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**Keywords:**

Language production, dual task demands, working memory

**Abstract:**

The present study compared how varying task priorities affected young and older adults' language production. Both young and older adults responded to monetary incentives to vary their performance when simultaneously talking and tracking a pursuit rotor. Tracking performance improved when they were rewarded for tracking and declined when they were rewarded for talking. Both young and older adults also spoke more slowly when rewarded for tracking and more rapidly when rewarded for talking. Young produced less complex sentences when rewarded for tracking and produced more complex sentences when rewarded for talking. However, older adults did not vary their grammatical complexity as a function of monetary incentives. These results are consistent with prior studies suggesting that older adults use a simplified speech register in response to dual task demands.

**Text of paper:**

The effects of varying task priorities on language production by young and older adults

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Language is a flexible system that allows for many variations of fluency, complexity, and content in response to individual, group, and situational factors. Many aspects of language are preserved across the life span while others decline as a result of sensory changes, reductions in processing speed, and working memory limitations (see Burke & Shafto, 2008 for a review). Studies of elicited speech have shown that older adults produce shorter utterances using simpler syntactic structures and reduced propositional content than young adults (Kemper, 1992; Kemper, Kynette, Rash, Sprott, & O'Brien, 1989; Kemper, Rash, Kynette, & Norman, 1990; Kynette & Kemper, 1986; ) reflecting the use of a simplified speech register. These age-related changes to language production have been linked to capacity limitations. Older adults have typically been found to have smaller working memory spans than young adults and such span measures have been found to correlate with language production and processing measures (Norman, Kemper, Kynette, Cheung, & Anagnopoulos, 1991; Stine & Wingfield, 1990; Tun, Wingfield, & Stine, 1991). For example Kemper et al. (1989) reported that the mean number of clauses per utterance (MCU), a general measure of the complexity of adults language, is positively correlated with the adults backward digit span using the WAIS-R subtest (Wechsler, 1981). Further, Kemper and Rash (1988) calculated Yngve depth (Yngve, 1960), a measure of linguistic complexity, and found that it was positively correlated with WAIS-R digit span as well as with MCU. However, uncontrolled age-related differences in discourse pragmatics that affect lexical choice, sentence structure, and expressive content or in the use of paralinguistic gestures may contribute to these findings (James, Burke, Austin, & Hulme, 1998). For example, older

adults may have learned that their listeners, often other older adults, have difficulty processing complex sentences, resulting in requests for repetition or clarification; hence, older adults may adopt a simplified speech register so as to minimize processing demands on their listeners.

To resolve this question, constrained production tasks have been used; constrained production tasks require the speaker to produce a sentence using specified words or phrases to control many pragmatic factors such as topic and focus while examining how the planning and production of fluent, complex sentences are affected by linguistic factors, such as verb complexity or lexical frequency, or by processing constraints such as memory demands (Altmann & Kemper, 2006; Kemper & Herman, 2006). For example, in a series of controlled production experiments (Kemper, Herman, & Lian, 2003; Kemper, Herman, & Liu, 2004), young and older adults were given 2, 3 or 4 words and asked to compose a sentence. The length, grammatical complexity, and propositional or informational content of each sentence produced was scored and the time to respond was tracked. Older adults' responses were similar to those of younger adults when given 2 or 3 words. When given 4 words, the older adults were slower to respond, made more errors, and their responses were shorter, less complex and less informative than the younger adults' responses. When different types of verbs were provided, young and older adults responded similarly with simple intransitive (*smiled*) and transitive (*replaced*) verbs but older adults encountered problems using verbs like *expected* that preferentially are used with embedded clauses, e.g., ...*expected the package to be delivered*. Older adults responded very slowly yet produced shorter, grammatically simpler, and propositionally less informative sentences. Thus, both working memory constraints and linguistic constraints limit older adults' responses even when pragmatic factors such as topic and word choice are controlled. However, even in these studies, some pragmatic factors may differentially affect young and older adults:

older adults may be less sensitive than young adults to the often implicit task demands to produce complex sentences or to respond as rapidly as possible.

Dual-task procedures can be used to study how individuals trade-off competing task demands, such as responding as rapidly as possible versus responding as accurately as possible. Dual-task costs may reflect the operation of a central bottleneck (Pashler, 1994) in selecting between the tasks or strategic differences how the tasks are coordinated (Meyer & Kieras, 1997a and b). Recent investigations (see the meta-reviews by Riby, Perfect, & Stollery, 2004, and Verhaeghen, Steitz, Sliwinski, & Cerella, 2003) suggest that older adults' experience greater dual-task costs than young adults, especially with tasks that involve controlled processing as well as executive functions such as task switching, time-sharing, and updating. Göthe, Oberauer, and Kliegl (2007), suggest that there are persistent differences in how young and older adults combine two tasks, even well-practiced tasks. Göthe, et al. have suggested that older adults adopt a "conservative" approach to dual-task demands that trades reduced speed for improved accuracy whereas young adults employ a more risky approach that emphasizes speed over accuracy.

The dual task approach can be used to examine how aging and task demands affect language production by requiring young and older adults to respond to probe questions while concurrently carrying out secondary tasks. When cognitive and motor tasks are performed simultaneously, older adults typically show greater dual-task costs than young adults (Li, Lindenberger, Freund, & Baltes, 2001; Lindenberger, Marsiske, & Baltes, 2000) although young and older adults may differ in how they trade-off costs to one task versus the other (Doumas, Rapp, & Krampe, 2009; Li et al., 2001; Verrel, Lövdén, Schellenbach, Schaefer, & Lindenberger, 2009).

