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Some Performance Effects of Age and Low Blood Alcohol Levels on a Computerized Neuropsychological Test

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INTRODUCTION

Age

A large body of literature associates quantitative changes in information processing speed with the cognitive reductions attributed to aging. This literature indicates that the perceived cognitive reduction is perhaps more an issue of processing speed rather than an actual cognitive deficit (Cerella, 1985, 1990; Hale, Myerson, & Wagstaff, 1987; Myerson, Hale Wagstaff, Poon, & Smith, 1990; Salthouse, 1985, 1991; Myerson & Hale, 1993). Some of the differences reported in simple reaction times from one task to another are accounted for by the nature of the task; however, in all psychomotor functioning tasks, age differences are apparent to some extent. This tendency is not restricted to a particular sensory modality or to a specific psychomotor response. (Davies, Taylor, & Dorn, 1992).

Cerella (1985) reviewed 35 studies on the decline in cognitive functioning in older age, comparing subjects 60 years and older with those below 60 years of age. His meta analysis demonstrated a slowing of sensory-motor processes, but found that it was less severe than the slowing of higher order processes. In a recent study, Salthouse (1991) demonstrated that, even though some differences in cognitive performance may be due to decreases in working memory, many age differences are seen largely due to reductions in the speed to carry out simple elementary processing operations. This contention was further supported by Hale, Lima, and Myerson (1991) in their study showing that older adults evidenced slower choice reaction times than younger adults.

Additionally, Lima, Hale, and Myerson (1991) reported that as task complexity increased so did the reaction times of older adults. Older adults were found to be slower than younger adults when performing non-lexical tasks, and the decrement doubled on lexical tasks.

Birren (1974) attributed mental processing time decrements to a basic neural slowing in the central brain mechanism, which results in a slowing of certain mental processes. Spiruduso and Clifford (1978) found an exception to this generalization, in that physically active older men (age 50-70) had both faster reaction times than their age cohorts, who were sedentary, and reaction times that were comparable to, or better than, those of sedentary college students in their twenties. As well, physical fitness training of older adults has produced improved psychomotor reaction times (Spiruduso & MacRae, 1990). These studies support the contention made by Birren (1974) that the slowing in mental processing is directly proportional to increases in blood pressure, regardless of age. That is, people with higher blood pressure tend to respond slower than those with lower blood pressure.

Alcohol

Although few studies in the alcohol literature have included an age variable in their research designs, alcohol has been demonstrated to increase the performance decrements of older aged subjects in our laboratory (Collins & Mertens, 1991). Other studies have also indicated that alcohol has a more profound effect on older individuals (Linnoila, Erwin, Ramm, and Cleveland, 1980; Morrow, Leirer, and Yesavage, 1990).

Collins and Mertens (1991) demonstrated an age by alcohol interactive effect in their study of two groups of male subjects, ages 30-39 and 60-69 years old using a multi-task instrument. Subjects attained mean peak blood alcohol concentrations (BACs) of .088%. Older age subjects performed more poorly under alcohol conditions than did the younger age group on all but one task presented. They also exhibited more performance decrements under high work load demand than did the younger subjects.

In a study comparing men, all light to moderate drinkers, of age 25 to 30 with those 35 to 40 years old, at BACs of .05, .08, and .12%, Linnoila et al. (1980) demonstrated significant age and alcohol effects but no significant age by alcohol interaction (p< .057). With only 10 subjects per group they believed the study lacked sufficient power to demonstrate a significant interaction. Since their age by alcohol interaction trend was strong (p< .057), t-tests were performed between the two groups and yielded a significant difference in performance at placebo, .05, and .08% BACs. They concluded that "age and alcohol have a deleterious synergistic effect on tracking performance" (p.494).

Morrow et al. (1990) tested non alcoholic social drinking male pilots to determine if age and alcohol would produce significant impairment differences between older subjects (mean age 42.1) and younger subjects (mean age 25.3) at .04 and .10% BAC, during simulator flights. The results of that study indicated that some aspects of performance (e.g., heading errors) did not appear to be significantly impacted by alcohol; however, there was an increase in altitude errors and in a combined-variable summary score for performance errors. These differences were more prominent for older subjects. In a later study, Morrow, Yesavage, Leirier, Dolhert, Taylor, and Tinkenberg (1993) failed to replicate the age related differences in performance.

Of particular interest were the effects of low doses of alcohol and their interaction with age. The eight-hour "bottle to throttle" rule has long governed behavior of the general aviation pilot with respect to alcohol consumption and flying. In 1985, Part 91 of the Federal Air Regulations (FAR) was modified to include a rule that no one could act or attempt to act as an air crew member with a blood alcohol concentration of 0.04% or higher. A year later, the regulation was modified to include an "implied consent" provision, under which the crew member is required to submit to an alcohol test when requested by a law enforcement official. One possible shortcoming of this regulation is that it may imply to some pilots that it is safe to fly with a BAC that is not higher than 0.04%. Despite the existence of these regulations, a recent postmortem inquiry found that 9.8% of general aviation fatal accidents during 1993 involved pilots with a BAC of 0.04% or higher (personal communication with Dr. Dennis V. Canfield, Toxicology and Accident Research Laboratory of the Civil Aeromedical Institute, Oklahoma City, Oklahoma). The National Transportation Safety Board, in their review of the accident statistics, "...believes that the presence of any alcohol in a pilot's blood jeopardizes safety" (p. 2, in Ross, 1988). These observations and conclusions raise a number of questions concerning the effects of low levels of alcohol on performance in flight and the potential efficacy of the existing regulation.

In a review of the literature concerning the effects of alcohol on driving-related behavior Moskowitz and Robinson (1988), report that behavioral skills impairment was observed in 158 out of the 177 studies. Of those studies, 35 reported that impairment was detected at BACs of 0.04% or less. After grouping the studies into nine behavioral skills categories (i.e., reaction time, tracking, concentrated attention, divided attention, information processing, visual functions, perception, psychomotor skills, and driving) the authors concluded that impairment would first be noted on divided attention tasks and then on tracking performance. Vigilance appeared to be least likely to be affected by low to moderate levels of alcohol. An updated review of the literature (Holloway, 1994) provides additional support to those conclusions.

Billings, Wick, Gerke, and Chase (1972) were the first to determine the effects of alcohol on pilot performance during an actual flight in a Cessna 172. They demonstrated that when pilots flew under the influence of a BAC of 0.04%, a significant increase in "major" procedural errors was found. Other aspects of pilot performance did not show any significant performance decrements. At about the same time, Gilson, Schroeder, Collins, and Guedry (1971) found that performance on a localizer/glide slope tracking task, administered during angular motion, resulted in a significant performance decrement at an average BAC as low as 0.027%, under the lower of two levels of instrument illumination. Ross and Mundt (1986) assessed the effects of alcohol (0.04% BAC) on the simulator performance of pilots and non-pilots during straight and level flight and during an unusual attitude flight segment where attention was diverted by other tasks. Alcohol significantly impaired performance on some tasks and this impairment was most evident in recovery from unusual attitudes.

In a recent study using four air carrier crew members, Billings, Demosthenes, White, and Ohara (1991) found that their classification of "serious" errors, but not the overall number of errors, increased significantly at a BAC of 0.025% when compared to baseline. However, at the 0.05% BAC level, both the serious errors and the overall number of errors were below those obtained at the 0.025% BAC level. Most recently, Ross, Yeazel, and Chau (1992), using several different simulator profiles, found that low BACs did affect some aspects of pilot performance. The effects were observed most frequently under the heaviest workload conditions. They also reported that, while subjects reported mental and physical effects of alcohol, they were still able to carry out a majority of the flight tasks without significant alcohol-related impairment. As mentioned earlier, Morrow et al. (1990) also assessed the effects of low BACs on pilot performance during simulator flights and found that some aspects of performance did not appear to be significantly impacted, but there was an increase in altitude errors and in the combined-variable summary scores.

