relations, may be planned and executed at one time. Each embedded or subordinate clause increases the burden on working memory by imposing additional requirements for, e.g., subject-verb agreement, pronominal choice, linear ordering of adjectives, and other grammatical rules. Both the MCU and D-Level measures of grammatical complexity are sensitive to the use of embedded and subordinate clauses and will therefore be limited by such working memory limitations. Processing efficiency appears to impose general limitations on language production, affecting how efficiently the mental lexicon can be searched for appropriate words and how efficiently a propositional text base can be searched for appropriate information. P-Density indicates how many basic ideas are expressed relative to the number of words required to express them. Averaged over a language sample, P-Density measures the consistently with which ideas are expressed succinctly or not. P-Density will therefore by reduced by age-related declines in processing efficiency.

The results of the present study as well as those of Kemper et al. (2003) suggest that these age-related declines in grammatical complexity and propositional density reach a “function floor” at D-Level = 2 and P-Density = 3.5. In the absence of dementia, the complexity and content of older adults' speech do not appear to decline below these scores (Kemper, Thompson, & Marquis, 2001). Neither score appears to be approaching the actual floor of 0.0 for grammatical complexity (a language sample composed of single clause sentences) or 0.0 propositions per 10 words (a language sample containing only fragments and fillers that do contribute any information). Fluent, grammatical, informative speech may impose a functional “floor” such that a language sample is likely to contain at least a few utterances with infinitive clauses, compound sentences and other forms that contribute 1 or 2 points to the calculation of D-Level and utterances that express 3 or 4 basic propositions that contribute to P-Density. Hence, the grammatical complexity and propositional content of older adults' speech appears to be buffered from dual task demands as a result of this functional “floor.” By reducing walking and talking rates, alternating talking and walking, and using more fillers and shorter sentences, older adults are able to draw upon sufficient cognitive reserve capacity to maintain the complexity and content of their speech.

References

Baddeley A, Lewis V, Eldridge M, Thomson N. Attention and retrieval from long-term memory. Journal of Experimental Psychology: General 1984;113:518–540.

Berg K, Wood-Dauphinee S, Williams JI. The Balance Scale: Reliability assessment for elderly residents and patients with an acute stroke. Scandinavian Journal of Rehabilitation Medicine 1995;27:27–36. [PubMed: 7792547]

Berg K, Wood-Dauphinee S, Williams JI, Maki B. Measuring balance in the elderly: Validation of an instrument. Canadian Journal of Public Health 1992;2:S7–11.

Camicioli R, Howieson D, Lehman S, Kaye J. Talking while walking: The effect of a dual task in aging and Alzheimer's disease. Neurology 1997;48:955–958. [PubMed: 9109884]

Chapman, R.; Miller, J. SALT: Systematic Analysis of Language Transcripts. University of Wisconsin; Madison, WI: 1984.

Chen HC, Ashton-Miller JA, Alexander NB, Schultz AB. Effects of age and available response time on ability to step over an obstacle. Journal of Gerontology: Medical Sciences 1994;49:M227–M233.

Chen H,C, Schultz AB, Ashton-Miller JA, Giordani B, Alexander NB, Guire KE. Stepping over obstacles: Dividing attention impairs performance of old more than young adults. Journal of Gerontology: Medical Sciences 1996;51:M116–M122.

Collin C, Wade DT, Davies S, Horne V. The Barthel ADL Index: A reliability study. International Disabilities Study 1988;10:61–63.

Craik FIM, Govoni R, Naveh-Benjamin M, Anderson ND. The effects of divided attention on encoding and retrieval processes from human memory. Journal of Experimental Psychology: General 1996;125:159–180. [PubMed: 8683192]

Daneman M, Carpenter PA. Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Ability 1980;19:450–466.

