AGE DIFFERENCES IN DUAL TASK PERFORMANCE: VALIDATING THE USE OF THE PURSUIT ROTOR

BY

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Age Differences in Dual Task Performance:
Validating the Use of the Pursuit Rotor

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Abstract

To validate a digital pursuit rotor task as a measure for dual task research, young (n=40) and older (n=40) adults were asked to produce language samples while engaged in the pursuit-rotor task. Young adults tracked faster at baseline and in dual task conditions. Young adults also spoke more rapidly than the older adults at baseline and in most dual task conditions. In task priority conditions, young adults appeared to be able to change their performance to match the priority whereas older adults' performance did not change in task priority conditions. Advantages of the rotor over other dual task measures are discussed.

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Age Differences in Dual Task Performance:
Validating the Use of the Pursuit Rotor

The use of concurrent tasks to study the allocation of attention and/or working memory has a rich history in psychology and neuropsychology (Baddeley, 1986; 1996; Baddely, Lewis, Eldridge, & Thompson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Rosen & Engle, 1997). In previous work in the fields of gerontology and geropsychology, one emphasis of concurrent task research has been to examine the "pentration" of cognitive and attentional tasks by the simultaneous performance of perceptual or motor and cognitive tasks performance. In these studies, some tasks, such as walking, have been shown to require more attention than others (like standing or sitting), as measured by dual task costs to a secondary task such as counting backward or reciting the alphabet (Lajoie, Teasdale, Bard & Fleury, 1993; Melzer, Menjuya, & Kaplanski, 2000; Teasdale, Lajoie, Bard, Fleury, & Courtemanche, 1993).

An influential series of studies by Lindenberger, Marsiske, and Baltes (2000) and Li, Lindernberger, Freund, and Baltes (2001) have investigated walking while memorizing within the context of the Baltes and Baltes (1990) *selection, optimization, and compensation* model. This model emphasizes the adaptability of aging individuals to select goals, optimize means to attain those goals, and utilize alternative means to compensate for losses or deficits. Measuring balance and gait as participants memorized lists of words, Lindenberger et al. showed dual task costs (measured in terms of memory accuracy, walking rate, and walking accuracy) increased with age. When participants were given a handrail to grasp in order to aid balance, Li et al. (2001) found that older adults prioritized walking at the expense of memory performance and utilized the handrail to compensate for walking difficulties. In this experiment, participants were also given the option to utilize a control box to slow the presentation of the to-be-remembered words. Young adults optimized memory performance by using this device to delay the presentation of the words. Dual-task costs have also been shown to increase in older adults as a result of performing spatial tasks, such as remembering the location of digits assigned to a 4-by-4 grid, as compared to non-spatial tasks, such as random number generation. (Maylor & Wing, 1996; Maylor, Allison, & Wing, 2001).

These studies of dual task costs confirm a link between cognition and sensory-motor control of behavior (Lindenberger et al., 2000; Welford, 1958) and suggest that simple tasks such as walking and maintaining balance become increasingly dependent upon cognitive reserve capacity in order to compensate for sensory losses, attentional lapses, slowing of response times, and other age-related deficits. The notion of cognitive reserve capacity (Kinsbourne & Hicks, 1978; Satz, 1993) is intended to capture the notion that trade-offs between cognition and task performance are revealed only when the two tasks are performed simultaneously under sufficiently challenging conditions.

Kemper, Herman, and Lian (2003) assessed the effects of simple motor and selective ignoring tasks on language production. Young and older adults were asked to provide language samples in response to a given question while concurrently carrying out a variety of motor tasks such as simple or complex finger tapping and walking, or selective listening tasks requiring participants to ignore concurrent speech. In general, both groups were able to meet the demands of doing two things at once. However, young adults exhibited greater dual-task costs than the older adults. Young adults' faster, more complex speech at baseline was affected by dual-task demands whereas older adults' slower, less complex speech at baseline was less affected by dual task demands. Young adults exhibited a decline in grammatical complexity, sentence length, and propositional content in response to the dual task demands whereas older adults did not. Instead, older adults spoke more slowly in all dual-task conditions compared to their single-task baseline. Thus, young and older adults adopted different strategies to accommodate the demands of the concurrent tasks. Kemper et al. speculated that older adults may exhibit further declines in speech rate and speech complexity when dual task costs are assessed under more demanding conditions.

The pursuit-rotor task has been used as a measure of attention for nearly 7 decades (Travis, 1937; McNemar & Biel, 1939). This task was first used to study practice and rest in motor learning. More recently, it has been used as a psychomotor task to induce behavioral impairment, mimicking a moderate consumption of alcohol (Harrison & Fillmore, 2005). This task has also been used to study vigilance and sustained attention in studies of sleep deprivation as well as pharmacological effects on performance. In general, the pursuit rotor task requires a track, which can be of any shape (oval, square, irregular), a target which follows that track, and a means for the participant to follow the target. Originally, the pursuit rotor was performed on a phonograph, and the goal was to keep a stylus on a dot that rotated with the speed of the phonograph. More recent versions utilize computerized displays along with touch pad or mouse control of a cursor to track the moving target. Common forms of measurement of rotor performance include the total time spent on the target (TOT), the distance the tracking device is from the target (error), and the number of target contacts (HITS).

This thesis validates using a digital pursuit-rotor task as a measure of dual-task demands for young and older adults. Previous work with the pursuit rotor in older adults has shown that there were no anxiety-related decrements in rotor performance of older adults in a divided attention task, even though there were age-related declines in tracking (Hogan, 2003). Therefore, we can assume that if there are age-group differences in rotor performance in the present dual-task paradigm, these differences are a product of the task demands. In order to validate the rotor as a measure for dual-task research, the results must parallel results using other, established measures for dual-task research such as walking or finger-tapping. In previous research, young adults were faster at baseline levels of walking and tapping and both groups exhibited dual-task costs (Kemper et al., 2003) on these rate measures. Of interest is whether both young and older adults experience dual task costs in tracking speed and accuracy on the pursuit rotor task. Further, speech rates of language samples collected while the participants simultaneously were engaged in the pursuit rotor tracking should also be affected by the dual task demands.

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 (see Appendix A for informed consent statement).

Cognitive Tests

The two groups did not differ significantly in the number of years of formal education completed ($M_Y = 16.2$, $SD_Y = 2.6$; $M_O = 17.1$, $SD_O = 3.0$), $p = .173$. Participants were given a battery of cognitive tests designed to assess verbal ability, working memory, inhibition, and processing speed. The Shipley (1940) Vocabulary Test was used to test verbal ability. It is comprised of 40 target words, and the participants choose the best synonym from 4 choices. Older adults scored slightly better on this test ($M_O = 34.4$, $SD_O = 3.3$) than the young adults ($M_Y = 31.4$, $SD_Y = 3.0$), $p < .001$. The Digits Forward and Digits Backwards tests (Wechsler, 1958) of working memory capacity were also administered. Participants repeated strings of numbers, either in the same (forward) or reverse (backward) order as presented. String length increased from 2 digits to a maximum of 9 digits. Two strings at each length were given to the participants, and a point was given for each string the participant repeated correctly. The young adults had higher 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 spans ($M_Y = 8.6$, $SD_Y = 2.4$) than the older adults ($M_O = 7.2$, $SD_O = 2.1$), $p = .009$. The Daneman and Carpenter (1980) Reading Span Test was also used to assess working memory. Participants are asked to remember the last word of each sentence in a series; the number of sentences, hence the number of words to be remembered, gradually increased. On this complex span test, the two groups did not differ in performance *(*M_Y = 3.7*,* SD_Y = 1.0; M_O = 3.6*,* SD_O = 3.6*),* $p = .881$. To test processing speed, participants were given the Digit Symbol Test (Wechsler, 1958). Participants were given symbols to pair with each digit, and had 45 seconds to fill as many symbols corresponding to a series of digits. The young adults scored higher on the Digit Symbol Test *(*M_Y = 33.7*,* SD_Y = 5.6*)* than the older adults *(*M_O = 24.5*,* SD_O = 4.5*),* $p < .001$. A Stroop test was also administered to assess processing speed and inhibition. Participants had 45 seconds to name the color of the ink of a series of X's and later to name the color of ink of a series of printed color words (e.g. the word RED printed in green ink). Speed of processing was measured by how many blocks of X's participants could name in 45 s; older adults named fewer blocks of X's *(*M_O = 71.7*,* SD_O = 13.4*)* than the young adults (M_Y = 91.1; SD_Y = 11.4*),* $p < .001$. Older adults also named fewer blocks of color words than young adults *(*M_Y = 66.2*,* SD_Y = 12.0*;* M_O = 41.5*,* SD_O = 8.8*),* $p < .001$. Inhibition was assessed by calculating an interference score using the following formula:

Interference = (blocks of Xs – color names) /

blocks of Xs * 100.

Young adults experienced less interference (M_Y = 27.5*,* SD = 7.6*)* than the older adults (M_O = 41.0, SD = 12.75*),* $p < .001$ (see Appendix J for a summary).