It is understood from this brief review of the alcohol literature that the tasks most often affected by alcohol ingestion require, in part, the component abilities of divided attention and multiple tasking. As the first of a series of investigations into the effects of low levels of alcohol, simplified cognitive tests were selected for this study as representing some of the basic parameters of performance in an operational aviation environment. Several tests comprising the recently developed COGSCREEN Battery (Horst & Kay, 1991a; 1991b; Kane & Kay, 1992) possess these qualities. During the development of this test battery for clinical purposes, two of several design goals were "...comprehensiveness with respect to range of cognitive functions assessed..." and the "...inclusion of tasks assessing cognitive abilities required for aviation safety..." (Kane and Kay, 1992, p.55). Hence, the component measures of divided and shifting attention, and combined tracking were of particular interest.

Previous findings illustrate that, on selected tasks, both age and alcohol can significantly impair performance. However, the potential interaction of those two factors is less clearly understood. This study was, therefore, designed to determine the effects of age and interactive effects of age and alcohol on cognitive functioning. Further, because a study by Obitz, Rhodes, and Creel (1977) indicated that a high level of subject attention (and perhaps motivation) could be maintained with monetary incentives, and that incentives could affect task performance even under alcohol conditions, an incentive condition was also included in this study.

METHOD

Subjects. A total of 61 men and 11 women were selected for this study – a gender ratio approximating that present in the general aviation pilot community. All subjects were screened with the Cahalan, Cisin, and Crossley (1967) Quality-Frequency-Variability Index to ensure that their drinking patterns conformed to that of "moderate" drinkers. Subjects were also screened to confirm that they were not taking drugs (over-the-counter, prescribed, or illicit) before or during the experiment. They were also instructed not to consume any alcoholic beverages (including beer and wine) on the day prior to participating in the experiment or during the test days.

Forty-eight subjects were offered "bonus" money, in addition to the sum that they were earning by participating in the study, as an incentive to maintaining a high level of performance. Each was offered a monetary reward of $8.00 per session if his/her performance on the pre-drinking session and the three post-drinking sessions exceeded that obtained in the last training session (held the previous day) on at least five of the measures that were being examined.

Table 1 shows the number of subjects selected for each condition and group. Three experimental alcohol/incentive groups comprised 12 subjects each in 3 age categories (27-32, 42-47, and 57-62 years). The mean age for each group was 29.8, 43.5, and 58.8 years old, respectively. Four subjects in each age category comprised the control/incentive groups (ingesting the placebo drink mixture). The alcohol/non-incentive

Table 1. The number of subjects assigned to each experimental condition by age group.

CONDITION	AGE GROUP YOUNGER	MIDDLE	OLDER		Total
ALCOHOL/INCENTIVE	12	12	12		36
CONTROL/INCENTIVE	4	4	4		12
ALCOHOL/NON-INCENTIVE	4	4	4		12
CONTROL/NON-INCENTIVE	4	4	4		12
				Total	72

and the control/non-incentive groups were comprised of four subjects in each age category. The control group's mean age was 44.1. One female subject was assigned to each conditional group, except for the older, alcohol/non-incentive group.

Cognitive Tests. The COGSCREEN test battery was developed by the Advanced Resource Development Corporation (ARD) and the Georgetown University School of Medicine in response to an FAA request for an automated test battery to detect subtle clinical changes in the cognitive function of pilots. The battery runs on a standard IBM PC-AT or compatible, under the DOS operating system, and uses a light pen as the primary input device for all tests except tracking, which uses the arrow keys on the standard keyboard (Horst & Kay, 1991a; 1991b). Nine of the tests from the COGSCREEN test battery were selected for this study. The tests were always presented in the same order. Brief descriptions of the nine tests are in Appendix A. A list of the variables measured and the types of data collected for each test are shown in Table 2.

Breath Alcohol Measurements. Breath Alcohol (BrAC) measurements provide rapid, inexpensive, and reliable assessment of an individual's alcohol level. BrACs are measured in terms of grams per 210 liters of air and provide readings that the legal and scientific communities consider representative of measures reported for blood alcohol concentration (BAC). BrACs were measured in the laboratory using a CMI, Inc. Intoxilyzer 5000, which measures a breath sample and reports its corresponding BrAC within 90 seconds.

Alcohol Condition. Subjects were instructed to pace their drinking so that they would consume one drink every seven and one half minutes. Each subject in the alcohol condition was given 1.62 milliliters (ml) of 80 proof vodka per kilogram of body weight (.505 g/kg), in two drinks mixed with orange juice and two ounces of crushed ice. This amount was derived by multiplying the Moskowitz, Burns, and Williams (1985) formula by 1.15, after adjusting for using 80 proof vodka. There were a few subjects who did not reach the desired level using this formula, in which case they were given a "booster" drink of 0.034 ml per kg of body weight (.011 g/kg)- a modification of the Lentz and Rundell (1976) formula, corrected for using 80 proof instead of 95% alcohol content.

Control (Placebo) Condition. In the control condition (four persons in each age category), subjects were given two drinks of orange juice and crushed ice with 5 ml of vodka floating at the top of each drink. As such, subjects could detect the odor and perhaps a slight taste of the vodka without ingesting enough alcohol to raise BrACs above the Intoxilyzer's "noise" level.

PROCEDURE

Four experimental sessions were conducted during the afternoon on each of two consecutive days. On the first day, subjects were given a brief explanation of the purpose of the study, followed by a general overview of the computer tests involved. They then read and signed a consent form, were weighed, given a breathalyzer test, and participated in an initial

Table 2. CogScreen test variables and performance measures— mean reaction time (MRT), number (#) correct, and average absolute error (AAE) listed by test.

TEST	TEST VARIABLES	PERFORMANCE MEASURE
BACKWARD DIGIT SPAN	attention, short term memory, verbal sequential processing	# Correct
VISUAL SEQUENCE COMPARISON	working memory, attention, sequencing ability	# Correct MRT
SYMBOL-DIGIT CODING	working memory, attention, verbal sequencing ability	# Correct MRT
SYMBOL-DIGIT IMMEDIATE RECALL	short term memory recall	# Correct MRT
SYMBOL-DIGIT DELAYED RECALL	long term memory recall	# Correct MRT
MATCHING TO SAMPLE	visual short term memory, attention	# Correct MRT
DIVIDED ATTENTION	divided attention, visual motor ability, working memory	Single Task # Correct MRT Dual Task # Correct MRT # Premature Responses
SHIFTING ATTENTION	attention, visual discrimination, concept formation, rules application	# Correct MRT # Lost Rules
DUAL TASKING coordination, visual	fine motor speed & # Previous Numbers spatial, verbal-sequential processing, working memory, divided attention	Tracking Error Correct MRT Dual Task # Correct MRT AAE

computer testing session with detailed instructions. The initial session was a self-paced practice session that ran from 30 to 45 minutes in length. Subjects were allowed to ask questions during and following the initial session, but proceeded on their own after that session. The subsequent computerized test sessions, which did not include detailed instructions, were also self-paced, and took approximately 30 minutes each to complete. Each of the four sessions conducted on Day 1 was followed by a 15-minute break, during which subjects could read magazines, watch television, or just relax quietly.

All responses to the tests were made through touching the CRT screen with a signal light pen, with the exception of the tracking task, which involved using the right and left arrow keys on the keyboard. Auditory (error) feedback occurred during the last three tests. Data were verified after each computer session to assess learning, check the programs, and determine if the incentive subjects were to receive additional "bonus" money.

Following the fourth session, subjects were instructed to return the next day at the same time. They were to eat a moderately sized lunch approximately 30 minutes prior to their arrival. They were also reminded not to consume any alcoholic beverages or medications during that evening.

On the second day, subjects took a baseline breathalyzer test upon arrival to assure their 0.00 BrAC status and then completed the first (baseline) computerized test session. After the baseline session, subjects were given 15 minutes to consume each of two drinks. Since blood alcohol levels are known to drop at the rate of approximately 0.004 every 15 minutes (Dubowski, 1985), and since the computer sessions were approximately 30 minutes in length, subject BrACs going into each testing session were 0.004 higher than the experimentally targeted BrACs of 0.04, 0.027, and 0.0135% in an attempt to have the target value be the average of each session.