In a series of studies using dual-task comparisons, Kemper and her colleagues (Kemper, Herman, & Lian, 2003; Kemper, Herman, & Nartowicz, 2005; Kemper, Schmalzried, Herman, & Mohankumar, 2008) found that young and older adults responded differentially to dual task demands when they are asked to talk while performing simple motor tasks, such as walking or tapping a finger, or when they are listening to noise. Both groups spoke more slowly but young adults' also used shorter, simpler sentences while engaged in the secondary tasks. However, even these studies are subject to the criticism that pragmatic factors may differentially affect how young and older adults' respond to dual task demands. It may be that young adults put less emphasis on language production and more emphasis on maintaining performance on the secondary tasks. In contrast, older adults may place more emphasis on language production at the cost of secondary task performance. Thus, young and older adults may have different task priorities that may affect their language production in spontaneous speech situations, controlled production studies, and in dual task studies.

The present study was undertaken to directly compare how varying task priorities affect young and older adults' language production using a dual task procedure. Language samples were collected from participants while they were engaged in a digital version of a pursuit rotor task. This task provides a continuous record of performance that can be synchronized with language production. As a result, variation in language production parameters, such as speech rate or grammatical complexity, are expected to affect tracking performance. Varying task priorities were compared in 3 conditions: a condition placing equal emphasis on talking and tracking; a condition in which talking performance was emphasized and rewarded over tracking; and a condition in which tracking performance was emphasized and rewarded over talking. Monetary incentives were used to differentially reward talking versus tracking performance.

Monetary incentives are effective in manipulating the performance of both young and older adults on a wide range of tasks (Birkhill & Schaie, 1975; Strayer & Kramer, 1994; Tournon, Swaim, & Hertzog, 2007) and appear to be equivalently motivating for both young and older adults on psychomotor tasks as well as on cognitive tasks (Grant, Storandt, & Botwinick, 1978; Hartley & Walsh, 1980; Surburg, 1976).

## Method

### *Participants*

Forty young adults (18 to 34 years old,  $M = 21.8$ ,  $SD = 3.17$ ) and 40 older adults (65 to 85 years old,  $M = 74.3$ ,  $SD = 6.07$ ) were tested. The young adults were recruited by signs posted on campus and class announcements while the older adults were recruited from a database of prospective and previous research participants. The participants were paid \$10/hour for their participation with the opportunity to earn bonuses based on performance. The older adults were also given compensation for driving to and from the testing site. Two additional young adults and three additional older adults were tested, but data from these participants was lost due to technical problems during testing.

The two groups were compared on a number of measures. The two groups did not differ significantly in the number of years of formal education completed ( $M_Y = 16.2$ ,  $SD_Y = 2.6$ ;  $M_O = 17.1$ ,  $SD_O = 3.0$ ),  $p = .173$ . Older adults scored slightly better on a vocabulary test (Shipley, 1940) ( $M_O = 34.4$ ,  $SD_O = 3.3$ ) than the young adults ( $M_Y = 31.4$ ,  $SD_Y = 3.0$ ),  $p < .001$ . The young adults had higher digit forward spans ( $M_Y = 10.2$ ,  $SD_Y = 2.0$ ) than the older adults ( $M_O = 9.0$ ,  $SD_O = 2.1$ ),  $p = .009$ , as well as higher backward digit spans ( $M_Y = 8.6$ ,  $SD_Y = 2.4$ ;  $M_O = 7.2$ ,  $SD_O = 2.1$ ),  $p = .009$ . The two groups did not differ in performance on a reading span test (Daneman & Carpenter, 1980) ( $M_Y = 3.7$ ,  $SD_Y = 1.0$ ;  $M_O = 3.6$ ,  $SD_O = 3.6$ ),  $p = .881$ . Scores on the three span

tests were correlated,  $r = .65$  to  $.75$ , for both young and older adults; a working memory composite score was based on a confirmatory factor analysis with a single latent working memory factor (Loehlin, 1998). Young adults had a higher composite working memory score than did older adults,  $F(1, 78) = 15.548, p < .001$ . The young adults scored higher on the Digit Symbol Test (Wechsler, 1958) ( $M_Y = 33.7, SD_Y = 5.6; M_O = 24.5, SD_O = 4.5$ ),  $p < .001$ . On a Stroop test, older adults named fewer blocks of colored X's ( $M_O = 71.7, SD_O = 13.4$ ) than the young adults ( $M_Y = 91.1; SD_Y = 11.4$ ),  $p < .001$ , and named fewer blocks of colored words than young adults ( $M_O = 41.5, SD_O = 8.8; M_Y = 66.2, SD_Y = 12.0$ ),  $p < .001$ . Inhibition was assessed by calculating an inhibition score:  $\text{Inhibition} = (\text{blocks of XXXs} - \text{blocks of color names}) / \text{blocks of XXXs} * 100$ . Older adults experienced more inhibition ( $M_O = 41\%$  decline,  $SD = 13\%$ ) than young adults ( $M_Y = 28\%$  decline,  $SD = 8\%$ ),  $p < .001$ . An alpha level of  $.05$  was set for these and all subsequent  $t$  and  $F$  tests.