Duncan PW, Goldstein LB, Horner RD, Landsman PB, Samsa GP, Matchar DB. Similar motor recovery of upper and lower extremities after stroke. Stroke 1994;25:1181–1188. [PubMed: 8202977]

Duncan PW, Propst M, Nelson SG. Reliability of the Fugl-Meyer Assessment of sensorimotor recovery following cerebrovascular accident. Physical Therapy 1983;63:1606–1610. [PubMed: 6622535]

Fugl-Meyer AR. Post-stroke hemiplegia assessment of physical properties. Scandinavian Journal of Rehabilitation Medicine 1980;7:85–93. [PubMed: 6932734]

Gupta P, MacWhinney B. Is the articulatory loop articulatory or auditory: Reexamining the effects of concurrent articulation on immediate serial recall. Journal of Memory and Language 1995;34:63–88.

Hogue, CC.; Studenski, S.; Duncan, PW. Assessing mobility: the first step in falls prevention. In: Funk, SG.; Tornquist, EM.; Champagne, MP.; Copp, LA.; Weise, RA., editors. Key aspects of recovery: Improving nutrition, rest, and mobility. Springer; New York: 1990. p. 275-280.

Kemper S, Herman RE, Lian CHT. The costs of doing two things at once for young and older adults: Talking while walking, finger tapping, and ignoring speech or noise. Psychology and Aging 2003;18:181–192. [PubMed: 12825768]

Kemper S, Kynette D, Rash S, Sprott R, O'Brien K. Life-span changes to adults' language: Effects of memory and genre. Applied Psycholinguistics 1989;10:49–66.

Kemper S, McDowd J, Pohl P, Herman R, Jackson S. Revealing language deficits after stroke: The costs of doing two things at once. Aging, Neuropsychology, and Cognition. in press

Kemper S, Sumner A. The structure of verbal abilities in young and older adults. Psychology and Aging 2001;16:312–322. [PubMed: 11405318]

Kemper S, Thompson M, Marquis J. Longitudinal change in language production: Effects of aging and dementia on grammatical complexity and propositional content. Psychology and Aging 2001;16:600–614. [PubMed: 11766915]

Kinsbourne, M.; Hicks, RE. Functional cerebral space: A model for overflow, transfer, and interference effects in human performance: A tutorial review. In: Requin, J., editor. Attention and performance. VII. Erlbaum; Hillsdale, NJ: 1978. p. 345-362.

Kinsbourne, M.; Hiscock, M. Asymmetries of dual task performance. In: Hellige, JB., editor. Cerebral hemisphere asymmetry: Method, theory, and application. Praeger; New York: 1983. p. 255-334.

Kyllonen PC, Christal RE. Reasoning ability is (little more than) working-memory capacity?! Intelligence 1990;14:389–433.

Lajoie, Y.; Teasdale, N.; Bard, C.; Fluery, M. Attentional demands for walking : Age-related changes. In: Fernandez, AM.; Teasdale, N., editors. Changes in sensory motor behavior in aging. Elsevier; Amsterdam: 1996. p. 235-256.

Li KZH, Lindenberger U, Freund AM, Baltes PB. Walking while memorizing: A SOC study of age-related differences in compensatory behavior under dual-task conditions. Psychological Science 2001;12:230–237. [PubMed: 11437306]

Lindenberger U, Marsiske M, Baltes PB. Memorizing while walking: Increase in dual-task costs from young adulthood to old age. Psychology of Aging 2000;15:417–436.

Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops when talking" as a predictor of falls in elderly people. The Lancet 1998;349:617.

Mahoney FI, Barthel D. Functional evaluation: The Barthel Index. Maryland State Medical Journal 1965;14:56–61.

Maylor EA, Allison S, Wing AM. Effects of spatial and nonspatial cognitive activity on postural stability. British Journal of Psychology 2001;92:319–338.

Maylor EA, Wing AM. Age differences in postural stability are increased by additional cognitive demands. Journal of Gerontology: Psychological Sciences 1996;51:P143–154.

Murray LL, Holland AL, Beeson PM. Spoken language of individuals with mild fluent aphasia under focused and divided-attention conditions. Journal of Speech, Language, and Hearing Research 1998;41:213–227.

Navon D, Gopher D. On the economy of the human-processing system. Psychological Review 1979;80:214–255.