Fifteen minutes after the second drink, the breathalyzer tests were resumed until the subjects had reached their BrAC peaks, and had then dropped to 0.044% BrAC on the descending limb of their blood alcohol curves. The first of three post-drinking test sessions was then conducted, after which a breathalyzer measure was obtained to permit the calculation of average BrAC of each subject during that test session. Breathalyzer tests continued until 0.031 was reached, and the second post-drinking session was conducted, again followed by breathalyzer tests until 0.018 was reached, when the subjects were given the final post-drinking session. After the final post-drinking test session, BrACs were determined periodically until a 0.00 level was reached. Subjects were allowed to leave the testing site shortly thereafter.

Design and Analysis. Two designs were used in this study. Control group subjects (N=24) in the three age groups were compared on the baseline session and all post-baseline sessions, while the Alcohol subjects (N=36) in the three age groups were compared on the baseline session and all alcohol condition to assess the effects of age on performance. Then, each of the three age groups of alcohol subjects was compared across the (pre-drinking) baseline session and three alcohol conditions to the mixed age control group (ingesting a placebo mixture throughout), to assess the effects of blood alcohol levels.

RESULTS

Prior to analysis, all measures were examined through various SPSS programs for accuracy of data entry, missing values, and fit between data distribution and the assumptions of multivariate analysis. Missing values were replaced with cell means according to acceptable statistical procedures (Tabachnick & Fidell, 1989). Outliers, those scores falling three standard deviations above or below the mean, occurred less than 1% of the time and were also replaced with cell means. No casewise deletion of scores was necessary after these procedures.

The incentive vs. non-incentive condition comparisons showed no significant differences between groups. A decision was made to pool data. However, during data acquisition, several computer failures occurred with the non-incentive alcohol group. Though these subjects were rerun at the time of the failures, their data were excluded from the overall analysis, obviating the pooling of data across alcohol groups; however, data from the control/non-incentive group were combined with the control/incentive

Table 3. Group means and standard deviations for 25 measures collected on 10 tests during baseline (pre-drinking) condition. (MRT= Mean Reaction Time.)

TEST Measure		Age groups YOUNGER	MIDDLE	OLDER
Backward Digit Span				
Number Correct	M	8.40	8.10	6.60
	SD	2.76	3.01	3.05
Visual Comparison				
Number Correct	M	19.64	19.75	19.45
	SD	.66	.44	.60
MRT	M	1788.68	2373.16	2913.14
	SD	500.76	799.08	624.28
Visual Comparison with dual tasking				
Number Correct	M	16.35	18.71	18.22
	SD	3.99	3.26	3.61
MRT	M	509.17	594.76	832.78
	SD	129.65	189.12	264.74
Premature centerings	M	2.20	2.19	1.78
	SD	2.12	1.66	1.33
Symbol Digit Coding				
Number Correct	M	73.91	62.25	46.10
	SD	16.00	14.61	13.33
MRT	M	1203.15	1444.35	2011.01
	SD	233.03	352.72	706.65
Symbol digit coding: Immediate recall				
Number Correct	M	5.94	5.45	5.20
	SD	.23	.39	1.06
MRT	M	1770.82	2634.90	3659.00
	SD	694.22	1396.88	1654.27
Matching to Sample				
Number Correct	M	19.15	18.90	17.71
	SD	1.08	1.07	1.43
MRT	M	1444.05	1727.02	2053.04
	SD	245.01	333.95	366.56
Divided Attention: Visual Comparison				
Number Correct	M	18.80	18.40	17.85
	SD	.70	1.27	1.04
MRT	M	1912.04	2447.95	2518.89
	SD	615.64	621.57	577.07
Symbol Digit Delay Recall				
Number Correct	M	5.84	5.68	4.85
	SD	.52	.65	1.27
MRT	M	1801.07	2552.19	4813.60
	SD	681.79	1196.92	2061.48
Shifting Attention				
Number Correct	M	49.15	39.85	36.45
	SD	2.51	12.67	13.06
MRT	M	640.67	894.59	1065.50
	SD	133.38	296.08	475.89
Lost Rule	M	1.45	3.15	2.85
	SD	1.15	2.39	2.08

Table 3 (Con't). **Group means and standard deviations for 25 measures collected on 10 tests during baseline (pre-drinking) condition. (MRT= Mean Reaction Time.)**

TEST Measure		YOUNGER	Age groups MIDDLE	OLDER
Single Task				
Tracking Alone				
Avg. Absolute Error	M	14.81	15.09	22.80
	SD	12.70	12.88	19.89
Previous Numbers Alone				
Number Correct	M	39.85	33.65	29.85
	SD	6.02	5.43	6.75
MRT	M	384.56	583.63	629.34
	SD	218.15	190.76	171.12
Dual Task: Tracking with Previous Number Recognition				
Tracking				
Avg. Absolute ErrorM	38.63	56.00	77.91	
	SD	23.79	28.08	19.16
Previous Number Recognition				
Number Correct	M	32.30	25.95	20.80
	SD	8.27	6.37	6.49
MRT	M	561.35	757.22	876.68
	SD	278.04	208.88	212.58

group. As a result, a total of 60 cases was used in the final overall analysis (36 alcohol subjects and 24 control subjects).

Age Differences. Three categories of age—younger, middle, and older with 20 subjects in each group were compared in a multivariate analysis of variance (MANOVA) with SPSS for the 25 measures listed in Table 2. The results of the MANOVA yielded a significant difference on 20 of the 25 baseline measures. The means and standard deviations for all 25 measures are listed in Table 3, and a summary of the MANOVA is presented in Table 4.

Posthoc tests using Tukey's Honestly Significant Differences (HSD) were performed on the 20 significant measures identified from the MANOVA. Results from the HSD tests are presented in Table 5.

The HSD results show that of the 20 measures identified as significant by the MANOVA, significant mean differences ($p < .05$) were found on all baseline measures between the younger and older age groups, with the younger group means being lower on MRT and higher on number correct. The mean number of lost rules on the shifting attention task was also lower for the younger age group. The means of the younger

Table 4. **MANOVA results grouped by test measures at the baseline session for all subjects. (MRT= Mean Reaction Time.)**

Test Measure	MS Error	F	p
Backward Digit Span			
Number Correct	8.66	2.15	.126
Visual Comparison			
Number Correct	.34	1.37	.261
MRT	426335.23	14.84	<.001
Visual Comparison with Dual Tasking			
Number Correct	12.42	2.51	.090
MRT	40886.57	13.75	<.001
Premature Centerings	3.01	.39	.678
Symbol Digit Coding			
Number Correct	215.89	18.07	<.001
MRT	226023.08	15.10	<.001
Symbol Digit Immediate Recall			
Number Correct	.65	4.32	.018
MRT	1723273.96	10.37	<.001
Matching to Sample			
Number Correct	1.46	8.08	.001
MRT	101974.06	18.21	<.001
Divided Attention: Visual Comparison			
Number Correct	1.06	4.28	.018
MRT	366126.84	6.01	.004
Symbol Digit Delay Recall			
Number Correct	.76	7.33	.001
MRT	2049049.92	24.00	<.001
Shifting Attention			
Number Correct	112.49	7.68	.001
MRT	110639.77	8.25	.001
LostRule	3.79	4.34	.018
Single Task			
Tracking Alone			
Avg. Absolute Error	240.87	1.71	.190
Previous Numbers Alone			
Number Correct	37.12	13.73	<.001
MRT	37753.06	.90	<.001
Dual Task: Tracking with Previous Number Recognition			
Tracking			
Avg. Absolute Error	573.85	13.50	<.001
Previous Number Recognition			
Number Correct	50.36	13.17	<.001
MRT	55376.73	9.15	<.001

(d.f.=2,57)

Table 5. **Significant posthoc comparisons results, using Tukey's HSD, for all significant measures listed by test and age group — Younger (Y), Middle (M), and Older (O). (MRT= Mean Reaction Time.)**

Test / Measure	AGE: Younger	Middle	Older
Visual Comparison			
MRT	M O	O Y	M Y
Visual Comparison with Dual Tasking			
MRT	O	O	M Y
Symbol Digit Coding			
Number Correct	M O	O Y	M Y
MRT	O	O	M Y
Symbol Digit Immediate Recall			
Number Correct	O	Y	
MRT	M O	O Y	M Y
Matching to Sample			
Number Correct	O	O	M Y
MRT	M O	O Y	M Y
Divided Attention: Visual Comparison			
Number Correct	O	Y	
MRT	M O	O Y	M Y
Symbol Digit Delay Recall			
Number Correct	O	O	M Y
MRT	O	O	M Y
Shifting Attention			
Number Correct	M O	Y	Y
MRT	M O	Y	Y
Lost Rule	M O	Y	Y
Single Task			
Previous Number Recognition Alone			
Number Correct	M O	Y	Y
MRT	M O	Y	Y
Dual Task: Tracking with Previous Number Recognition			
Tracking			
Avg. Absolute Error	M O	O Y	M Y
Previous Number Recognition			
Number Correct	M O	O Y	M Y
MRT	M O	O Y	M Y

age group were better on 15 of the 25 measures when compared to the middle age group. The means for 13 measures for the middle age group were lower on MRT and higher on number correct when compared with the older age group.