#### *Pursuit-Rotor Tracking Program*

A digital pursuit rotor tracking task, developed by the Digital Electronics and Engineering Core of the Biobehavioral Neurosciences and Communication Disorders Center, a component of the Schiefelbusch Institute for Life Span Studies at the University of Kansas. The pursuit rotor featured an elliptical track with a bull's-eye target that rotated along the track displayed on a 15" high resolution flat-screen. Participants tracked the target using a 4" x 6" touchpad or a trackball mouse to control the cursor. Once a tracking device was selected, the participant continued to use the same device in baseline and all dual task conditions. At the start of a trial, the participant saw a red bull's-eye target and an elliptical track. The participant positioned a pair of cross-hairs over the target using the touchpad or trackball. Positioning the cross-hairs on the target turned the target from red to green and started the target moving along

the track at a variable speed determined by the experimenter. The program measured sampled the location of the cross-hairs every 10 ms, and determined whether they were on or off the target, and if off target, how far off they were. The probability that the cross-hairs were on-target was averaged over 3 successive 10-ms intervals, and a moving average Time on Target (TOT) score was computed over successive intervals. In addition, an average TOT score was computed for the duration of the trial or any segment of the trial. Tracking error, computed as the distance, in pixels, from of the target to the cross-hairs, was also averaged over 3 successive 10 ms intervals; a moving average error score was determined over successive intervals and an average error score was calculated for the duration of the trial or segment. The continuous tracking record was time-locked to a digital recording of a speech sample produced by the participant. Since the speech wave form was synchronized with the tracking record, it was used to segment the TOT and error records.

### *Pursuit Rotor Training*

Participants were initially trained on the pursuit rotor task to an asymptotic level of performance. A “2 up/1 down stair-case” training procedure was used to gradually increase tracking speed on successive 30-s trials: if TOT was 80% for a trial, the speed was increased by 10% for the next trial; if TOT was less than 80%, the speed was decreased by 5%. The stair-case procedure converged on an asymptotic tracking speed when the speed oscillated around the same value, moving “up” and “down” past this value 3 times. In general, young adults took more trials to reach an asymptotic tracking speed ( $M_Y = 23.8$  trials,  $SD_Y = 7.0$ ) than did older adults ( $M_O = 16.1$  trials,  $SD_O = 4.3$ ),  $t(78) = 5.868$ ,  $p < .001$ . After training, the young adults' asymptotic tracking speed ( $M_Y = 3.4$  rev/min,  $SD_Y = 0.1$ ) was faster than the older adults' ( $M_O = 1.5$  rev/min,  $SD_O = 0.1$ ),  $t(78) = 10.697$ ,  $p < .001$ . However, relative to starting speed, after

training, older adults had improved 200% whereas the young adults had improved by 170% of their starting speed. Asymptotic tracking speed was not correlated with Shipley vocabulary scores, working memory scores, and Stroop interference scores but was correlated significantly with processing speed, measured by the Digit Symbol test: faster individuals attained faster asymptotic tracking speeds ( $r(40) = +.68$  and  $+.54$ , for young and older adults, respectively).

After the asymptotic tracking speed was established for each participant, participants were given a 4 min tracking task to establish a baseline of performance. The two groups did not differ in their TOT performance during the 4 min baseline and both groups were able to maintain near 80% TOT ( $M_Y = 81\%$ ,  $SD_Y = 3.5$ ;  $M_O = 78\%$ ,  $SD_O = 7.1$ ),  $p = .295$ . However, tracking error for young adults ( $M_Y = 1.6$  pixels,  $SD_Y = 0.7$ ) was significantly lower than that of the older adults ( $M_O = 3.6$  pixels,  $SD_O = 0.6$ ),  $p < .001$ . Therefore, when the participants were off target, older adults were off by a greater distance than young adults. Baseline tracking performance was not correlated with Shipley vocabulary scores, working memory scores, and Stroop interference scores but was correlated significantly with processing speed, measured by the Digit Symbol test: faster individuals were more likely to be on-target ( $r(40) = +.35$  and  $+.41$ , respectively), and closer to the target ( $r(40) = -.39$  and  $-.40$ , respectively) than slower individuals, all  $p < .05$ .

### *Varying Task Priorities*

After training and the 4 minute baseline test, 3 dual-task conditions were administered. During these dual-task conditions, participants responded orally to a probe question while engaged in pursuit rotor tracking. Three probe questions were used: “Who was the greatest president of the USA and why?” “What was the most significant invention of the 20<sup>th</sup> C and how does it affect your life?” and “What do you like the most about living in Lawrence? What do you

like the least?" When a participant 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. There is wide spread agreement between and within groups in the content of responses to these questions and language sample measures derived from these responses are highly correlated for individual speakers indicating they elicit a similar speech style. The 3 probe questions were counter-balanced across three dual task conditions: a condition with equal emphasis on tracking and talking, a condition emphasizing talking, and a condition emphasizing tracking. Monetary incentives were used to vary task priority. Participants first began tracking and after 1 revolution of the pursuit rotor, a small window opened up within the rotor track and a prompt question was displayed. Participants read the question aloud and responded orally.

The equal emphasis task was administered first; the order of remaining 2 conditions were counter-balanced across participants. Instructions for the equal emphasis condition were:

Now I want you to repeat the talking and tracking game. As before, the question will appear when the rotor ball has made 1 complete revolution. Read the question aloud and try to answer it as fully and completely as you can. Try to be as accurate as you possibly can and try to answer the question as fully and completely as you can.

When the participants were asked to emphasize talking, a monetary reward was given to encourage them to focus on the language production task. Instructions for the emphasis on talking condition were:

Now I want you to repeat the talking and tracking game but this time I want you to try to provide as much information as you can in response to the question. As before, the question will appear after the rotor ball has made 1 complete revolution. Read the

question aloud and try to answer it as fully and completely as you can. I'll pay you an extra \$1 for each fact or idea you provide. So, if you tell me a lot of information in response to the question, you can earn extra money. BUT you must still keep on doing the tracking task.