Noldus Information Technology. The Observer Video Pro Version 4.0 [Support package for video analysis, reference manual]. Author; Wageningen, The Netherlands: 1997.

Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. Journal of the American Geriatrics Society 1975;23:433–441. [PubMed: 1159263]

Rosenberg S, Abbeduto L. Indicators of linguistic competence in the peer group conversational behavior of mildly retarded adults. Applied Psycholinguistics 1987;8:19–32.

Satz P. Brain reserve capacity and symptom onset after brain injury: a formulation and review of evidence for threshold theory. Neuropsychology 1993;7:273–295.

Shipley WC. A self-administered scale for measuring intellectual impairment and deterioration. Journal of Psychology 1940;9:371–377.

Staudinger UM, Marsiske M, Baltes PB. Resilience and levels of reserve capacity in later adulthood: Perspectives from life-span theory. Development and Psychopathology 1993;5(4):541–566.

Staudinger, UM.; Marsiske, M.; Baltes, PB. Resilience and reserve capacity in later adulthood: Potentials and limits of development across the life span. In: Cicchetti, Dante; Cohen, Donald J., editors. Developmental psychopathology, Vol. 2: Risk, disorder, and adaptation. Wiley series on personality processes. John Wiley & Sons; Oxford, England: 1995. p. 801-847.

Teasdale N, Bard C, LaRue J, Fleury M. On the cognitive penetrability of posture control. Experimental Aging Research 1993;19:1–13. [PubMed: 8444263]

Turner, A.; Greene, E. The construction and use of a propositional text base. University of Colorado Psychology Department; Boulder, CO: 1977.

Turner ML, Engle RW. Is working memory capacity task dependent? Journal of Memory and Language 1989;28:127–154.

Ventry I, Weinstein B. The Hearing Handicap Inventory for the Elderly: A new tool. Ear and Hearing 1982;3:128–134. [PubMed: 7095321]

VerhaeghenPSteitzDWSliwinskiMJCerellaJAging and dual task performance: A meta-analysis. 2001Unpublished manuscript

Wechsler, D. The measurement and appraisal of adult intelligence. Williams & Wilkins; Baltimore: 1958.

Welford, AT. Aging and human skill. Oxford University Press; London: 1958.

Wright D, Kemp T. The dual-task methodology and assessing the attention demands of ambulation with walking devices. Physical Therapy 1992;72:306–312. [PubMed: 1584862]