Pursuit-Rotor Tracking Program

Participants were trained on a digital pursuit-rotor tracking (PRT) task, which was 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 PRT featured an elliptical track with a bull's-eye target that rotated along the track. Participants used either a Fingerworks iGesture 4"x6" touchpad or a trackball mouse to control the cursor and track the target, displayed on a 15" high resolution flat-screen. The PRT was controlled by a separate laptop computer. All young adults used the iGesture touchpad, and most older adults used the trackball mouse, as the touchpad did not always recognize the touch of the older participants. Older adults were given a choice of tracking devices and allowed to practice with each before training began.

At the start of a trial, the participant saw a red bull's-eye target and positioned a pair of cross-hairs over the target using the touchpad or trackball mouse (see Appendix B for an example of the rotor display). Positioning the cross-hairs on the target turned the target from red to green. After a 3-second delay, the target started moving along the track. As the target rotated along the track, the participant tracked the moving target, attempting to keep the cross-hairs superimposed on the target. The experimenter set the speed at which the target rotated along the track as well as the duration of the trial. The speed varied from approximately .23 to 22.8 revolutions per minute; trials varied from 30 s to 4 min in duration.

The program measured tracking Time on Target (TOT) in successive 10 ms intervals and calculated an average TOT over the duration of the trial. Tracking error, computed as the distance, in pixels, between the center of the target and the cross-hairs, was also calculated in successive 10 ms intervals. A second version of the PRT allowed the continuous tracking record to be time-locked to a digital recording of a speech sample produced by the participant. The speech wave form was synchronized with the continuous TOT and tracking error records. TOT and tracking error could also be calculated for any segment of the trial by identifying a segment corresponding to an utterance as indicated by the speech wave form (see Appendix C for an example of the rotor performance display).

PRT Training

Participants were initially trained on the PRT to an asymptotic level of performance. An initial training speed was selected based on pilot testing. Starting speeds for young and older adults were .02 and .0075, respectively. These values correspond approximately to 1.2 and .75 revolutions per minute, respectively. Participants practiced tracking for 30 s and received feedback on their tracking performance. A "stair-case" training procedure was used to gradually increase tracking speed on successive 30-s trials: if TOT was 80% for a 30-s trial, the speed was increased by 10% for the next 30 s trial; if TOT was less than 80%, the speed was decreased by 5%. The "2 up-1 down" 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 ($M_Y = 23.8$, $SD_Y = 7.0$) than did older adults ($M_O = 16.1$, $SD_O = 4.3$), $p < .001$. Given their slower starting rate, the tracking speed was changed in smaller increments for the older adults, and therefore the older adults reached asymptotic levels more quickly than young adults. After training, the young adults' asymptotic tracking speed ($M_Y = .0344$, $SD_Y = 0.01$) was faster than the older adults' ($M_O = .0145$, $SD_O = 0.01$), $p < .001$. However, relative to starting speed, after training, older adults had improved 200% whereas the young adults had improved by 170% of their starting speed.

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 ($M_Y = 77.27$, $SD_Y = 3.54$; $M_O = 78.60$, $SD_O = 7.17$), $p = .295$. However, tracking error for young adults ($M_Y = 1.56$ pixels, $SD_Y = 0.68$) was significantly lower than that of the older adults ($M_O = 3.61$, $SD_O = 0.62$), $p < .001$. Therefore, when the participants were off target, older adults were off by a greater distance than young adults.

Talking Baseline

A talking baseline sample was collected from each participant. Participants were asked to answer the question, "What do you remember about 9/11? Where were you and what were you doing that morning?" Participants were instructed to answer the question as completely and fully as they could, and no time limit was given. These language samples were digitally recorded for later analysis.

Dual Task Conditions

Participants were asked to respond orally to a total of 6 questions, while engaged in the PRT. These questions were administered in two blocks of three questions each. The first block of dual-task trials had participants respond to the following questions: "Count backwards by 7s from 393," "Recite the alphabet over and over," and "Describe someone you admire and why you admire them." On these trials, participants first started tracking the rotating target; the questions appeared in the middle of the screen after either 1 revolution, or 1 min had passed, whichever came first. Then participants were asked to continue tracking while responding to the question for three minutes. The PRT program recorded a continuous record of TOT, error, and the speech sample.

A second block of dual-task trials was also administered. These trials were designed to compare the dual-task priorities of young and older adults. This set of three questions asked participants to answer the following thought-provoking questions: "Who was the greatest president of the USA and why?" "What was the most significant invention of the 20^{th} 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?" Three conditions were compared: equal emphasis on tracking and talking, emphasis on talking, and emphasis on talking.

The equal emphasis task was administered first and the order of the emphasize talking and emphasize tracking trials were counter-balanced across participants. The assignment of the questions to tasks was also counter-balanced across participants. With the exception of speech rates, the language samples collected during these 3 tasks were not examined as part of this thesis; this thesis is focused on the influence of dual-task priorities on rotor performance.

The directions given to participants 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. Ok?

When the participants were asked to emphasize talking, they had a chance to earn extra money to encourage them to focus on the language production task. The following directions were given:

> 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 one 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. Ok?

The average payoff for this payoff did not differ between the two age groups ($M_O = 19$, $SD_O = 4.8$; $M_Y = 19$, $SD_Y = 6.3$), $p = 0.83$. See Appendix D for a transcript and computation of the payoff amount.

Similarly, there was a reward for maintaining tracking performance when the participants were asked to emphasize tracking. The instructions given for the emphasize 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 (after 1 minute). 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. Ok?

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

Speech Rates

Language samples produced during each dual-task condition and the talking baseline condition were transcribed by an experienced coder; a second coder computed speech rates based on these transcripts. Speech rates were computed by taking three random samples from each transcript, such that each sample was at least 10 words in length and spanned several utterances. These samples were matched to the digital recording of the speech sample. The number of words in the sample was divided by the duration of the segment in seconds, then multiplied by 60 to obtain words per minute speech rate. The words per minute speech rates from each of the three samples were then averaged for each participant.

Results

A series of analyses compared rotor performance for the two age groups in each of the three dual-task conditions: alphabet repetition, backward 7 counting, and "admire" statement. Multivariate tests are first reported followed by univariate tests for each task. A second series of analyses examined the effect of task priorities of young and older adults on rotor performance.

Task Comparisons

A repeated measures analysis of variance (ANOVA) was used to compare rotor performance on the baseline condition and on the three dual-task conditions. An Age (young and older adults) x Task (tracking baseline, alphabet repetition, backwards 7 counting, and "admire" statement) ANOVA examined whether the two age groups responded to the 3 dual tasks differently compared to the tracking baseline condition using rotor TOT and error measures. For the TOT measure, there was a significant main effect of task, $F(3, 73) = 12.86$, $p < .001$, $\eta^2 = 0.35$ and a significant interaction between task and age, $F(3, 73) = 2.72$, $p = .05$, $\eta^2 = 0.10$ (see Appendix E). Simple contrasts revealed that the interaction between age group and TOT was significant. Simple contrasts within each age group indicated that both groups found the counting backward task to be more difficult than the other two tasks as indicated by reduced TOT. Young adults found reciting the

Table 1.

Means and standard deviations for Rotor TOT and error performance in baseline and 3 task conditions for both age groups.

	TOT		Error	
	M	*SD*	*M*	*SD*
Tracking Baseline				
Young Adults	77.27	3.54	1.56	0.68
Older Adults	78.60	7.17	3.61	0.62
Admire				
Young Adults	75.38	9.82	3.90	0.71
Older Adults	77.48	8.75	3.79	1.15
Count Back				
Young Adults	74.32	6.41	0.61	0.61
Older Adults	71.34	9.81	1.24	1.24
Alphabet				
Young Adults	76.02	5.24	0.45	0.45
Older Adults	75.79	10.15	0.93	0.93

alphabet to be the easiest task whereas older adults found producing an “admire” statement to be the easiest task (see Table 1) using the TOT measure.

A second repeated measures analysis of variance (ANOVA) compared the error rates. There was a significant main effect of task, $F(3, 72) = 96.90$, $p < .001$, $\eta^2 = 0.80$. See Appendix F and Table 1 for a summary. Simple contrasts revealed that the error was significantly different between the baseline and all three dual task conditions. Additionally, the interaction between age group and task was also significant between the baseline error and all three dual task conditions, $F(3, 72) = 60.92$, $p < .001$, $\eta^2 = 0.72$. Simple contrasts within each age group showed that the young adults had a lower error in the tracking baseline condition than in other conditions. They were much closer to the target during the baseline condition than in the talking and tracking conditions. In contrast, older adults’ error did not vary between the conditions.