The average incentive for this condition did not differ between the two age groups ( $M_O = \$19$ ,  $SD_O = 4.8$  ;  $M_Y = \$19$ ,  $SD_Y = 6.3$ ),  $p = 0.83$ .

A similar monetary incentive was used for maintaining tracking performance when the participants were asked to emphasize tracking. Instructions for the emphasis on tracking condition were:

Now I want you to repeat the talking and tracking game but this time, I want you to try to be as accurate as you possibly can in tracking. As before, the question will appear when the rotor ball has made 1 complete revolution. Read the question aloud and try to answer it as fully and completely as you can. I'll pay you an extra \$10 if you can remain at 80% or better tracking accuracy and an extra \$15 if you can reach 90% or better tracking accuracy. So, if you are really accurate in tracking the rotating ball, you can earn extra money. BUT you must still keep on talking.

Again, the two age groups did not differ in average monetary incentives for this condition ( $M_O = \$8$ ,  $SD_O = 5.4$  ;  $M_Y = \$7$ ,  $SD_Y = 4.6$ ),  $p = 0.51$ .

### *Language Samples*

Each language sample was 3 to 4 min in duration and included at least 50 utterances. The samples were analyzed following the procedures described by Kemper, Kynette, Rash, Sprott, & O'Brien (1989). The samples were transcribed and coded by first segmenting each language sample into utterances and then coding each utterance. Utterances include well-formed

sentences as well as ungrammatical fragments; both sentences and fragments may contain lexical fillers such as “like” and “you know.” Two trained coders independently scored 10% of the language samples to establish reliability. Agreement exceeded  $r(40) > .90$  for all measures and interclass correlations for all coders exceeded .8 for all language sample counts and measures. Previous comparisons of language samples collected from young and older adults (Kemper et al., 2003; 2005) have examined a range of measures of fluency, grammatical complexity, and lexical and propositional content. Based on this research, 5 measures were selected for analysis of the effects of varying task priorities on dual task performance: speech rate, sentence length in words (MLU), 2 measures of grammatical complexity (DLevel and MCU), and propositional density (PDensity). These measures were selected because they can be reliably scored, show good consistency across different elicitation questions, and have been previously shown to correlated with working memory, or other cognitive abilities. (i) Speech rate was computed by timing the duration of 3 different 45 sec segments, counting the total number of words including all lexical fillers in each segment, and computing an average word per min rate. (ii) Mean Length of Utterance (MLU) was obtained automatically using the Systematic Analysis of Language Transcripts (SALT) software (Chapman & Miller, 1984) to determine the average number of words per utterance. MLUs are reduced by the occurrence of fragments but inflated by the use of lexical fillers. (iii) Mean Clauses per Utterance (MCU), a measure of grammatical complexity, was obtained by identifying each main and embedded or subordinate clause in each utterance. (iv) Developmental Level (DLevel), a 2<sup>nd</sup> measure of grammatical complexity, was scored based on a scale originally developed by Rosenberg and Abbeduto (1987); each complete sentence was scored and the average DLevel for each language sample was then calculated. MCUs are low (in the range of 1.0 to 2.0) when speech is highly

fragmented and few well-formed sentences are produced; DLevels are low ( in the range of 0 to 1.5) when speakers produce many single-clause sentences or sentences with, e.g., infinitive complements, conjoined clauses, or wh-clauses in the predicate. (v) Propositional Density (PDensity) was calculated according to the procedures described by Turner and Greene (1977) to decompose each utterance into its constituent propositions, which represent ideas and the relations between them. The PDensity for each speaker was defined as the average number of propositions per 100 words. Lexical fillers reduce PDensity since they add words but no propositional information.

## Results

The results are organized into 4 sections: first: the effects of varying task priorities on tracking performance are examined; second, the effects of varying task priorities on language production are examined; third, dual task priorities are compared by examining how language production covaries with tracking performance; fourth, correlations were used to examine how individual differences on the cognitive tests affected tracking performance and language production.

### *Effects of Varying Task Priorities on Tracking Performance*

Differing task priorities can lead to different accommodations to dual task demands such that some participants prioritize tracking performance whereas others might prioritize language production. The first set of analyzes examined whether young and older adults had similar task priorities with regards to tracking performance. Preliminary analyses indicated that there were no order effects for either tracking measure so repeated measures ANOVAs with Age Group (young and older adults) x Priority (equal emphasis, emphasis on talking, and emphasis on tracking) were used to compare tracking performance as a function of task priority. See Table 1.

For the TOT measure, the effect of task priority was significant,  $F(2, 77) = 15.66, p < .001, \eta^2 = .281$ . For both groups, TOTs were ordered: emphasis on tracking > equal emphasis > emphasis on talking, all  $p < .05$ . There was also a significant main effect of age group,  $F(1, 78) = 5.81, p = .004, \eta^2 = .281$ , favoring young adults, although the effect of task priority on TOT was similar for both age groups. A second repeated measures ANOVA compared tracking error; there was a significant effect of task priority,  $F(2, 77) = 77.00, p < .001, \eta^2 = .373$ . For the error measure, the effect of task priority was significant,  $F(2, 77) = 15.66, p < .001, \eta^2 = .28$ . For both groups, tracking error was ordered: emphasis on tracking < equal emphasis < emphasis on talking. Young adults' tracking was somewhat more accurate than older adults,  $F(1, 78) = 9.135, p < .003, \eta^2 = .105$ , and they responded somewhat more dramatically to the monetary incentives when tracking was rewarded than did the older adults, resulting in a significant age group by task priority interaction,  $F(2, 77) = 21.678, p < .001, \eta^2 = .217$ . Thus, both groups prioritized tracking performance when they were monetarily rewarded for tracking accuracy and sacrificed tracking performance when they were monetarily rewarded for speaking.