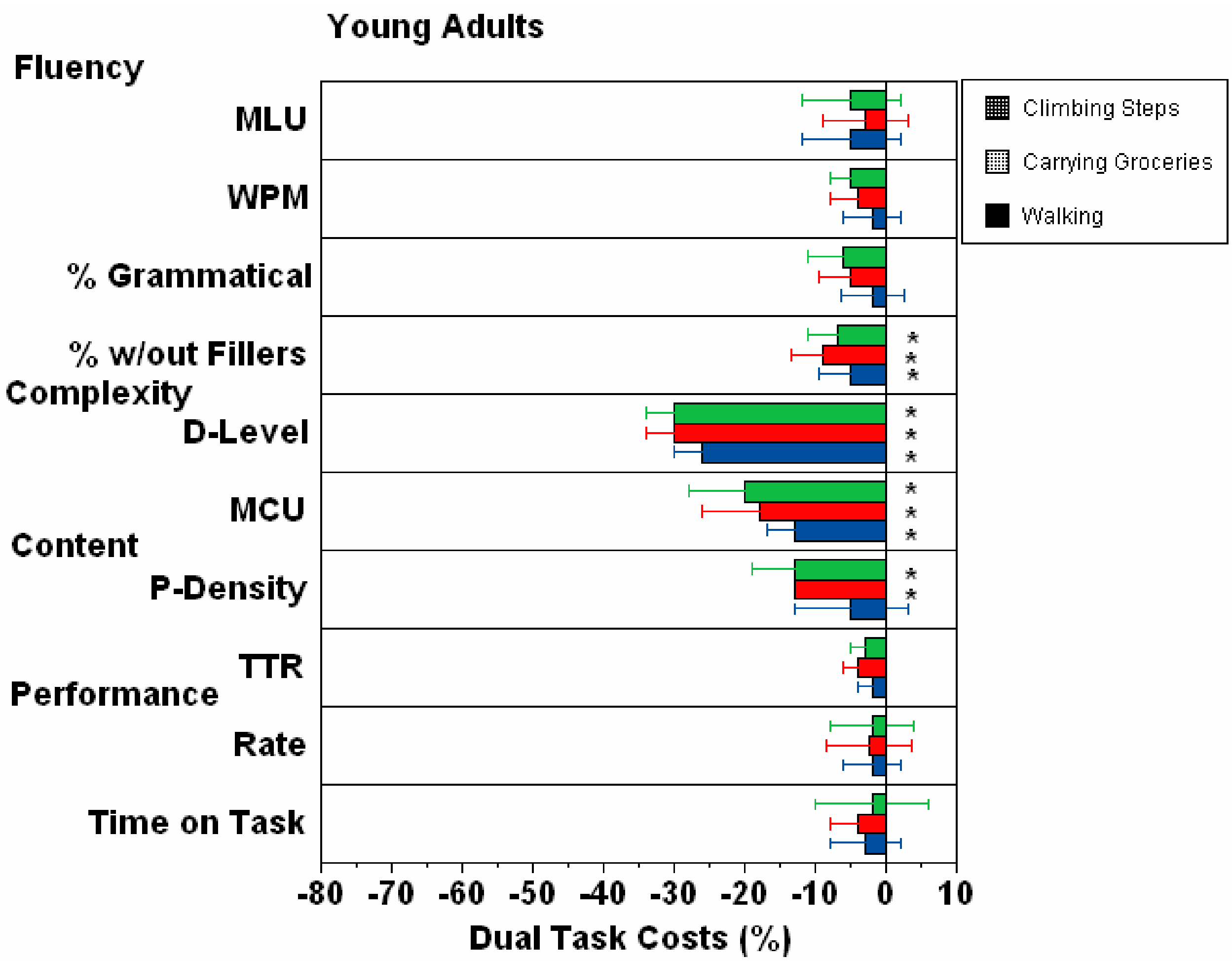

Figure 1.
Dual Task Costs (DTCs) (and standard errors) for the Young Adults on the Language Sample Measures comparing Walking Baseline to Three Dual Tasks: Walking and Talking, Walking, Talking, and Carrying Groceries; and Walking, Talking, and Climbing Steps. An asterisk (*) marks DTCs significantly greater than zero.