Stability of Age Differences Across Sessions A MANOVA, using only the 36 alcohol subjects, was performed, contrasting the baseline and all post-drinking sessions across the three age groups to test for the stability of age effects across the (alcohol) sessions. As summarized in Table 6, the MANOVA yielded significant age effects on 15 of the 25 baseline and 13 (.040%), 11(.027%) and 10 (.014%) of the 25 on the alcohol sessions measures. Of the seven significant MRT measures at the baseline session, three remained significant on all of the post drinking trials. The four non significant mean reaction time measures on the final trial were symbol digit coding immediate recall, visual comparison, visual comparison with dual tasking, and symbol digit coding delayed recall. The mean reaction time for shifting attention decisions showed significant age effects at all post-drinking sessions, but no significant age effect at the baseline session. The reduction in the number of significant age main effects for the post-drinking sessions was attributed to a reduction in the performance levels between the older and younger age groups in 15 of 20 cases. In most of these cases, the older age subjects improved performance, whereas, the younger age group demonstrated a performance decrement. The remaining five were attributed to an elevation of the within-subject variability. Table 13 in Appendix C displays the performance measure, non-significant BrAC level (Post-drinking session), and type of change in performance.

A MANOVA, using only the 24 control subjects, was performed comparing the baseline and final non-alcohol sessions across the three age groups to test for the stability of age effects across the (control) sessions. These findings showed consistency across sessions. As summarized in Table 7, the MANOVA yielded significant age effects on 18 of the 25 measures for each of the baseline and 3 post-baseline sessions. Of the 10 significant MRT measures at the baseline session, 8 remained significant at all post-drinking sessions. The 2 non-significant mean reaction time measures were symbol digit coding immediate recall and divided attention visual comparison. The number of lost rules for shifting attention decisions and symbol digit delay recall number correct showed significant age effects at all post-baseline sessions, but no significant age effect at the baseline session.

Following the analysis of the age-related performance data, the subjects were re-configured for the "age by alcohol" analysis. Three categories of age— younger, middle, and older with 12 subjects in each group— and a control group (N=24) comprised of 8 subjects from each age category, were compared across the baseline (pre-drinking, 0.00) session and 3 levels of intoxication— 0.04, 0.027, and 0.014% BrACs in a doubly repeated MANOVA (Tabachnick and Fidell, 1989) with SPSS.

Alcohol/Session Differences A MANOVA, using the 36 alcohol subjects, was performed across all pre- and post- drinking sessions to identify measures evidencing an alcohol/session effect. The results of the MANOVA are summarized in Table 8.

Three of the 13 significant main effects for the alcohol/session variable posthoc analysis revealed significant mean differences in the direction that suggests an alcohol pattern: dual task previous numbers MRT, symbol digit delay recall correct, and visual comparison MRT with dual tasking. These measures are also those which demonstrated a significant age by session interaction, and the posthoc analysis are discussed in more detail in the next section.

Alcohol and the Alcohol/Session interaction The results of the MANOVA indicated that significant age by alcohol session interactions were obtained only for three measures; performance means and standard deviations for those measures are presented in Tables 9-11. The interaction effects included the mean reaction time (MRT) of both the dual task previous numbers ($F_{6,99}$=2.39, p=.014), and the symbol-digit delayed recall ($F_{6,99}$=2.04, p=.038) task, and the number correct measure for the symbol-digit delayed recall task ($F_{6,99}$=2.90, p=.003). The divided attention visual comparison MRT measure showed a borderline non-significant effect with a trend similar to the dual task MRT measure.

Table 6. **MANOVA results of 36 alcohol subjects grouped by test measures at the baseline and last alcohol (.014%) sessions for alcohol subjects. (MRT= Mean Reaction Time.)**

Test Measure	MS Error	Baseline F	p	MS Error	.040% F	p	MS Error	.027% F	p	MS Error	.014% F	p
Backward Digit Span												
Number Correct	8.84	.28	.753	7.21	.33	.721	11.51	.97	.390	8.95	.85	.437
Visual Comparison												
Number Correct	.42	.47	.629	.50	.06	.949	.86	.43	.650	.63	.41	.549
MRT	404672.22	8.46	.001	482321.28	3.98	.028	471028.47	2.61	.089	374006.41	3.15	.056
Visual Comparison with Dual Tasking												
Number Correct	16.17	1.39	.281	17.17	1.33	.278	20.49	.17	.844	15.96	1.85	.172
MRT	28015.43	6.96	.003	3.66	.65	.529	3.41	.90	.415	31560.20	3.24	.052
Premature Centerings	3.78	.27	.965	68393.16	4.60	.017	48132.74	5.43	.009	1.99	.90	.414
Symbol Digit Coding												
Number Correct	277.43	8.41	.001	295.67	2.56	.092	272.62	5.38	.010	184.05	6.77	.003
MRT	300573.81	7.05	.003	106781.54	6.67	.004	180651.41	8.19	.001	194807.24	6.93	.003
Symbol Digit Immediate Recall												
Number Correct	.61	2.37	.109	.86	2.85	.072	.24	.17	.847	1.25	1.70	.199
MRT	1793627.28	3.79	.033	4241823.39	1.73	.193	790429.52	5.43	.009	1924832.74	.76	.476
Matching to Sample												
Number Correct	1.23	6.30	.005	1.23	10.58	<.001	2.62	2.61	.068	1.03	2.04	.146
MRT	141351.90	7.91	.002	153123.51	4.47	.020	192955.83	3.59	.039	138293.60	5.53	.008
Divided Attention: Visual Comparison												
Number Correct	.97	3.09	.059	2.01	2.38	.108	2.20	2.08	.141	1.95	8.91	.001
MRT	4619184.66	2.28	.117	696559.68	2.12	.136	721577.08	.40	.672	702552.93	.78	.446
Symbol Digit Delay Recall												
Number Correct	.62	4.82	.015	1.32	4.96	.013	1.16	2.47	.101	1.51	1.52	.234
MRT	179775.83	13.37	<.000	2848242.52	4.98	.013	4934086.17	2.34	.113	1636890.70	2.47	.783
Shifting Attention												
Number Correct	129.87	4.16	.024	50.19	5.26	.010	87.68	7.82	.002	76.93	3.65	.037
MRT	134437.56	2.45	.102	61981.12	6.97	.002	115931.22	3.86	.031	108234.83	5.02	.013
Lost Rule	3.15	4.54	.018	4.58	2.87	.071	2.17	2.52	.099	2.48	2.50	.098

Table 6 (Con't). MANOVA results of 36 alcohol subjects grouped by test measures at the baseline and last alcohol (.014%) sessions for alcohol subjects. (MRT= Mean Reaction Time.)