### *Effects of Varying Task Priorities on Language Production*

The second set of analyses examined whether young and older adults had similar task priorities with regards to language production. Preliminary analyses indicated that the 3 probe questions resulted in similar speech rates, language samples of similar length, grammatical complexity, and propositional density so the primary analyses assessed the effects of varying task priorities on language production with a series of Age Group by Task Priority ANOVAs. Significant interactions were then decomposed using *t*-tests to compare performance on the individual task priority conditions separately for the two groups. These analyses indicate that

some aspects of language production are modifiable by monetary incentives that affect task priorities whereas other aspects of language are not.

Overall, young adults spoke more rapidly than older adults,  $F(1, 78) = 50.493, p < .001, \eta^2 = 0.396$ , and speech rates for both groups were affected by varying task priorities,  $F(2, 77) = 7.376, p < .001, \eta^2 = 0.291$ . For both groups, speech rates in words per min were ordered: emphasis on tracking < equal emphasis < emphasis on talking (see Table 2).

Young adults produced more complex sentences than older adults, on both the DLevel measure,  $F(1,78) = 11.317, p = .001, \eta^2 = 0.128$ , and the MCU measure,  $F(1,78) = 7.976, p = .006, \eta^2 = .093$ . However, there were significant age by task interactions for both DLevel,  $F(2, 77) = 5.578, p = .001, \eta^2 = 0.229$ , and MCU,  $F(2, 77) = 12.003, p < .001, \eta^2 = 0.390$ . Young adults' DLevels and MCUs were ordered: Emphasis on tracking < equal emphasis < Emphasis on talking. Older adults' grammatical complexity did not vary with condition.

In contrast, varying task priorities did not affect sentence length or propositional content. Regardless of condition, young adults used longer sentences than older adults,  $F(1, 78) = 4.575, p < .036, \eta^2 = 0.055$ , with greater propositional density,  $F(1,78) = 13.226, p < .001, \eta^2 = 0.145$ . Neither sentence length nor PDensity was affected by varying task priorities as indicated in Table 2.

### *Dual-Task Priorities*

Dual-task priorities were assessed by deriving a series of slopes, for each participant, by contrasting individual tracking performance measures with individual language production measures. The resulting graphs are analogous to Speed-Accuracy Operating Characteristic (SAOC) curves (Pew, 1969) or Attention Operating Characteristic (AOC) curves (Sperling &

Melchner, 1978) (see Li et al., 2001, for a related approach). Figure 1 compares tracking TOT and error rates with speech rates; means and 95% confidence limits are plotted separately for each age group and each measure of tracking performance. Parallel slopes indicate that the two age groups share a similar strategy for trading-off speech rate for tracking performance; differing slopes indicate that the two groups have different dual-task priorities. ANOVAs were used to compare the slopes for young versus older adults; the slopes for speech rates did not differ significantly for either tracking measure: tracking TOTs and speech rate:  $F(1,78) = 4.873, p > .05, \eta^2 = 0.036$ ; tracking error and speech rate:  $F(1,78) = 4.438, p > .05, \eta^2 = 0.0376$ . For both groups, speech rate declined as tracking TOT increased and speech rates increased as tracking error declined.

Slopes were also derived from both measures of tracking performance and the 2 measures of grammatical complexity, DLevel and MCUs (see Figures 2 and 3). In each case, there was a significant difference in the slopes for young versus older adults, tracking TOTs and DLevel:  $F(1,78) = 27.791, p = .001, \eta^2 = 0.265$ ; tracking error and DLevel:  $F(1,78) = 47.737, p = .001, \eta^2 = 0.383$ ; tracking TOTs and MCU:  $F(1,78) = 18.909, p = .001, \eta^2 = .195$ ; tracking error and MCU:  $F(1,78) = 44.407, p = .001, \eta^2 = 0.356$ . These analyses confirm that young and older adults differed in the effects of task priorities on language production. For young adults, grammatical complexity declined as tracking TOT increased and grammatical complexity increased as tracking error declined. For older adults, there was little change in grammatical complexity with tracking performance.

### *Correlational analyses*

To examine how tracking and talking were affected by individual differences in processing speed, inhibition, and working memory, a series of correlations was computed between the performance measures and the cognitive measures. These are summarized in Table 3. Note that similar patterns hold for both young and older adults. In the equal emphasis condition, faster participants, as measured by the Digit Symbol test, spoke more rapidly, used longer sentences, and had better tracking performance. They were able to maintain these advantages when tracking was emphasized and when talking was emphasized. In the equal emphasis condition, participants with greater working memory capacity, as measured by the span tests, produced more complex sentences and they continued to do so when tracking was emphasized and when talking was emphasized. Interference on the Stroop task was not correlated with tracking performance and speech rate: participants who experienced less interference on the Stroop test spoke no more rapidly and had no better tracking performance than participants who experienced more interference on the Stroop test. Performance on the Shipley vocabulary test was correlated with propositional density in all conditions.

### Discussion

This study was designed to determine whether young and older adults differ in how they prioritize dual task demands in response to monetary incentives that rewarded either language production or performance on a pursuit rotor task. The “value” of monetary incentives appears to be equivalent for young and older adults in other studies (Birkhill & Schaie, 1975; Strayer & Kramer, 1994; Touron, Swaim, & Hertzog, 2007) and in this study, both young and older adults responded alike to monetary incentives to vary their tracking performance when simultaneously talking and tracking a pursuit rotor. Tracking performance improved when they were rewarded for tracking and declined when they were rewarded for talking, compared to the equal-emphasis

condition. Speech rates of both young and older adults were also similarly affected by monetary incentives such that they spoke more slowly when rewarded for tracking and more rapidly when rewarded for talking. Young adults' grammatical complexity was affected by the monetary incentives such that they produced less complex sentences when rewarded for tracking and produced more complex sentences when rewarded for talking. However, unlike young adults, older adults did not vary their grammatical complexity as a function of monetary incentives.