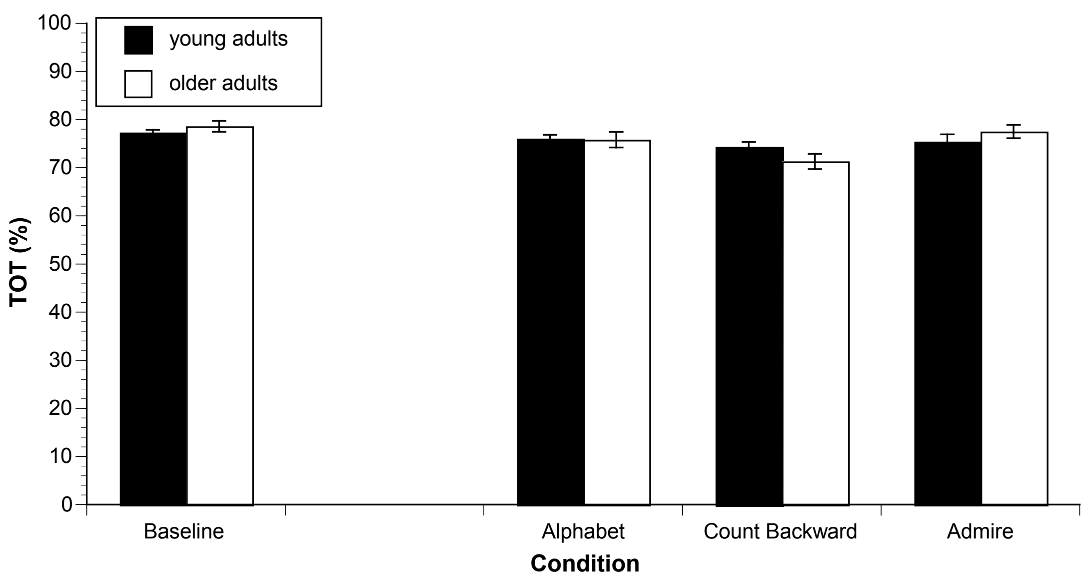

Figure 1. Mean TOT (+SE) for young (n=40) and older (n=40) adults in baseline and three dual task conditions.

There were no significant univariate effects of age group for either rotor performance measure. For the alphabet repetition task, the univariate effect of age group was not significant for the rotor TOT measure, $F(1, 77) = 0.02$, $p = 0.90$, $\eta^2 = 0.00$ nor for the rotor error measure, $F(1, 76) = 0.18$, $p = 0.68$, $\eta^2 = 0.00$. Similarly, in the backward 7 counting task, the univariate effect for age group was not significant for the rotor TOT measure, $F(1, 75) = 2.47$, $p = 0.12$, $\eta^2 = 0.03$ nor for the rotor error measure, $F(1, 74) = 1.97$, $p = 0.16$, $\eta^2 = 0.03$. Finally, for the "admire" statement task, neither the univariate effect for age group for the rotor TOT measure, $F(1, 78) = 1.02$, $p = 0.32$, $\eta^2 = 0.01$, nor for the rotor error measure, $F(1, 78) = 0.26$, $p = 0.61$, $\eta^2 = 0.00$ was significant (see Appendices K and L). Figures 1 and 2 summarize rotor performance for the two age groups in these dual task conditions.

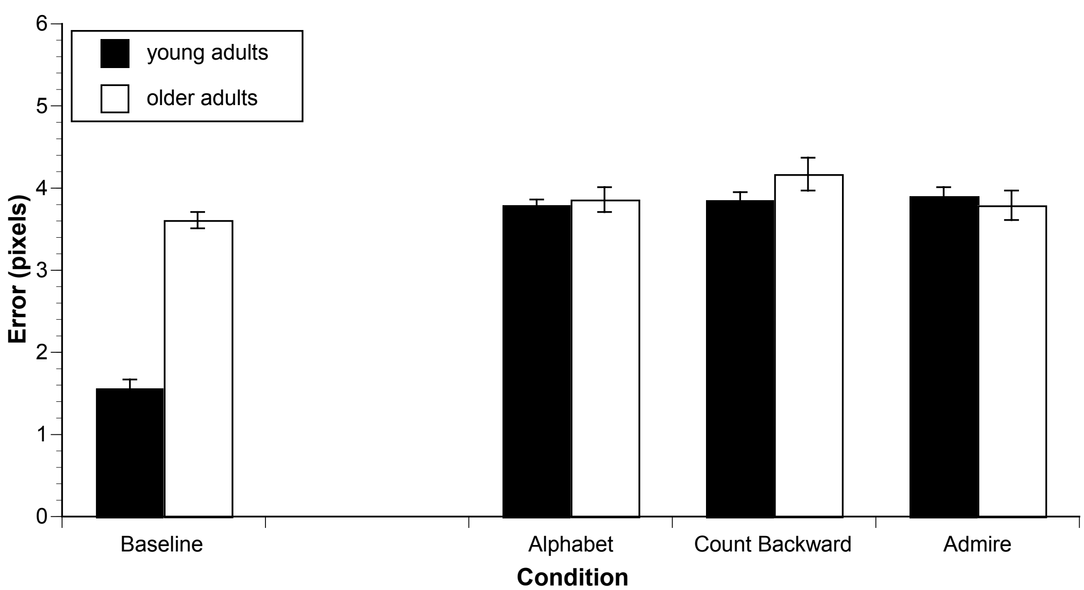

Figure 2. Mean Error (+SE) for young (n=40) and older (n=40) adults in baseline and three dual task conditions.

Table 2

Means and Standard Deviations for Speech Rates in all Conditions for Both Age Groups

	Young Adults		Older Adults	
	M	*SD*	*M*	*SD*
Speech Rates				
Talking Baseline 9/11 Statement	193	47	126	35
Admire Statement	155	36	121	34
Equal Emphasis	144	37	128	35
Emphasize Tracking	135	27	128	32
Emphasize Talking	159	44	128	36
Task Rate Measures				
Alphabet total letters repeated	685	206	497	178
Alphabet letters per minute	199	57	167	55
Count Backwards last number	87	176	191	101
Count Backwards counts per minute	14	7	10	5

On the alphabet repetition task, young adults repeated more letters than older adults $F(1, 78) = 18.96$, $p < .001$, $\eta^2 = 0.20$. Not surprisingly, younger adults produced more letters per minute than older adults $F(1, 78) = 6.37$, $p = .01$, $\eta^2 = 0.08$. On the backward 7 counting task, young adults reached a lower final number than older adults $F(1, 76) = 10.15$, $p = .002$, $\eta^2 = 0.12$. The lower final number indicates that the young adults counted backwards further from the starting number (393) than the older adults. Consequently, young adults counted more rapidly in counts per minute than older adults $F(1, 76) = 7.40$, $p = .008$, $\eta^2 = 0.09$. In the "admire" task, young adults again produced more words per minute than older adults $F(1, 78) = 18.26$, $p < .001$, $\eta^2 = 0.19$. In the baseline talking condition, young adults spoke more rapidly than the older adults $F(1, 78) = 53.31$, $p < .001$, $\eta^2 = 0.41$. See Table 2 and Appendices M and N for a summary of means and standard deviations.

Task Priorities

A repeated measures analysis of variance (ANOVA) was used to compare rotor performance on the three task priority tasks. An Age (young and older adults) x Priority (tracking baseline, equal emphasis, emphasis on talking, and emphasis on tracking) ANOVA examined whether the two age groups responded to the 3 tasks differently compared to the tracking baseline condition. For the TOT measure, there was a significant effect of task $F(3, 76) = 17.72$, $p < .001$, $\eta^2 = 0.41$ (see Appendix G). The interaction between task priority and age was not significant, $F(3, 76) = 2.12$, $p = .11$, $\eta^2 = 0.08$ (refer to Figure 3). Simple contrasts revealed that the TOT at baseline was significantly different from all of the task priority conditions. Both groups had the highest TOT performance

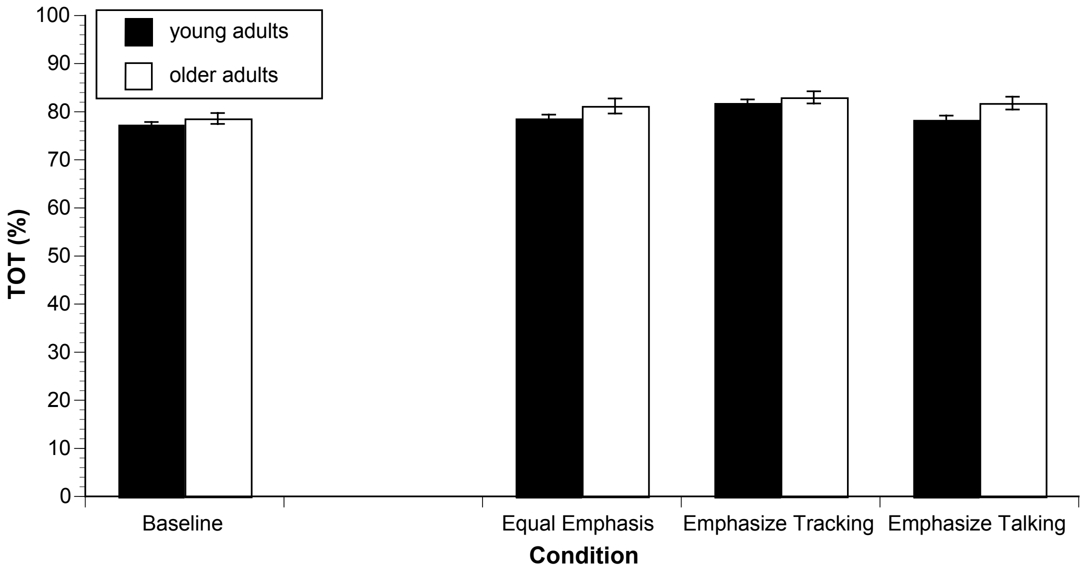

Figure 3. Mean TOT (+SE) for young (n=40) and older (n=40) adults in baseline and three dual task priority conditions.