Test		**Baseline**			**.040%**			**.027%**			**.014%**	
Measure	MS Error	F	p	MS Error	F	p	MS Error	F	p	MS Error	F	p
Single Task												
Tracking Alone												
Avg. Absolute Error	266.28	.20	.823	251.04	2.98	.065	157.09	.07	.931	163.14	.99	.382
Previous Numbers Alone												
Number Correct	32.58	7.80	.002	45.74	3.64	.037	583.84	7.84	.002	24.68	7.23	.002
MRT	31436.40	5.22	.011	50950.41	3.00	.063	37.60	5.50	.009	21826.08	5.52	.009
Dual Task												
Tracking												
Avg. Absolute Error	710.99	4.27	.022	548.03	10.25	<.000	44630.39	2.77	.078	770.82	5.19	.011
Previous Number Recognition												
Number Correct	41.78	5.19	.006	41.13	8.44	.001	47.04	10.40	<.001	40.27	7.17	.003
MRT	47829.02	2.72	.080	37028.21	8.71	.001	39596.73	9.07	.001	49766.94	2.68	.084

(d.f.=2,33)

Table 7. **MANOVA results of 24 control subjects grouped by test measures at the baseline and last non-alcohol sessions for alcohol subjects. (MRT= Mean Reaction Time.)**

Test	Baseline			.040%			.027%			.014%		
Measure	MS Error	F	p	MS Error	F	p	MS Error	F	p	MS Error	F	p
Backward Digit Span												
Number Correct	6.58	6.80	.005	7.64	3.50	.049	9.04	4.15	.031	7.73	3.67	.044
Visual Comparison												
Number Correct	.23	1.61	.223	.37	.36	.697	.58	.02	.979	.20	.62	.549
MRT	517049.22	5.65	.011	155856.79	10.91	.001	223805.43	9.16	.001	229820.33	9.73	.001
Visual Comparison with Dual Tasking												
Number Correct	7.07	2.08	.149	19.95	.65	.529	15.58	.87	.435	21.27	2.85	.080
MRT	44805.56	9.62	.001	28065.07	6.56	.006	60927.10	5.55	.012	90680.97	3.65	.043
Premature Centerings	2.03	1.07	.223	5.07	.04	.962	2.89	.16	.850	3.23	.74	.491
Symbol Digit Coding												
Number Correct	145.45	10.85	.001	231.34	6.38	.007	183.48	9.95	.001	129.23	6.30	.007
MRT	140665.56	9.21	.001	135444.99	7.93	.003	196564.62	6.55	.006	108810.86	7.65	.003
Symbol Digit Immediate Recall												
Number Correct	.69	3.90	.036	1.10	.75	.487	.18	.91	.415	1.20	2.72	.089
MRT	1695702.60	7.35	.004	196553.57	8.08	.003	3173986.33	3.62	.037	1130719.35	1.73	.202
Matching to Sample												
Number Correct	1.80	2.52	.105	1.60	7.97	.003	1.81	3.22	.061	2.47	.49	.618
MRT	49231.71	16.00	<.001	56993.85	11.35	.001	139252.99	3.56	.042	83991.58	6.19	.008
Divided Attention: Visual Comparison												
Number Correct	1.35	1.20	.320	2.12	.81	.458	3.46	3.62	.041	5.73	5.07	.016
MRT	247836.67	4.68	.021	291070.44	2.32	.123	396792.36	2.15	.143	408459.87	3.72	.035
Symbol Digit Delay Recall												
Number Correct	1.00	3.44	.051	.72	5.14	.016	.24	5.56	.010	1.11	5.81	.010
MRT	2631305.88	9.81	.001	1781956.44	19.75	<.001	2508444.52	5.69	.011	1602516.45	4.84	.019
Shifting Attention												
Number Correct	90.33	4.83	.019	34.84	18.16	<.000	61.39	8.01	.003	53.59	9.87	.001
MRT	79780.94	8.20	.002	89769.77	5.73	.011	63933.21	7.81	.003	44618.56	5.44	.013
Lost Rule	4.55	2.23	.132	3.10	6.00	.002	2.12	5.27	.014	2.59	3.77	.040

Table 7 (Con't). MANOVA results of 24 control subjects grouped by test measures at the baseline and last non-alcohol sessions for alcohol subjects. (MRT= Mean Reaction Time.)

Test		Baseline			.040%			.027%			.014%	
Measure	MS Error	F	p	MS Error	F	p	MS Error	F	p	MS Error	F	p
Single Task												
Tracking Alone												
Avg. Absolute Error	167.48	5.52	.012	375.76	2.17	.140	237.42	2.20	.137	459.42	2.97	.073
Previous Numbers Alone												
Number Correct	47.55	5.52	.012	415.08	11.68	<.001	535.20	8.81	.002	24.56	12.61	<.001
MRT	52130.66	3.51	.049	35.61	9.31	.001	27.53	6.20	.008	33677.18	10.15	.001
Dual Task: Tracking with Previous Number Recognition												
Tracking												
Avg. Absolute Error	366.40	14.19	.022	42108.73	7.96	.003	37627.32	4.47	.025	485.54	9.94	.001
Previous Number Recognition												
Number Correct	55.13	7.63	.003	42.50	13.38	<.001	29.44	11.72	<.001	52.42	8.26	.002
MRT	38927.04	11.18	<.001	41668.30	24.65	<.001	47494.92	5.79	.010	38927.04	11.18	<.001

(d.f.=2,21)

Table 8. MANOVA results of 36 alcohol subjects grouped by test measures across all pre- and post- drinking sessions for the alcohol/session main effect. (MRT= Mean Reaction Time.)

Test Measure	MS Error	F	p
Backward Digit Span			
Number Correct	4.76	.62	.605
Visual Comparison			
Number Correct	.46	2.11	.104
MRT	83097.44	2.88	.040
Visual Comparison with Dual Tasking			
Number Correct	.70	3.81	.012
MRT	24368.86	9.50	<.001
Premature Centerings	2.03	1.17	.323
Symbol Digit Coding			
Number Correct	52.68	3.35	.021
MRT	48517.28	3.49	.019
Symbol Digit Immediate Recall			
Number Correct	.53	3.95	.010
MRT	1416892.95	3.26	.026
Matching to Sample			
Number Correct	1.09	6.35	.001
MRT	53823.69	9.23	<.001
Divided Attention: Visual Comparison			
Number Correct	1.56	1.16	.326
MRT	66019.26	2.46	.067
Symbol Digit Delay Recall			
Number Correct	.70	3.00	.038
MRT	1287347.16	1.07	.362
Shifting Attention			
Number Correct	36.44	.26	.856
MRT	17402.98	.23	.870
Lost Rule	1.75	5.53	.001
Single Task			
Tracking Alone			
Avg. Absolute Error	156.83	.17	.915
Previous Numbers Alone			
Number Correct	14.92	2.52	.063
MRT	14920.26	6.11	.001
Dual Task: Tracking with Previous Number Recognition			
Tracking			
Avg. Absolute Error	104.25	.89	.448
Previous Number Recognition			
Number Correct	13.72	4.25	.007
MRT	17269.84	7.02	<.001

(d.f.=2,33)

Table 9. Dual task previous numbers mean reaction time, means and standard deviations (msec.) for three age categories at baseline (.00) and three levels of alcohol intoxication

Age Category		Alcohol intoxication level .00	.04	.027	.0135
Younger	MEAN	498.10	639.60	588.69	602.27
	SD	146.59	239.54	131.30	180.77
Middle	MEAN	524.2	714.14	739.31	706.19
	SD	169.88	250.44	264.48	165.97
Older	MEAN	730.78	949.79	882.37	786.45
	SD	183.57	291.60	245.04	185.62
Control	MEAN	737.42	694.78	740.27	797.96
	SD	279.99	202.28	288.58	306.63

A test for simple effects was performed for each of the significant interactions. The results of these tests revealed significant differences for the dual task previous numbers MRT for both age ($F2_{,33}=3.92$ $p=.013$) and session ($F_{2,33}=7.02$, $p<.001$), symbol-digit delayed recall MRT for age ($F_{2,33}=2.98$, $p=.039$) only, and symbol-digit delayed recall number correct for both age ($F_{2,33}=3.00$, $p=.038$) and session ($F_{2,33}=4.22$, $p=.007$).