These results suggest that older adults, in response to age-related loss of processing speed and working memory capacity, have developed a simplified speech register. Although their speech is slower and less complex than young adults, it is better able to resist dual task demands. By slowing down, older adults are able to maintain their (reduced) level of grammatical complexity even when challenged by monetary incentives that rewarded tracking performance. However, they are unable to increase their level of grammatical complexity when the monetary incentives rewarded talking. This pattern suggests there is a 'ceiling' imposed on older adults' production of complex sentences and this ceiling cannot be breached even when there are monetary incentives to do so.

This interpretation is consistent with the results of the correlational analyses that indicated that faster participants, as assessed by performance on the digit symbol test, had higher speech rates and better tracking performance in all conditions. In contrast, participants with greater working memory capacity, as measured by performance on the span tests, produced more complex sentences in all conditions. Monetary incentives may induce young adults to slow down or speed up, affecting speech rate and tracking performance, or to increase or decrease their grammatical complexity by reallocating working memory capacity. In contrast, while older

adults can slow down or speed, affecting speech rate and tracking performance, they cannot increase working memory capacity, hence, their grammatical complexity.

Previous research (Kemper et al., 1989, 2003, 2004, 2006) has demonstrated that there are age-related declines in the length, complexity, and propositional content of older adults' spontaneous speech, responses during controlled production tasks, and speech elicited during dual task situations. These declines have been attributed to age-related declines in working memory and processing speed. However, an alternative interpretation of these findings is that pragmatic factors may affect older adults' use of complex grammatical sentences: older adults may opt not to use complex sentences in order to reduce processing demands on their listeners, because of situational factors that limit their expression of complex ideas requiring the use of complex sentences, or because they resist pressures to respond quickly, etc. The findings from this study argue against this account, suggesting that older adults are unable to use complex grammatical sentences even when rewarded for doing so by monetary incentives. Older adults' grammatical complexity did not vary with dual task priorities – they neither used more complex sentences when rewarded for talking nor used less complex ones when rewarded for tracking.

Young adults' more complex speech can be flexibly tuned to accommodate dual task demands and varying task priorities by adjusting either grammatical complexity, speech rate, or both. When dual task demands increase or when monetary payoffs reward tracking performance, young adults reduce grammatical complexity and speech rates. When dual task demands decrease or when monetary payoffs reward talking performance, young adults increase grammatical complexity and speech rates.

Older adults' speech is less flexible. Their speech can slow down or speed up, but in response to dual task demands or monetary incentives, grammatical complexity does not vary.

Older adults use a simplified speech register in both spontaneous speech, controlled production tasks, and during dual task situations that is an accommodation to resource limitations on processing speed and working. These resource limitations affect the ability of older adults to plan and produce complex, multi-clause utterances and impose limitations on ideation, word retrieval, and other aspects of sentence planning and production. Their simplified speech register serves them very well – it enables them to respond to dual task demands and varying task priorities without a further loss of grammatical complexity.

It is unclear just how well protected older adults' simplified speech register is. It may be that older adults are drawing on cognitive reserve capacity (Christensen, Anstey, Leach, & Mackinnon, 2008; Stern, 2002) to maintain the complexity and content of their speech. It appears that the limits of this reserve capacity are soon reached for older adults during dual task procedures, limiting the grammatical complexity of their speech even when rewarded for talking. As further task demands exceed some threshold, older adults' speech may not only decline further in speech rate but also be affected in other ways, as cognitive reserves are drained. It is hypothesized that under very demanding conditions, older adults' speech will be disfluent and marked by short sentences, many ungrammatical sentences and sentence fragments, and much repetition and redundancy, resulting in reduced low propositional density.

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Table 1

Means And Standard Deviations For Tracking Time on Target (TOT) And Tracking Error in Pixels for the Three Dual Task Conditions Varying Task Priorities.

	Young Adults		Older Adults	
	TOT	Error	TOT	Error
Emphasis on Tracking	85 <sub>a</sub> (4.9)	1.3 <sub>a</sub> (3.8)	79 <sub>a</sub> (9.9)	3.6 <sub>a</sub> (2.6)
Equal Emphasis	77 <sub>b</sub> (4.9)	4.7 <sub>b</sub> (4.6)	71 <sub>b</sub> (9.9)	4.0 <sub>b</sub> (4.5)
Emphasis on Talking	72 <sub>c</sub> (5.8)	6.1 <sub>c</sub> (5.1)	66 <sub>c</sub> (8.3)	6.1 <sub>c</sub> (4.4)

Note: Means in the same column with different subscripts are significantly different at  $p < .05$ .

Table 2

Language Sample Measures For Young And Older Adults.