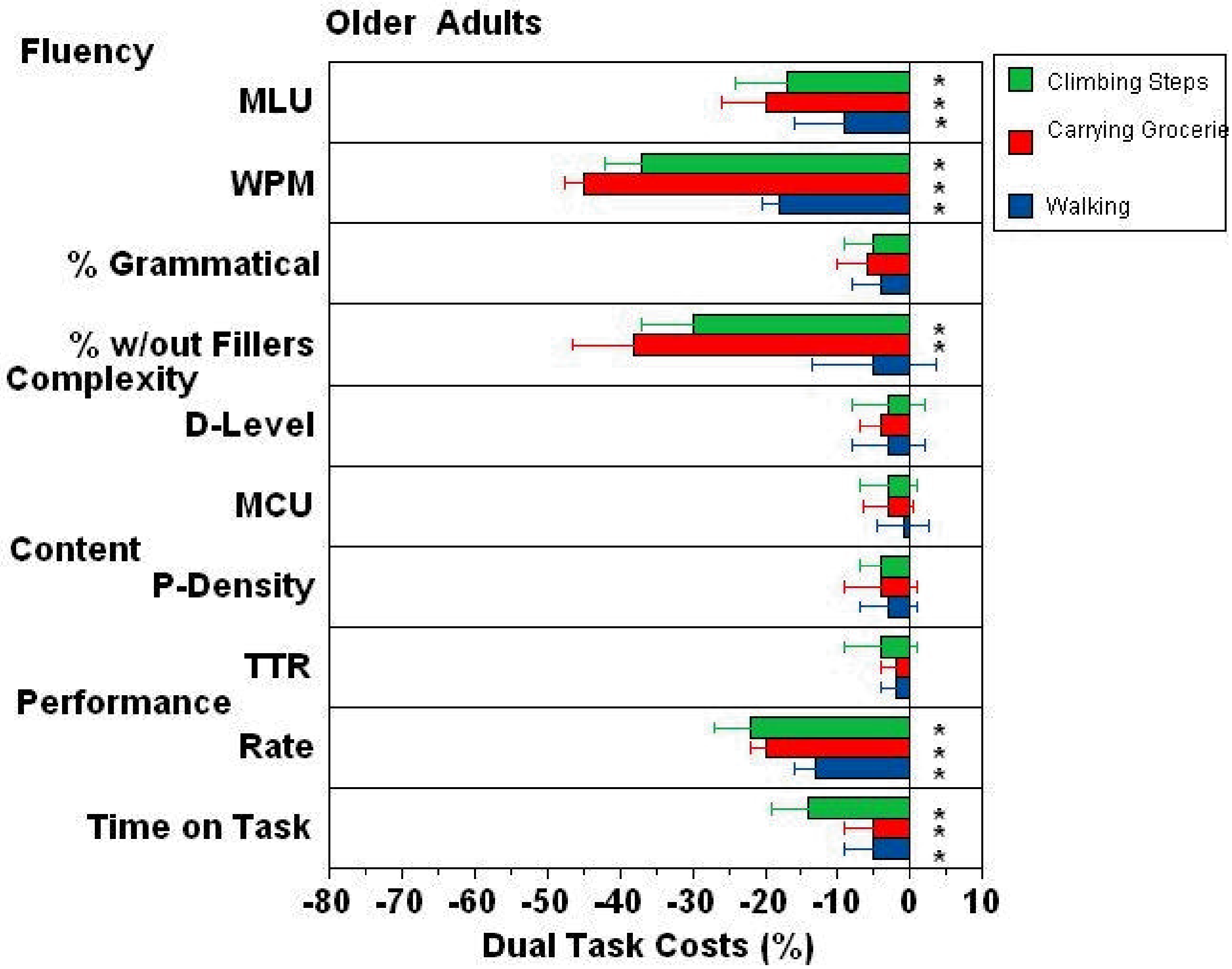

Figure 2.
Dual Task Costs (DTCs) (and standard errors) for Older Adults on the Language Sample Measures comparing Walking Baseline to Three Dual Tasks: Walking and Talking, Walking, Talking, and Carrying Groceries; and Walking, Talking, and Climbing Steps. An asterisk (*) marks DTCs significantly greater than zero.

Table 1

Age Differences in Baseline Language Sample Measures, Walking and Tapping Rates, and the Time-on-task Measures; Means (SDs) are given along with Results of the Multivariate and Univariate ANOVAs.

Measure	Young Adults Mean	Young Adults SD	Older Adults Mean	Older Adults SD	F	df	p	η^2
Fluency MANOVA					4.828	4,43	.003	.310
MLU	6.18	0.93	5.36	0.92	9.533	1,46	.003	.172
WPM	173.32	35.02	140.20	28.08	13.068	1,46	.001	.221
% Grammatical	74.31	11.48	76.84	11.5	<1.0	1,46	.659	.004
% w/out Fillers	92.61	5.46	95.04	3.61	3.159	1,46	.082	.064
Complexity MANOVA					16.193	2,45	<.001	.418
MCU	1.39	0.44	0.83	0.15	32.929	1,46	<.001	.417
D-Level	2.65	0.93	2.05	0.72	<1.0	1,46	.345	.019
Content MANOVA					4.717	2,45	.014	.173
TTR	0.44	0.04	0.49	0.06	<1.0	1,46	.345	.019
P-Density	3.93	0.44	3.81	0.41	8.294	1,46	.006	.153
Walking MANOVA					<1.0	2,45	.385	.041
Walking Rate	1.60	0.18	1.62	0.18	<1.0	1,46	.769	.002
Time-on-Task	100%	0.00	99.85	0.54	1.971	1,46	.167	.041

Note. MLU = mean length of utterance; WPM = word per minute speech rate; % Grammatical = percentage of grammatical sentences; % w/out Fillers = percentage of utterances without fillers; MCU = mean clauses per utterance; D-Level = Developmental Level; TTR = type-token ratio; P-Density = propositional density.