A Tukey's Honestly Significant Differences (HSD) test was performed on the cell means for the significant simple effects and yielded significant mean differences ($p<.05$) for the dual task previous numbers MRT, the symbol-digit delayed recall MRT, and number correct measure for the age variable. Simple effects tests on the session variable produced mean differences on the symbol digit delay recall MRT and number correct, and visual comparisons with divided attention MRT. The results of those tests are explained below for each measure. Figures 1-3 display each effect, respectively. Figure 4 displays the divided attention visual comparison MRT trend. For other trend information, means and standard deviations for all non significant measures are shown in Table 12 of Appendix B.

The dual task previous numbers MRT measure yielded significant mean differences during all four sessions for the age variable and one significant mean difference for younger age subjects on the sessions variable (Figure 1). Mean differences were detected at the baseline (pre-drinking) session between the younger and older age groups, the younger age group and the control group, the middle and older age groups, and the middle age group and the control group. Significant mean differences were demonstrated at the 0.04% session between the older age group and both the younger age group and the control group. The 0.027% session yielded one significant mean difference, that between the younger and older age groups. The only significant mean difference at the 0.0135% intoxication session occurred between the younger age group and the control group. The only significant mean difference for the session variable was in the younger age group between the baseline and the .027% session, in the direction expected for an alcohol effect.

The symbol-digit delayed recall MRT measure (Figure 2) showed significant mean differences for the age variable at the baseline session between the older and younger age groups, and between the older and middle age groups, and significant mean differences on the sessions variable for the younger age group.

Table 10. Symbol-digit delayed recall mean reaction time, means and standard deviations (msec.) for three age categories at baseline (.00) and three levels of alcohol intoxication.

Age Category		Alcohol intoxication level .00	.04	.027	.0135
Younger	MEAN	1843.39	2336.13	2215.90	2998.53
	SD	654.30	1137.66	1177.43	1301.04
Middle	MEAN	2487.00	3037.62	2319.10	3089.14
	SD	916.39	1418.57	1131.10	1213.85
Older	MEAN	4553.03	4470.25	3978.07	3351.83
	SD	2030.97	2288.69	3418.90	1320.82
Control	MEAN	3197.34	3057.45	2744.94	3047.42
	SD	2156.18	2152.11	1853.74	1461.97

Table 11. Symbol-digit delayed recall number correct, means and standard deviations (msec.) for three age categories at baseline (.00) and three levels of alcohol intoxication

Age Category		Alcohol intoxication level .00	.04	.027	.0135
Younger	MEAN	6.00	5.66	5.70	5.52
	SD	0.00	0.60	0.62	0.99
Middle	MEAN	5.54	4.75	4.83	4.67
	SD	0.78	1.36	1.59	1.50
Older	MEAN	5.00	4.20	5.43	5.25
	SD	1.12	1.34	0.79	1.14
Control	MEAN	5.36	5.54	5.83	5.25
	SD	1.10	1.00	0.48	1.26

There was a mean difference at the 0.04% session between only the older and the younger age groups. The only significant mean difference for the session variable was for the younger age group between the baseline and the .014% session, in the direction that suggests an alcohol effect.

The symbol-digit delayed recall correct measure (Figure 3) yielded significant mean differences for the age variable and the session variable. The significant mean differences for the age variable were between the younger and older age groups at both the baseline and the 0.04% session. The only significant mean difference for the sessions variable was for the older age group between the baseline and the .04% session, in the direction that indicates an alcohol effect.

Posthoc analysis for the Divided Attention Visual Comparison MRT measure (Figure 4) indicated significant mean differences for the age variable and the session variable. The significant mean differences for the age variable occurred at both the baseline and the 0.04% session between the younger and the middle and older age groups. Significant mean differences for the sessions variable were between the baseline and the 0.04% session for both the older and middle age groups, in the direction that indicates an alcohol effect. The younger age group demonstrated a significant mean difference between the baseline and the 0.027% session and between the 0.04% and the 0.027% sessions, in the direction of an alcohol effect for the 0.027% session.

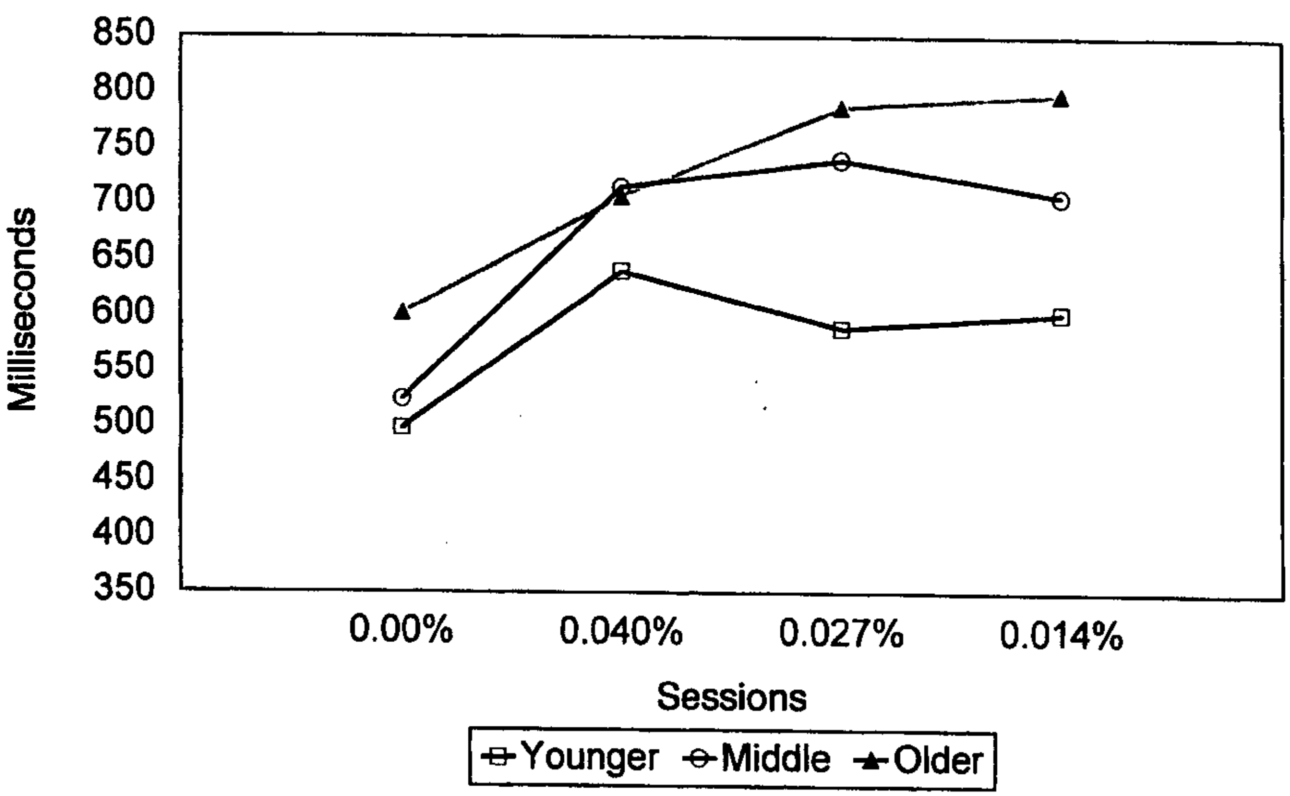

Figure 1. Mean reaction time for divided attention dual task compared across pre- and post-drinking sessions by age group.