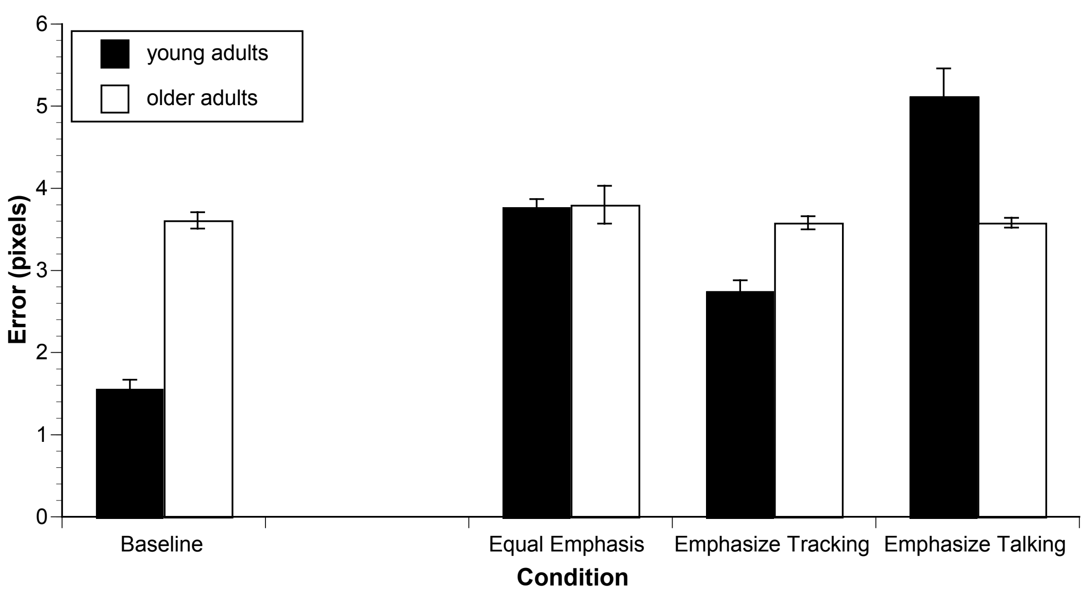

Figure 4. Mean Error (+SE) for young (n=40) and older (n=40) adults in baseline and three dual task priority conditions.

when asked to focus on tracking. Young adults had the lowest TOT accuracy when focusing on talking, while older adults had the lowest when asked to give both tasks equal emphasis. Note, however, that TOT's for both groups varied by 3 to 5% across conditions. See Table 3 for a summary.

A second repeated measures ANOVA for the task priorities compared the error rates. There was a significant main effect of task priority, $F(3, 75) = 74.52$, $p < .001$, $\eta^2 = 0.75$. This effect was modified by a significant age by task priority interaction, $F(3, 75) = 66.12$, $p < .001$, $\eta^2 = 0.73$ (see Appendix H). Simple contrasts revealed that the baseline error was significantly different from the error in all 3 priority conditions. Simple contrasts were used to examine the effect of condition within each age group. See the right portion of Figure 4. Task priority did not affect older adults' error across the three conditions whereas young adults allowed more tracking error when focusing on talking and less tracking error when focusing on tracking, compared to the equal emphasis condition.

The univariate tests for the equal emphasis condition indicated no significant age group differences in TOT performance, $F(1, 78) = 2.20$, $p = 0.14$, $\eta^2 = 0.03$, or in error, $F(1, 78) = 0.01$, $p = 0.93$, $\eta^2 = 0.00$. On the emphasis on tracking condition, the two groups did not differ in TOT performance, $F(1, 78) = 0.66$, $p = 0.42$, $\eta^2 = 0.01$. There was, however, a significant age group difference in error, $F(1, 78) = 28.62$, $p < 0.001$, $\eta^2 = 0.27$, in this condition, such that older adults allowed more tracking error than young adults. On the emphasis on talking condition, the two groups differed in TOT performance, $F(1, 78) = 4.93$, $p = 0.03$, $\eta^2 = 0.06$, such that young adults were "on task" less often than older adults. There was also a significant age group difference in error, $F(1, 78) = 20.42$, $p < 0.001$, $\eta^2 =$

0.21, in this condition such that older adults allowed less error than young adults (Refer to Appendices K and L).

Speech Rates

A repeated measures analysis of variance (ANOVA) was used to compare speech rates in all conditions. An Age (young and older adults) x task (talking baseline, "admire" statement, equal emphasis, emphasis on talking, and emphasis on tracking) ANOVA examined whether the two age groups differed in speech rates in all conditions relative to the baseline talking condition. For the speech rates, there was a significant effect of task $F(4, 74) = 7.61, p < .001, \eta^2 = 0.29$. The interaction between the task and age was also significant, $F(4, 74) = 7.38, p < .001, \eta^2 = 0.29$ (see Appendix I). Simple contrasts

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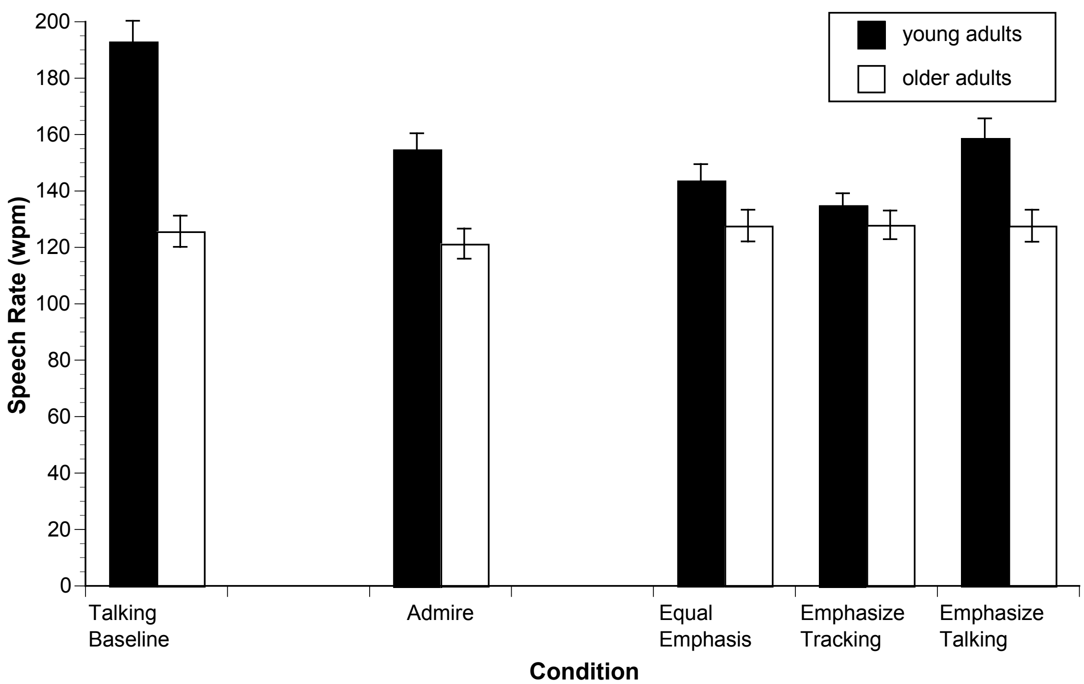

Figure 5. Mean Speech Rates (+SE) for young (n=40) and older (n=40) adults in talking baseline, "admire" statement, and 3 dual task priority conditions.

revealed that overall, the baseline condition was significantly different from all other conditions. However, the interaction indicates that young adults spoke faster in the baseline condition than in any other condition, whereas older adults' speech rates did not differ in any condition (see Figure 5).

Table 3

Means and standard deviations for Rotor TOT and error performance in tracking baseline and 3 task priority conditions for both age groups.