	Young Adults		Older Adults	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
MLU				
Emphasis on Tracking	13.6 <sub>a</sub>	4.1	12.1 <sub>a</sub>	4.3
Equal Emphasis	13.6 <sub>a</sub>	3.5	11.9 <sub>a</sub>	4.1
Emphasis on Talking	13.7 <sub>a</sub>	3.9	11.7 <sub>a</sub>	4.3
WPM				
Emphasis on Tracking	131 <sub>c</sub>	27	96 <sub>a</sub>	38
Equal Emphasis	143 <sub>b</sub>	44	103 <sub>b</sub>	37
Emphasis on Talking	158 <sub>a</sub>	37	126 <sub>c</sub>	35
MCU				
Emphasis on Tracking	1.1 <sub>c</sub>	0.4	1.1 <sub>a</sub>	0.4
Equal Emphasis	1.4 <sub>b</sub>	0.5	1.2 <sub>a</sub>	0.4
Emphasis on Talking	2.5 <sub>a</sub>	0.4	1.1 <sub>a</sub>	0.4
DLevel				
Emphasis on Tracking	3.1 <sub>c</sub>	1.1	3.1 <sub>a</sub>	0.9
Equal Emphasis	3.6 <sub>b</sub>	1.2	3.2 <sub>a</sub>	1.0
Emphasis on Talking	3.9 <sub>a</sub>	1.4	3.2 <sub>a</sub>	1.1

Table 2, continued

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PDensity				
Emphasis on Tracking	5.6 <sub>a</sub>	1.1	5.3 <sub>a</sub>	0.6
Equal Emphasis	5.8 <sub>a</sub>	0.8	5.4 <sub>a</sub>	0.6
Emphasis on Talking	5.9 <sub>a</sub>	1.3	5.5 <sub>a</sub>	0.8

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Note: MLU = mean length of utterance; WPM = words per minute; MCU = mean clauses per utterance; DLevel = developmental level; PDensity = propositional density.

Note: For each measure, means in the same column with different subscripts are significantly different at  $p < .05$ .

Table 3

Correlations between Cognitive Measures and Talking and Tracking Performance in the 3

Task Priority Conditions.

	Stroop		Digit Symbol		Working		Shipley	
	Interference		Speed		Memory		Vocabulary	
	Composite							
	Young	Older	Young	Older	Young	Older	Young	Older
	Adults	Adults	Adults	Adults	Adults	Adults	Adults	Adults
Equal Emphasis								
MLU	-.02	-.09	+.40**	+.39*	+.31	+.31	+.23	+.18
WPM	+.12	+.17	+.41**	+.44**	-.12	+.01	+.13	+.15
MCU	-.11	-.19	+.14	+.19	+.54**	+.37*	+.10	+.14
DLevel	-.11	-.21	+.10	+.19	+.64**	+.41**	+.12	+.15
PDensity	-.09	-.10	+.14	+.11	+.14	+.11	+.46*	+.37*
Tracking TOT	+.23	+.18	+.37*	+.44**	-.04	-.01	-.04	-.05
Tracking error	-.21	-.19	-.42**	-.43**	+.03	-.03	+.10	+.04
Emphasize on Tracking								
MLU	-.12	-.04	+.45**	+.42**	+.24	+.21	+.17	+.16
WPM	+.20	+.19	+.47**	+.52**	-.09	+.11	+.15	+.15
MCU	-.01	-.10	+.15	+.11	+.39*	+.43**	+.11	+.12
DLevel	-.16	-.11	+.12	+.08	+.42**	+.45**	+.14	+.13
PDensity	-.02	-.08	+.12	+.09	+.10	+.14	+.43**	+.39*

Tracking TOT	+.17	+.19	+.42**	+.39*	-.08	-.05	-.06	-.05
Tracking error	-.19	-.23	-.36*	-.41**	+.03	+.12	+.08	+.12
Emphasis on Talking								
MLU	-.02	-.09	+.40**	+.39*	+.31	+.31	+.21	+.23
WPM	+.12	+.14	+.41**	+.44**	-.12	+.01	+.14	+.16
MCU	-.11	-.19	+.14	+.19	+.54**	+.37*	+.09	+.05
DLevel	-.11	-.21	+.10	+.19	+.64**	+.41**	+.11	+.06
PDensity	-.01	+.04	+.13	+.15	+.11	+.09	+.46**	+.41**
Tracking TOT	+.24	+.21	+.46**	+.45**	-.08	-.05	-.01	-.08
Tracking error	-.22	-.23	-.38*	-.43**	+.10	+.09	+.04	+.06

\* $p < .05$ , \*\*  $p < .01$

### Figure Caption

Figure 1. Slopes for Young Adults and Older Adults comparing the Effects of Dual Task

Priorities on Tracking Performance and Speech Rates. Three conditions are shown: an Equal emphasis condition, a condition emphasizing Talking, and a condition emphasizing Tracking. Dashed lines indicate 95% Confidence Limits.

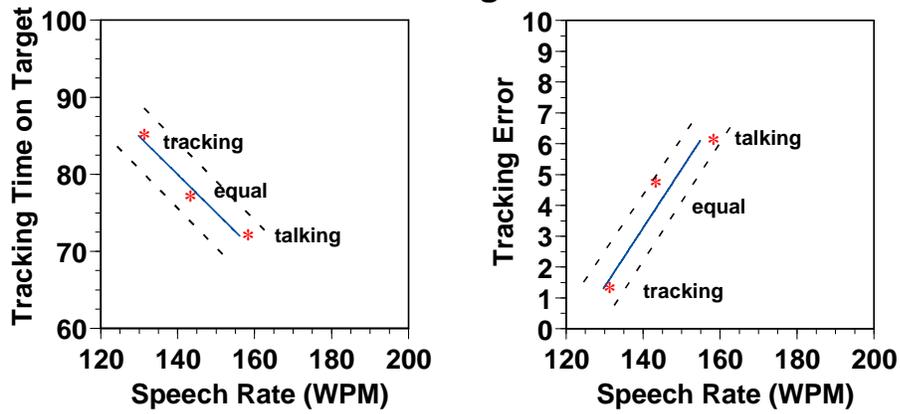
Figure 2. Slopes for Young Adults and Older Adults comparing the Effects of Dual Task

Priorities on Tracking Performance and DLevel Measure of Grammatical Complexity. Three conditions are shown: an Equal emphasis condition, a condition emphasizing Talking, and a condition emphasizing Tracking. Dashed lines indicate 95% Confidence Limits.