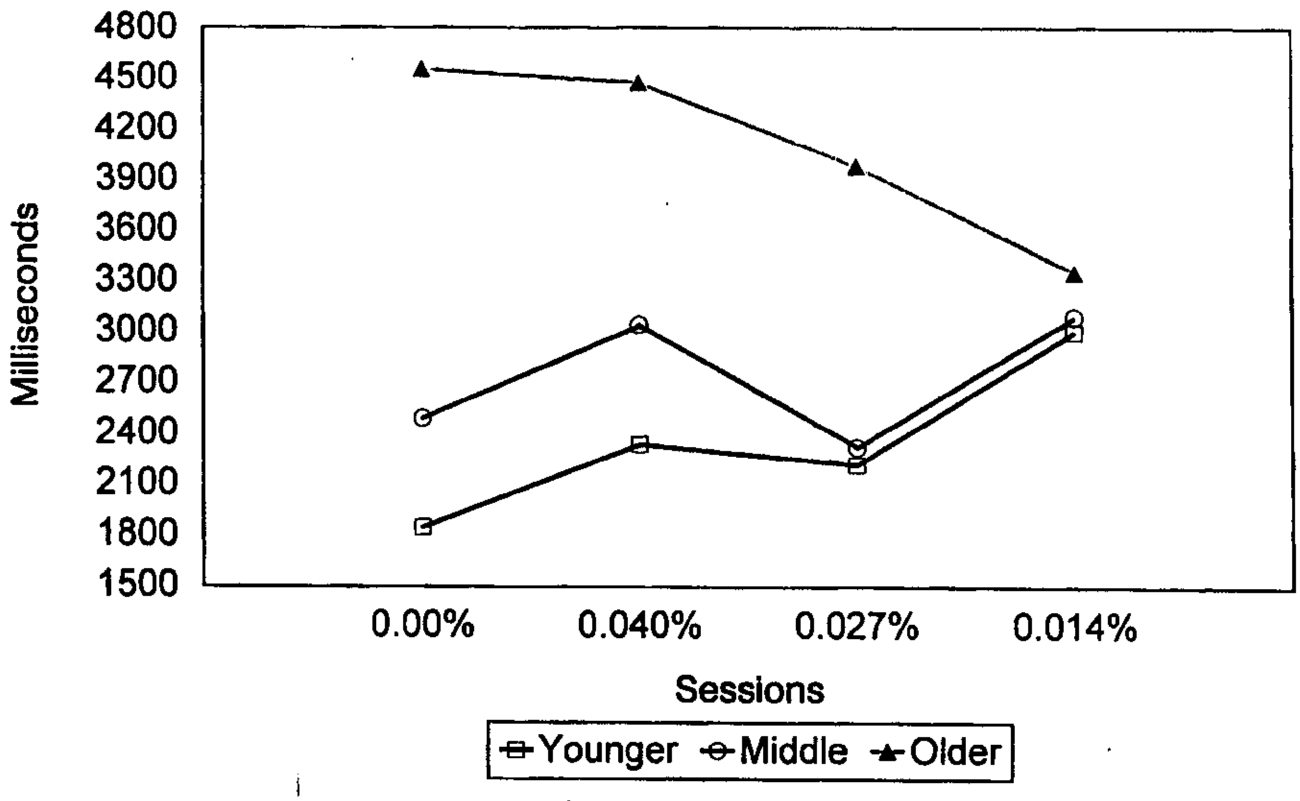

Figure 2. Mean reaction time for symbol-digit delay recall compared across pre- and post- drinking sessions by age group.

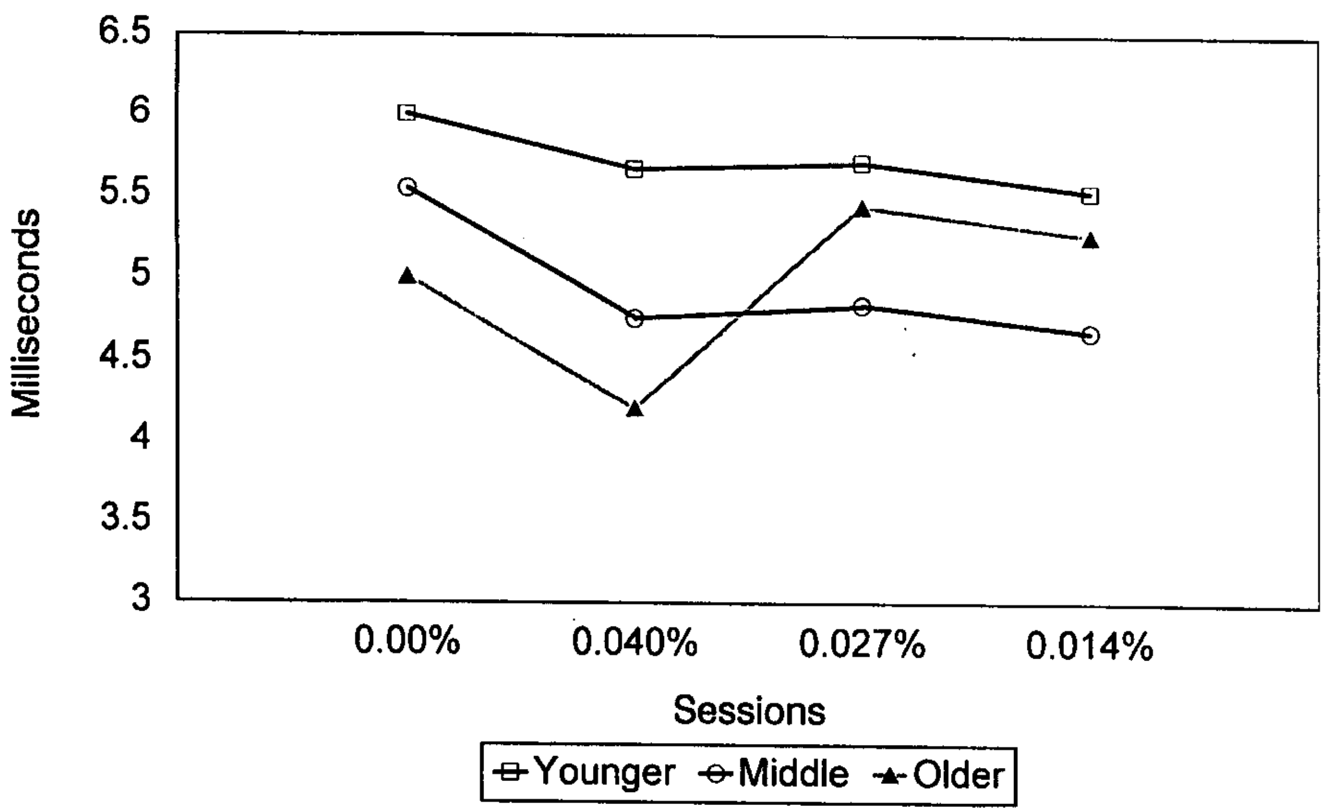

Figure 3. Mean reaction time for symbol-digit delay recall number correct compared across pre- and post- drinking sessions by age group.