	TOT		Error	
	M	*SD*	*M*	*SD*
Tracking Baseline				
Young Adults	77.27	3.54	1.56	0.68
Older Adults	78.60	7.17	3.61	0.62
Equal Emphasis				
Young Adults	78.59	4.87	3.77	0.63
Older Adults	81.18	9.93	3.80	1.46
Emphasize Talking				
Young Adults	78.25	5.83	5.12	2.12
Older Adults	81.83	8.35	3.58	0.39
Emphasize Tracking				
Young Adults	81.83	4.68	2.75	0.85
Older Adults	83.02	7.99	3.58	0.49

The univariate tests for age group differences in these task priority condition indicated in the equal emphasis condition, the young adults had a marginally higher speech rate than older adults, $F(1, 77) = 3.86$, $p = .05$, $\eta^2 = 0.05$ (see Figure 5). In the emphasis on tracking condition, young adults spoke more slowly so that the two groups did not differ in speech rates, $F(1, 77) = 1.07$, $p = .31$, $\eta^2 = 0.01$. In the emphasis on talking condition, young adults spoke more rapidly than the older adults, $F(1, 77) = 11.92$, $p = .001$, $\eta^2 = 0.13$.

Discussion

One of the main objectives of this thesis was to validate the rotor as an appropriate measure to use in dual-task research. To be valid, performance on the rotor should parallel other established methodologies used in dual-task research such as walking and talking or talking and finger tapping. In the Kemper et al. (2003) dual task study, older adults' walking rates and speech rates were slower than young adults' in baseline assessments, just as the older adults' tracking rates and speech rates were slower than young adults' in baseline assessments in the present experiment. Additionally, both young and older adults exhibited some forms of dual-task costs in this research: both groups experienced some decreases in TOT in the alphabet repetition and backward 7 counting dual-task conditions compared to the baseline. Young adults also experienced a decline in TOT in the admire dual-task condition and an increase in tracking error in all 3 dual task conditions compared to the baseline whereas older adults did not.

Concurrent task demands affect the speech rates and rotor performance in dual-task situations but do so differently for the young and older adults. Young adults accommodated the dual task demands partly by slowing their speech rates in all conditions compared to their talking baseline rate. Older adults, on the other hand, kept their speech rate constant across conditions, even though it was slower than the young adults' in almost every condition. The young adults recited the alphabet, counted backwards by 7, and talked faster than the older adults in these conditions. For both groups, TOT performance was the worst for the backward 7 condition, supporting the subjective view that this is a very demanding task. TOTs for older adults were best when they were producing the "admire" statement, whereas young adults' TOTs were best when reciting the alphabet. These two tasks could have differential effects on young and older adults since the young adults were undergraduate or graduate students accustomed to the rote repetition of learned information, whereas for older adults rote recitation may be less common and less practiced than oral discourse.

Task priority effects also differ somewhat for young and older adults. Older adults' tracking error performance was relatively unaffected by the task priorities, whereas varying task priorities affects young adults' error measures. TOTs for neither group varied with task priority. Young adults' tracking error increased in the emphasize talking condition and decreased in the emphasize tracking condition, relative to the equal emphasis condition. This demonstrates that while focusing on talking, the young adults allowed themselves to drift further from the target. However, when focusing on tracking, the young adults kept much closer to the target. It appears that the older adults did not change their strategy for accommodating the demands of the simultaneous tasks in response to the differential pay-offs for talking and tracking, whereas young adults changed their strategies in response to the pay-offs. It may be that the monetary pay-offs were insufficient to motivate the older adults to vary their tracking performance.

Speech rates were also affected by dual-task demands, but somewhat differently for young and older adults. The young adults slowed their speech from baseline in all conditions in order to allow them to accommodate to the concurrent task demands. Young adults talked faster in the emphasize talking condition and slower in the emphasize tracking condition (see Figure 5). Older adults' speech rates, on the other hand, did not vary from baseline in the admire or task priority conditions. This suggests that the older adults may have already slowed their speech to accommodate the simultaneous demands of everyday life and further reductions in speech rates may not be possible without disruption of other aspects of language production.

All of these findings validate the rotor as an appropriate measure for dual-task research. The results are parallel to what we see in other dual-task research, although young adults and older adults appeared to differ in their strategies to meet the dual-task demands. Some questions remain: would increasing the monetary pay-offs or using other forms of motivation result in varying task priorities for older adults? Would further increasing dual-task demands affect older adults' speech rates? It may be that older adults will not be able to maintain dual task performance when processing demands are increased by speeding up the pursuit rotor.

The rotor has several advantages over other dual-task measures: It is not inherently risky unlike walking or balance tasks. Older adults are already prone to falling and this risk increase when they are pushed to walk faster or traverse a more difficult course. The rotor task is also challenging, unlike finger tapping tasks, and both young and older participants found it to be enjoyable and engaging. It can be combined with a wide range of concurrent tasks and is apparently differentially sensitive to the demands of these tasks. The rotor task is also portable and can therefore be used in diverse settings and with other populations, such as older adults with physical limitations. It may also be suitable for use with older adults with cognitive or physical impairments as individuals can be trained relatively quickly on this task and it can be performed using a variety of computer-controlled devices.

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Appendix A

INFORMED CONSENT STATEMENT

Tracking Language Production
Language Across the Life Span Study
Gerontology Center, University of Kansas

INTRODUCTION

The Gerontology Center at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE OF THE STUDY

We are interested in how people talk. We are especially interested in how aging and health can affect speaking and listening. We are asking you to participate in a series of studies of talking. Our goal is a very simple one, to see if the difficulty of the talking tasks affects your ability to do two things at once. While you are talking, we will ask you to play a computer "game" by tracking a moving object. We have previously found that talking is affected by simultaneous task demands such as walking versus tapping a finger. Now we want to measure how talking affects your perceptual-motor coordination and your ability to "do two things at once".

PROCEDURES

First we will ask you some questions about yourself and your background. We will ask you to take a series of short tests to assess your cognitive ability. We will also allow you to practice our computer game that requires you to track a objecting moving around the computer screen. Then we will ask you to participate in a short series of "talking and tracking" tasks. We will pose a series of questions and ask you to respond orally to the questions; at the same time, you'll be playing our computer game. Most of the questions concern your likes and dislikes or personal experiences. Sometimes we will simply ask you to repeat the alphabet or perform other simple tasks. We will record your answers and monitor your performance on the computer game. The tasks will take approximately 2 hours today.

RISKS

There are no risks associated with this research. If you get tired, please ask for a break to sit quietly or walk around.

BENEFITS

There are no direct benefits to your for participating. However, we hope that this research will advance our understanding of why older adults are vulnerable to task coordination problems such as "doing two things at once."

PAYMENT TO PARTICIPANTS

You will be paid $10 per hour for participating. In addition you can earn some bonuses based on your performance. Payment is not contingent on your completing all of the tasks. You will be paid for your participation at the end of each days' tasks. Investigators may ask for your social security number in order to comply with federal and state tax and accounting regulations.

INFORMATION TO BE COLLECTED

To perform this study, we will collect a variety of information about you. This information will be obtained from: a short interview about your personal history and education, and your ability to perform a number of cognitive tasks including tests of working memory, verbal ability, and problem solving. Also, information will be collected from the study activities that are listed in the Procedures section of this consent form, including your response to the questions about your personal experiences and likes and dislikes. You may refuse to answer any question if you find it too personal or intrusive.

Your name will not be associated in any way with the information collected about you or with the research findings from this study. We will use a study number or a pseudonym instead of your name for all tests, questionnaires, audio and video tapes, transcripts, and data files. All recordings will be kept under lock-and-key in a secure location.

The information collected about you will be used by: Dr. Kemper, members of the Language across the Life Span research group, investigators with the Center for Biobehavioral Neuroscience in Communication Disorders, the KU Center for Research, and with officials at KU that oversee research, including committees and offices that review and monitor research studies.

In addition, Dr. Kemper and her team may share the information gathered in this study, including your information, with: collaborating researchers, professional colleagues, representatives of the National Institute of Aging or other federal research agencies for purposes of scientific dissemination, education, or data sharing. Some persons or groups that receive your information may not be required to comply with the Health Insurance Portability and Accountability Act's privacy regulations, and your information may lose this federal protection if those persons or groups disclose it.

The researchers will not share information about you with anyone not specified above unless required by law or unless you give written permission.

Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your information for purposes of this study at any time in the future.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about you, in writing, at any time, by sending your written request to: Susan Kemper, Gerontology Center, 3090 Dole Building, 1000 Sunnyside Ave. University of Kansas, Lawrence, KS 66045. If you cancel permission to use your information, the researchers will stop collecting additional information about you. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

PARTICIPANT CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study and the use and disclosure of information about me for the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7563, email dhann@ku.edu.