Table 2

Multivariate and Univariate ANOVAs for the Age x Task Interactions in Dual Task Costs for the Language Sample Measures, Walking and Tapping Rates, and the Time on Task Measures for the three Walking Tasks.

	Age by Task Interaction			
	F	**df**	**p**	**η^2**
Fluency MANOVA	3.792	8,180	<.001	.144
MLU	8.096	2,92	.001	.150
WPM	8.355	2,92	<.001	.154
% Grammatical	<1.0	2,92	.673	.003
% w/out Fillers	5.820	2,92	.004	.112
Complexity MANOVA	11.879	4,184	<.001	.205
MCU	25.299	2,92	<.001	.355
D-Level	4.687	2,92	.012	.092
Content MANOVA	7.368	4,184	<.001	.138
TTR	<1.0	2,92	.70	.007
P-Density	17.122	2,92	<.001	.271
Performance MANOVA	1.154	3,184	.344	.097
Walking Rate	1.112	2,92	.333	.024
Time-on-Task	3.782	2,92	.026	.076

Note. MLU = mean length of utterance; WPM = word per minute speech rate; % Grammatical = percentage of grammatical sentences; % w/out Fillers = percentage of utterances without fillers; MCU = mean clauses per utterance; D-Level = Developmental Level; TTR = type-token ratio; P-Density = propositional density.

Table 3

Multivariate and Univariate ANOVAs for Age Group Differences Dual Task Costs for the Language Sample Measures, Walking and Tapping Rates, and the Time on Task Measures for the three Tasks.

	Walking and Talking				Walking, Talking, & Carrying Groceries				Walking, Talki	
	F	df	p	η^2	F	df	p	η^2	F	df
Fluency MANOVA	3.989	4,43	.008	.271	18.712	4,43	<.001	.635	37.943	4,43
MLU	5.235	1,46	.027	.610	14.746	1,46	<.001	.243	31.482	1,46
WPM	3.653	1,46	.062	.465	39.038	1,46	<.001	.459	11.842	1,46
% Grammatical	<1.0	1,46	.580	.085	<1.0	1,46	.695	.004	<1.0	1,46
% w/out Fillers	1.480	1,46	.229	.223	19.489	1,46	<.001	.298	114.428	1,46
Complexity MANOVA	30.776	2,45	<.001	.578	25.995	2,45	<.001	.536	31.418	2,45
MCU	3.912	1,46	.054	.078	37.435	1,46	<.001	.449	44.241	1,46`
D-Level	53.028	1,46	<.001	.538	9.133	1,46	.004	.166	12.658	1,46
Content MANOVA	<1.0	2,45	.936	.003	<1.0	,2,45	.932	.003	1.382	2,45
TTR	<1.0	1,46	.897	.000	<1.0	1,46	.710	.003	2.81	1,46
P-Density	<1.0	1,46	.757	.002	<1.0	1,46	.957	.000	8.294	1,46
Performance MANOVA	5.804	2,45	.006	.205	5.748	2,46	.006	.203	8.816	2,45
Walking Rate	10.035	1,46	.003	.179	9.606	1,46	.003	.173	13.387	1,46
Time-on-Task	1.328	1,46	.255	.028	<1.0	1,46	.334	.020	5.327	1,46

Note. MLU = mean length of utterance; WPM = word per minute speech rate; % Grammatical = percentage of grammatical sentences; % w/out Fillers = percentage of utterances without fillers; MCU = mean clauses per utterance; D-Level = Developmental Level; TTR = type-token ratio; P-Density = propositional density.