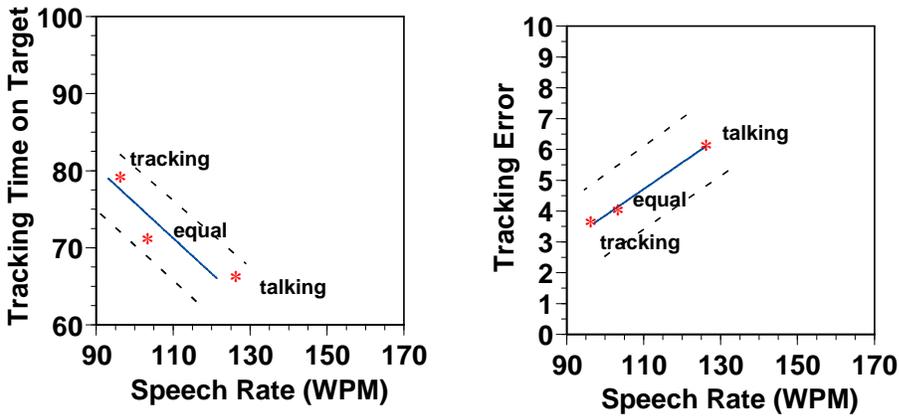
Figure 3. Slopes for Young Adults and Older Adults comparing the Effects of Dual Task

Priorities on Tracking Performance and MCU Measure of Grammatical Complexity. Three conditions are shown: an Equal emphasis condition, a condition emphasizing Talking, and a condition emphasizing Tracking. Dashed lines indicate 95% Confidence Limits.

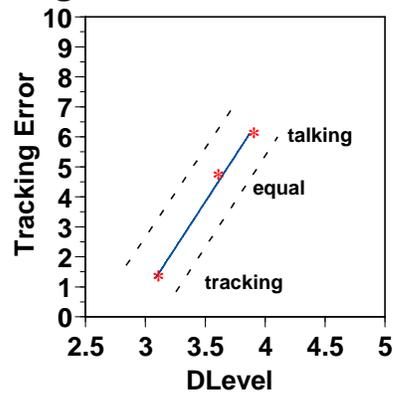
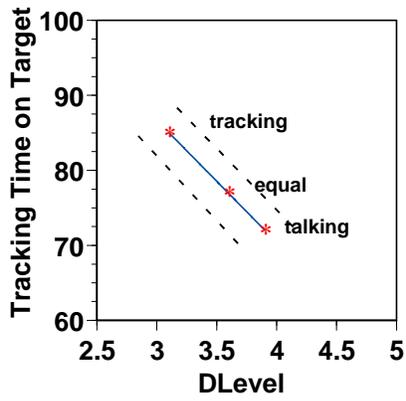
### Young Adults



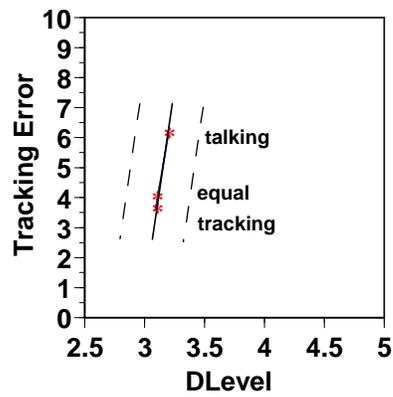
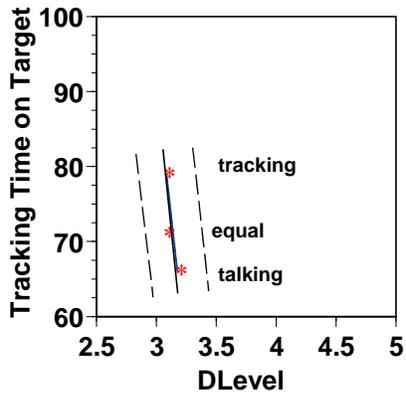
### Older Adults



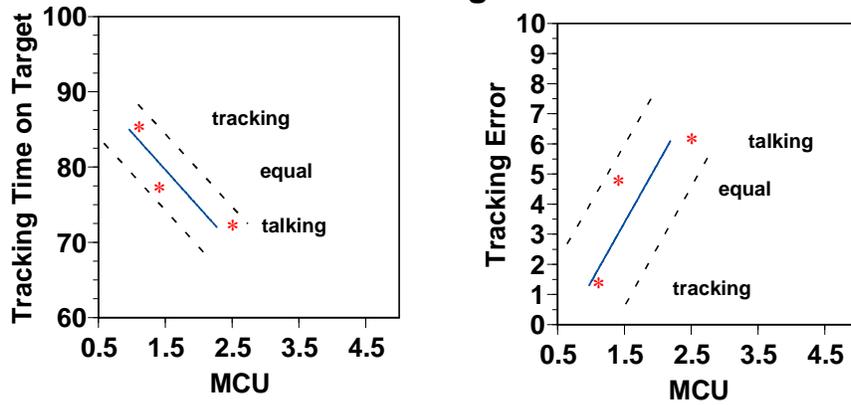
### Young Adults



### Older Adults



### Young Adults



### Older Adults