I agree to take part in this study as a research participant. I further agree to the uses and disclosures of my information as described above. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_______________________________ _____________________
Type/Print Participant's Name Date

____
Participant's Signature

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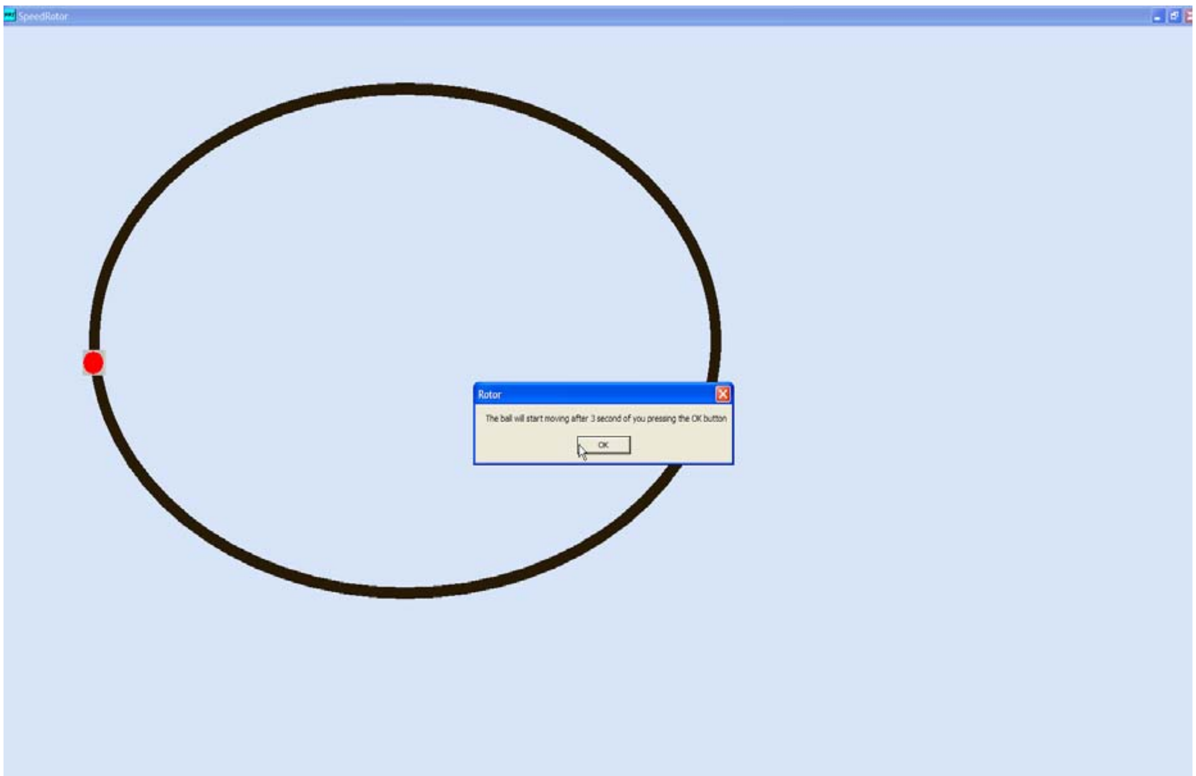
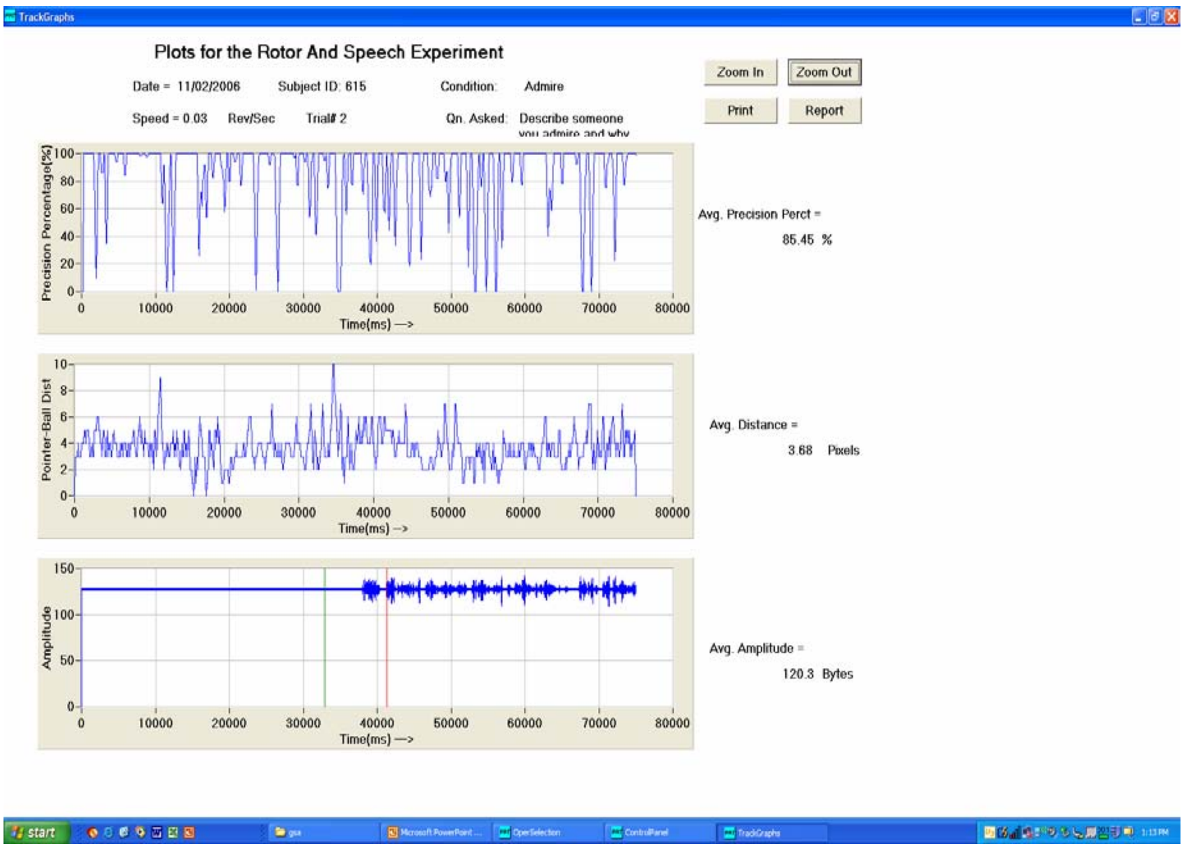
Appendix B

Picture of rotor display with start command.



Appendix C

Display of rotor performance graphs. TOT is on the top, error is in the middle, and the speech wav form is on the bottom.



Appendix D

Transcript of older participant answering the question "Who was the greatest president and why?" in the emphasize talking condition. Payoff dollar amounts are in the parenthesis at the end of the utterances.

```
O Who was the greatest president of the USA and why?
O Well, I would have to say AbrahamLincoln. (1)
O Because he was so^
O Had such, such great intuition of doing [RIGHT] what was supposed to
done^ (1)
O He had so many much^
O Difficulty throughout his entire presidency but came through with
flying colors^ (1)
O And^
O Kept the UnitedStates as one instead of two^ (1)
O Instead of a separate^
O Abolished slavery as, as a result which was his main thing that he^ (1)
O What he was after^
O And^
O Was a^
O A great lawyer all over all^ (1)
O But more of a common man than he was any, anything else I think^ (1)
O At least in what I've read about him^
O So, so^
O He was^
O He was of course an attorney before he became president. (1)
O He also served some time in the^
O In, in the legislature before he became president^ (1)
O But of course, he was assassinated. (1)
O By a person named JohnWilkesBooth^
O And^
O Booth was finally caught although it^ (1)
O And that was at the FordTheatre in, in WashingtonDC on some evening
that they were watching a play. (3)
O A comedy^
O And JohnWilkesBooth jumped from the^ (1)
O From the loges where the president onto the stage and broke his leg^
O And^
O And they^
O The story goes that at least history says that he was caught in a barn
not too far from^(1)
O From, from the capital so^
O And of course, the president lingered for a short time after being
shot. (1)
O But passed away within a few hours^
O I think^
O And of course, a guy that name of^
O The vicepresident at that time was AndrewJohnson.
O That he took his place^ (1)
O And^
O Had, had more trouble than, than was^
```

O Than he anticipated for sure so^ (1)
O But^
O I would say that AbrahamLincoln was certainly the number one as far as I'm concerned allthough there were several others that, that might come awful close. (1)
O HarryTruman is one of 'em.
O RonaldReagan is another one.
O In, in my opinion so^

Appendix E

MANOVA tables for TOT in 3 task conditions:

Descriptive Statistics:

	agegroup	Mean	Std. Deviation	N
Accuracy 4 minutes	1.00	77.2521	3.60302	38
	2.00	78.4869	7.22185	39
	Total	77.8775	5.72571	77
Admire accuracy	1.00	75.5037	9.99858	38
	2.00	77.2674	8.75461	39
	Total	76.3970	9.36909	77
Alphabet accuracy	1.00	76.040	5.3057	38
	2.00	75.623	10.2244	39
	Total	75.829	8.1252	77
Back 7 accuracy	1.00	74.318	6.4072	38
	2.00	71.343	9.8082	39
	Total	72.811	8.3861	77

factor1	Dependent Variable
1	acc4min
2	admac
3	alphaacc
4	back7acc

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Observed Power(a)
factor1	Pillai's Trace	.346	12.862(b)	3.000	73.000	.000	1.000
	Wilks' Lambda	.654	12.862(b)	3.000	73.000	.000	1.000
	Hotelling's Trace	.529	12.862(b)	3.000	73.000	.000	1.000
	Roy's Largest Root	.529	12.862(b)	3.000	73.000	.000	1.000
factor1 * agegroup	Pillai's Trace	.101	2.724(b)	3.000	73.000	.050	.639
	Wilks' Lambda	.899	2.724(b)	3.000	73.000	.050	.639
	Hotelling's Trace	.112	2.724(b)	3.000	73.000	.050	.639
	Roy's Largest Root	.112	2.724(b)	3.000	73.000	.050	.639

a Computed using alpha = .05 b Exact statistic c Design: Intercept+agegroup
Within Subjects Design: factor1

Tests of Within-Subjects Contrasts

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
factor1	Level 2 vs. Level 1	169.535	1	169.535	2.701	.104	.368
	Level 3 vs. Level 1	319.753	1	319.753	6.303	.014	.698
	Level 4 vs. Level 1	1954.842	1	1954.842	37.946	.000	1.000
factor1 * agegroup	Level 2 vs. Level 1	5.385	1	5.385	.086	.770	.060
	Level 3 vs. Level 1	52.543	1	52.543	1.036	.312	.171
	Level 4 vs. Level 1	340.988	1	340.988	6.619	.012	.719
Error(factor1)	Level 2 vs. Level 1	4706.716	75	62.756			
	Level 3 vs. Level 1	3804.620	75	50.728			
	Level 4 vs. Level 1	3863.770	75	51.517			

Measure: MEASURE_1
a Computed using alpha = .05

Appendix F

MANOVA tables for Error in 3 task conditions

Descriptive Statistics

	agegroup	Mean	Std. Deviation	N
Error 4 minutes	1.00	1.56135	.699397	37
	2.00	3.61513	.625846	39
	Total	2.61526	1.225181	76
Admire error	1.00	3.8222	.56018	37
	2.00	3.8038	1.15950	39
	Total	3.8128	.91208	76
Alphabet error	1.00	3.788	.4594	37
	2.00	3.873	.9366	39
	Total	3.832	.7400	76
Back 7 error	1.00	3.854	.6080	37
	2.00	4.171	1.2375	39
	Total	4.016	.9893	76

factor1	Dependent Variable
1	err4min
2	admerr
3	alphaerr
4	back7err

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Observed Power(a)
factor1	Pillai's Trace	.801	96.901(b)	3.000	72.000	.000	1.000
	Wilks' Lambda	.199	96.901(b)	3.000	72.000	.000	1.000
	Hotelling's Trace	4.038	96.901(b)	3.000	72.000	.000	1.000
	Roy's Largest Root	4.038	96.901(b)	3.000	72.000	.000	1.000
factor1 * agegroup	Pillai's Trace	.717	60.915(b)	3.000	72.000	.000	1.000
	Wilks' Lambda	.283	60.915(b)	3.000	72.000	.000	1.000
	Hotelling's Trace	2.538	60.915(b)	3.000	72.000	.000	1.000
	Roy's Largest Root	2.538	60.915(b)	3.000	72.000	.000	1.000

a Computed using alpha = .05 b Exact statistic c Design: Intercept+agegroup
Within Subjects Design: factor1

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
factor1	Level 2 vs. Level 1	113.925	1	113.925	198.264	.000	1.000
	Level 3 vs. Level 1	117.219	1	117.219	131.417	.000	1.000
	Level 4 vs. Level 1	153.984	1	153.984	119.196	.000	1.000
factor1 * agegroup	Level 2 vs. Level 1	81.521	1	81.521	141.872	.000	1.000
	Level 3 vs. Level 1	73.558	1	73.558	82.467	.000	1.000
	Level 4 vs. Level 1	57.290	1	57.290	44.347	.000	1.000
Error(factor1)	Level 2 vs. Level 1	42.521	74	.575			
	Level 3 vs. Level 1	66.005	74	.892			
	Level 4 vs. Level 1	95.598	74	1.292			

a Computed using alpha = .05

Appendix G

MANOVA tables for TOT priority conditions

Descriptive Statistics

	agegroup	Mean	Std. Deviation	N
Accuracy 4 minutes	1.00	77.2720	3.54108	40
	2.00	78.6043	7.16718	40
	Total	77.9381	5.65674	80
Equal accuracy	1.00	78.5903	4.86573	40
	2.00	81.1823	9.92828	40
	Total	79.8862	7.87720	80
Talk accuracy	1.00	78.2525	5.82690	40
	2.00	81.8280	8.35490	40
	Total	80.0402	7.37959	80
Track accuracy	1.00	81.8307	4.68122	40
	2.00	83.0240	7.99355	40
	Total	82.4274	6.53626	80

task_priority	Dependent Variable
1	acc4min
2	eqac
3	talkac
4	trackac

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Observed Power(a)
task_priority	Pillai's Trace	.412	17.721(b)	3.000	76.000	.000	1.000
	Wilks' Lambda	.588	17.721(b)	3.000	76.000	.000	1.000
	Hotelling's Trace	.700	17.721(b)	3.000	76.000	.000	1.000
	Roy's Largest Root	.700	17.721(b)	3.000	76.000	.000	1.000
task_priority * agegroup	Pillai's Trace	.077	2.117(b)	3.000	76.000	.105	.521
	Wilks' Lambda	.923	2.117(b)	3.000	76.000	.105	.521
	Hotelling's Trace	.084	2.117(b)	3.000	76.000	.105	.521
	Roy's Largest Root	.084	2.117(b)	3.000	76.000	.105	.521

a Computed using alpha = .05 b Exact statistic c Design: Intercept+agegroup
Within Subjects Design: task_priority

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	task_priority	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
task_priority	Level 2 vs. Level 1	303.615	1	303.615	8.463	.005	.819
	Level 3 vs. Level 1	353.514	1	353.514	8.101	.006	.803
	Level 4 vs. Level 1	1612.269	1	1612.269	42.212	.000	1.000
task_priority * agegroup	Level 2 vs. Level 1	31.739	1	31.739	.885	.350	.153
	Level 3 vs. Level 1	100.643	1	100.643	2.306	.133	.323
	Level 4 vs. Level 1	.386	1	.386	.010	.920	.051
Error(task_priority)	Level 2 vs. Level 1	2798.161	78	35.874			
	Level 3 vs. Level 1	3403.980	78	43.641			
	Level 4 vs. Level 1	2979.212	78	38.195			

Appendix H

MANOVA tables for Error priority conditions

Descriptive Statistics

	agegroup	Mean	Std. Deviation	N
Error 4 minutes	1.00	1.56333	.681184	39
	2.00	3.60725	.619777	40
	Total	2.59823	1.214800	79
equal error	1.00	3.7780	.63831	39
	2.00	3.7965	1.45717	40
	Total	3.7874	1.12261	79
Talk error	1.00	5.1572	2.13317	39
	2.00	3.5803	.38744	40
	Total	4.3587	1.70923	79
Track error	1.00	2.7305	.84806	39
	2.00	3.5783	.49370	40
	Total	3.1597	.80882	79

task_priority	Dependent Variable
1	err4min
2	eqerr
3	talkerr
4	trackerr

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Observed Power(a)
task_priority	Pillai's Trace	.749	74.518(b)	3.000	75.000	.000	1.000
	Wilks' Lambda	.251	74.518(b)	3.000	75.000	.000	1.000
	Hotelling's Trace	2.981	74.518(b)	3.000	75.000	.000	1.000
	Roy's Largest Root	2.981	74.518(b)	3.000	75.000	.000	1.000
task_priority * agegroup	Pillai's Trace	.726	66.115(b)	3.000	75.000	.000	1.000
	Wilks' Lambda	.274	66.115(b)	3.000	75.000	.000	1.000
	Hotelling's Trace	2.645	66.115(b)	3.000	75.000	.000	1.000
	Roy's Largest Root	2.645	66.115(b)	3.000	75.000	.000	1.000

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	task_priority	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
task_priority	Level 2 vs. Level 1	114.116	1	114.116	131.334	.000	1.000
	Level 3 vs. Level 1	251.227	1	251.227	111.789	.000	1.000
	Level 4 vs. Level 1	25.581	1	25.581	33.847	.000	1.000
task_priority * agegroup	Level 2 vs. Level 1	81.010	1	81.010	93.233	.000	1.000
	Level 3 vs. Level 1	258.891	1	258.891	115.199	.000	1.000
	Level 4 vs. Level 1	28.255	1	28.255	37.384	.000	1.000
Error(task_priority)	Level 2 vs. Level 1	66.905	77	.869			
	Level 3 vs. Level 1	173.045	77	2.247			
	Level 4 vs. Level 1	58.196	77	.756			

Appendix I

MANOVA tables for speech rates

Descriptive Statistics

	AGEGROUP	Mean	Std. Deviation	N
Speech rate 911	1.00	191.9400	46.76898	39
	2.00	125.7358	34.90376	40
	Total	158.4189	52.76726	79
Speech rate Admire	1.00	154.1600	36.54740	39
	2.00	121.3035	33.63469	40
	Total	137.5238	38.59639	79
Speech rate Equal Pay	1.00	143.6479	36.67837	39
	2.00	127.7057	35.40637	40
	Total	135.5759	36.69539	79
Speech rate Pay talk	1.00	158.7224	43.68204	39
	2.00	127.7043	35.88229	40
	Total	143.0170	42.62561	79
Speech rate Pay track	1.00	134.9010	26.82135	39
	2.00	128.0120	32.14761	40
	Total	131.4129	29.65162	79

task	Dependent Variable
1	Sprate911
2	SprateAdm
3	SprateEqP
4	SpratePta
5	SpratePtr

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Observed Power(a)
task	Pillai's Trace	.291	7.609(b)	4.000	74.000	.000	.996
	Wilks' Lambda	.709	7.609(b)	4.000	74.000	.000	.996
	Hotelling's Trace	.411	7.609(b)	4.000	74.000	.000	.996
	Roy's Largest Root	.411	7.609(b)	4.000	74.000	.000	.996
task * AGEGROUP	Pillai's Trace	.285	7.376(b)	4.000	74.000	.000	.995
	Wilks' Lambda	.715	7.376(b)	4.000	74.000	.000	.995
	Hotelling's Trace	.399	7.376(b)	4.000	74.000	.000	.995
	Roy's Largest Root	.399	7.376(b)	4.000	74.000	.000	.995

a Computed using alpha = .05 b Exact statistic c Design: Intercept+AGEGROUP
Within Subjects Design: task

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	task	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power(a)
task	Level 2 vs. Level 1	35186.438	1	35186.438	17.650	.000	.986
	Level 3 vs. Level 1	42371.518	1	42371.518	13.753	.000	.956
	Level 4 vs. Level 1	19282.919	1	19282.919	5.258	.025	.620
	Level 5 vs. Level 1	59220.041	1	59220.041	22.163	.000	.996
task * AGEGROUP	Level 2 vs. Level 1	21959.962	1	21959.962	11.015	.001	.906
	Level 3 vs. Level 1	49886.013	1	49886.013	16.192	.000	.978
	Level 4 vs. Level 1	24447.812	1	24447.812	6.666	.012	.722
	Level 5 vs. Level 1	69475.373	1	69475.373	26.002	.000	.999
Error(task)	Level 2 vs. Level 1	153508.453	77	1993.616			
	Level 3 vs. Level 1	237233.932	77	3080.960			
	Level 4 vs. Level 1	282403.073	77	3667.572			
	Level 5 vs. Level 1	205741.236	77	2671.964			

a Computed using alpha = .05

Appendix J

ANOVA: Descriptive Tests

		Sum of Squares	df	Mean Square	F	Sig.
Age in years	Between Groups	55230.050	1	55230.050	2356.772	.000
	Within Groups	1827.900	78	23.435		
	Total	57057.950	79			
Education in Number of years	Between Groups	14.878	1	14.878	1.890	.173
	Within Groups	613.994	78	7.872		
	Total	628.872	79			
Number of Training trials	Between Groups	1162.813	1	1162.813	34.436	.000
	Within Groups	2633.875	78	33.768		
	Total	3796.687	79			
Speed 4 minute	Between Groups	.008	1	.008	124.929	.000
	Within Groups	.005	78	.000		
	Total	.013	79			
Amount of money received for talking emphasis	Between Groups	1.512	1	1.512	.049	.826
	Within Groups	2429.675	78	31.150		
	Total	2431.187	79			
Amont of money received for tracking emphasis	Between Groups	11.250	1	11.250	.442	.508
	Within Groups	1987.500	78	25.481		
	Total	1998.750	79			

ANOVA: Cognitive Tests

		Sum of Squares	df	Mean Square	F	Sig.
Digits Forward	Between Groups	30.012	1	30.012	7.140	.009
	Within Groups	327.875	78	4.204		
	Total	357.888	79			
Digits Backward	Between Groups	36.450	1	36.450	7.247	.009
	Within Groups	392.300	78	5.029		
	Total	428.750	79			
Shipley's Vocabulary Score	Between Groups	177.013	1	177.013	18.156	.000
	Within Groups	760.475	78	9.750		
	Total	937.488	79			
Stroop Test	Between Groups	7527.200	1	7527.200	48.551	.000
	Within Groups	12093.000	78	155.038		
	Total	19620.200	79			
Stroop Test- Color	Between Groups	12251.250	1	12251.250	110.700	.000
	Within Groups	8632.300	78	110.671		
	Total	20883.550	79			
stroop proportional difference score	Between Groups	.364	1	.364	33.049	.000
	Within Groups	.859	78	.011		
	Total	1.223	79			
Digit Symbol	Between Groups	1702.012	1	1702.012	67.162	.000
	Within Groups	1976.675	78	25.342		
	Total	3678.687	79			
Reading Span	Between Groups	.153	1	.153	.022	.881
	Within Groups	530.969	78	6.807		
	Total	531.122	79			

Appendix K

ANOVA tables for TOT

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Accuracy 4 minutes	Between Groups	35.498	1	35.498	1.111	.295
	Within Groups	2492.401	78	31.954		
	Total	2527.899	79			
Admire accuracy	Between Groups	87.927	1	87.927	1.017	.316
	Within Groups	6743.042	78	86.449		
	Total	6830.970	79			
Equal accuracy	Between Groups	134.369	1	134.369	2.198	.142
	Within Groups	4767.600	78	61.123		
	Total	4901.969	79			
Talk accuracy	Between Groups	255.684	1	255.684	4.929	.029
	Within Groups	4046.529	78	51.879		
	Total	4302.213	79			
Track accuracy	Between Groups	28.477	1	28.477	.664	.418
	Within Groups	3346.616	78	42.905		
	Total	3375.093	79			
Back 7 accuracy	Between Groups	170.265	1	170.265	2.468	.120
	Within Groups	5174.578	75	68.994		
	Total	5344.843	76			
Alphabet accuracy	Between Groups	1.070	1	1.070	.016	.899
	Within Groups	5057.494	77	65.682		
	Total	5058.564	78			

Appendix L

ANOVA tables for Error

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Error 4 minutes	Between Groups	82.494	1	82.494	194.769	.000
	Within Groups	32.613	77	.424		
	Total	115.108	78			
Admire error	Between Groups	.237	1	.237	.259	.613
	Within Groups	71.358	78	.915		
	Total	71.595	79			
equal error	Between Groups	.009	1	.009	.007	.931
	Within Groups	98.309	78	1.260		
	Total	98.319	79			
Talk error	Between Groups	47.386	1	47.386	20.422	.000
	Within Groups	180.985	78	2.320		
	Total	228.371	79			
Track error	Between Groups	13.728	1	13.728	28.621	.000
	Within Groups	37.413	78	.480		
	Total	51.142	79			
Back 7 error	Between Groups	1.905	1	1.905	1.971	.164
	Within Groups	71.497	74	.966		
	Total	73.401	75			
Alphabet error	Between Groups	.096	1	.096	.176	.676
	Within Groups	41.313	76	.544		
	Total	41.408	77			

Appendix M

ANOVA tables for Speech Rates

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Speech rate 911	Between Groups	90381.888	1	90381.888	53.305	.000
	Within Groups	132254.313	78	1695.568		
	Total	222636.202	79			
Speech rate Admire	Between Groups	22321.659	1	22321.659	18.260	.000
	Within Groups	95351.705	78	1222.458		
	Total	117673.364	79			
Speech rate Equal Pay	Between Groups	5018.705	1	5018.705	3.864	.053
	Within Groups	100012.322	77	1298.861		
	Total	105031.026	78			
Speech rate Pay talk	Between Groups	18998.935	1	18998.935	11.921	.001
	Within Groups	122722.593	77	1593.800		
	Total	141721.528	78			
Speech rate Pay track	Between Groups	937.142	1	937.142	1.067	.305
	Within Groups	67641.906	77	878.466		
	Total	68579.047	78			

Appendix N

ANOVA tables for Dual Task Rate Measures

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Alphabet repetitions- number of letters	Between Groups	703500.05	1	703500.050	18.958	.000
	Within Groups	2894493.9	78	37108.896		
	Total	3597993.9	79			
Alphabet- letters per minute	Between Groups	20308.20	1	20308.202	6.373	.014
	Within Groups	248549.73	78	3186.535		
	Total	268857.94	79			
Counting backward 7s Last number	Between Groups	212178.33	1	212178.334	10.149	.002
	Within Groups	1588862.5	76	20906.086		
	Total	1801040.8	77			
Counting backward 7s Number per minute	Between Groups	291.669	1	291.669	7.396	.008
	Within Groups	2997.202	76	39.437		
	Total	3288.871	77			