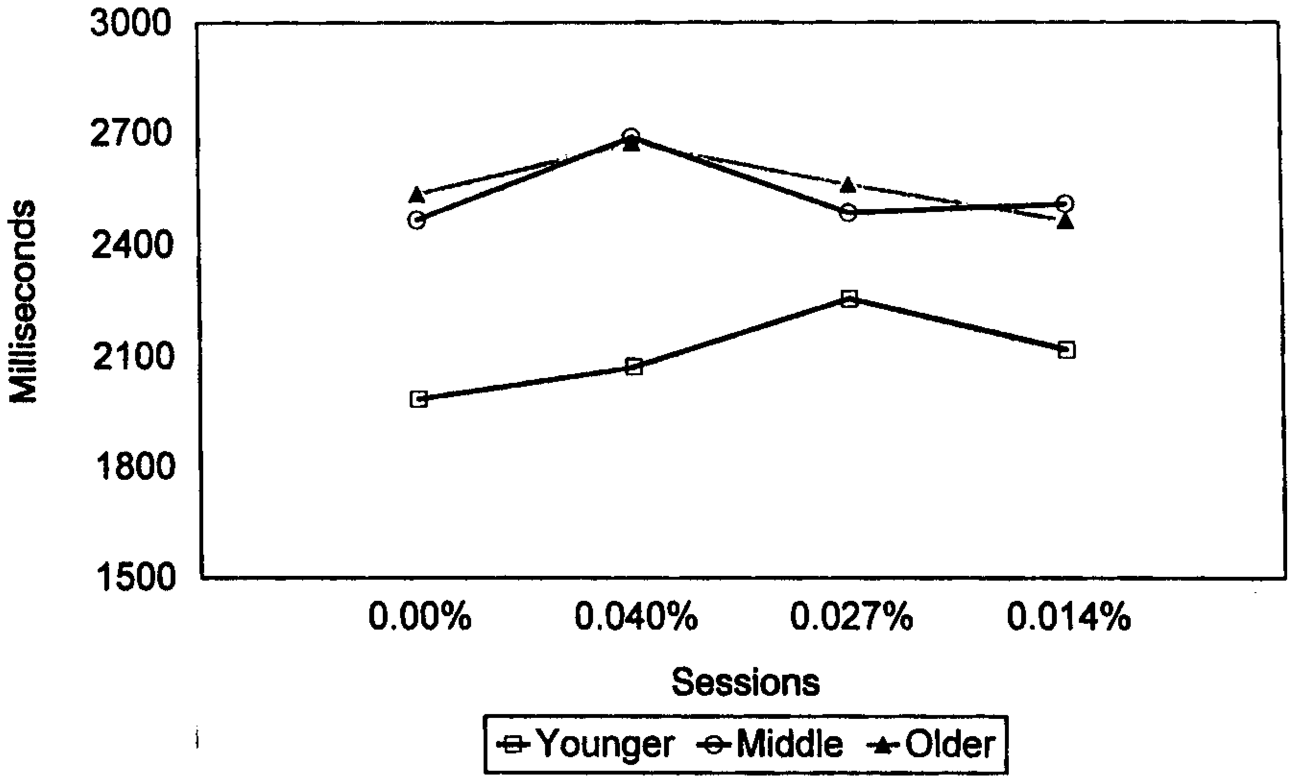

Figure 4. Mean reaction time for divided attention visual comparison compared across pre- and post- drinking sessions by age group.

DISCUSSION

These data support the existing literature concerning quantitative changes in information processing speed with aging (Cerella, 1985, 1990; Hale et al., 1987; Myerson et al., 1990; Salthouse, 1985, 1991; Myerson & Hale, 1993). There was an increase in mean reaction time across tasks and across the three age groups, supporting the findings of Davies, Taylor, and Dorn (1992) that an age effect is apparent, to some extent, across different tasks. Younger age subjects in the study performed significantly faster than older age subjects on all of the baseline MRT measures, and performed significantly faster than the middle age subjects on 70% of the baseline MRT measures. The middle age group was significantly faster than the older age group on 80% of the MRT measures.

The longer MRTs demonstrated by older subjects did not enhance their accuracy when compared to the younger age subjects. Younger subjects produced more accurate (statistically significant) scores on 80% of the tests that measured MRT and number correct. Our older aged subjects demonstrated increasingly longer reaction times as task complexity increased, thus supporting the findings of Lima et al. (1991). Older age subjects also demonstrated more within subject variance as the tasks became more complex. Two tests proved to be particularly troublesome for subjects over age 40. The shifting attention test required subjects to identify a rule underlying the presented stimuli. The "previous number alone" test required subjects to indicate which number (1, 2, or 3) was displayed after another number appeared on the screen. Younger subjects significantly outperformed both the middle and older subjects on all of the measures for both of these tasks, further supporting Lima et al.

Two potential subjects removed themselves from the experiment on the basis of the computerized nature of the testing process. While unfamiliarity with computers might be perceived as the basis for some of the obtained differences, this seems unlikely, since all tests were administered by computer. Subjects who were computer illiterate were given additional time to familiarize themselves with the computer and overcome their fears on the initial training day. Additionally, the human/computer interaction, with the exception of the tracking task, was solely with the light pen. That mode of interaction placed limited demands on subjects relative to their ability to interact with the computer.

In the overall comparison of baseline (pre-drinking) performance of alcohol subjects with performance on the alcohol measures, the alcohol sessions yielded significant age differences on 52% (.040%), 44% (.027%) and 40% (.014%) of the measures, whereas the baseline session yielded significant differences on 60% of the measures. However, the comparison of control group subjects yielded a significant difference on 72% of the measures for the baseline and all post-baseline sessions. This finding suggests that the alcohol sessions altered (reduced) the pattern of performance differences between age groups, in a way that control sessions did not. The drop in significant age differences on these sessions for alcohol subjects can be attributed to a constriction in the range of scores on the measures between the older and younger age alcohol subjects. Of interest is the last session measures where the older age subjects improved, while the younger age subjects showed a slight decrement in performance. Further research is indicated to determine age-related learning curves as related to test stability with this battery. In age and alcohol research, concerns about stability of performance across measures are important issues. These data indicate that the COGSCREEN test battery is sensitive to decremental effects on information processing time and cognitive reductions associated with aging.

Generally, the results of this study do not support a typical alcohol effect. The MANOVA results indicate significant age and session interactions on 16% of the measures; however, the simple effects tests yielded results that failed to evidence sessional patterns consistent with BrAC levels. It may be that the alcohol levels used in this study were low enough that subjects were able to overcome the effects of the ingested alcohol by motivation. However, the alcohol sessions did appear to reduce differences between the age groups.

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APPENDIX A

Backward Digit Span

Groups of three to six digits are presented sequentially, with the subject being required to reproduce each sequence in reverse order.

Visual Sequence Comparison

Pairs of alphanumeric strings, four to eight characters in length, are presented simultaneously on the right and left halves of the screen. The subject indicates "same" or "different" for each pair of strings, with "same" meaning the same characters in the same positions.

Symbol Digit Coding

Six paired symbols and digits are displayed near the top of the screen throughout the test. Farther down the screen a row of symbols are presented in random order, with associated blank spaces. The subject fills in the associated digit for each symbol, referring to those displayed at the top of the screen.

Symbol Digit Coding-Immediate Recall, Delayed Recall

Immediately after the Symbol Digit Coding Test, and again after an approximately 30 minute delay, the six symbols appear in random order and the subject's task is to recall the digits that had been paired with each of the six symbols.

Matching to Sample

A grid pattern with filled and empty cells (the "sample") is presented briefly, followed after a short delay by that same pattern along with a slightly different "foil" pattern. A forced-choice response is required, with the subject indicating the grid pattern that is the same as the one presented previously.

Divided Attention

In the upper half of the screen a horizontal bar moves continuously up or down within a circular display, changing direction at unpredictable times. The subject is instructed to respond when the moving bar passes from the center region of the circle into the upper or lower regions, which are delimited by a different color. This response temporarily returns the bar to the center of the circle. This monitoring task is performed alone and concurrently with a Visual Sequence Comparison task.

Shifting Attention

Four response boxes are displayed near the bottom of the screen, one with a colored border, one with an uncolored border, one with no border both containing a colored arrow pointing right, and one with no border but with an uncolored arrow pointing left. Stimuli are displayed in a similar box above this row of response boxes. There are five conditions, requiring the subject to respond according to different rules.

Dual Task Tracking

There are two tasks, each performed separately and then concurrently. One is a second-order compensatory tracking task in which the subject taps the right and left arrow keys on the keyboard in an attempt to center a vertical bar moving along a horizontal line. The other task involves the sequential presentation of three numbers in random order with the subject responding with the light pen as to the previous number presented.

APPENDIX B

TABLE 12. **Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and older, 57-62.**

PERFORMANCE MEASURE AND GROUP			.00	.04	.027	.0135
BACKWARD DIGIT SPAN						
Number Correct						
	YOUNGER	MEAN	7.917	7.091	6.417	7.273
		S.D.	2.644	3.476	3.753	3.570
	MIDDLE	MEAN	7.000	7.750	8.167	8.750
		S.D	3.191	1.765	2.290	2.667
	OLDER	MEAN	7.417	6.900	7.083	7.500
		S.D	3.147	3.017	3.349	3.083
	CONTROL	MEAN	8.083	7.667	7.542	7.875
		S.D.	3.147	3.017	3.349	3.083
VISUAL SEQUENCE COMPARISON						
Number Correct						
	YOUNGER	MEAN	19.570	19.500	19.201	19.500
		S.D.	.786	.674	.897	.905
	MIDDLE	MEAN	19.750	19.583	19.167	19.750
		S.D.	.452	.515	.937	.452
	OLDER	MEAN	19.500	19.500	19.500	19.750
		S.D.	.674	.879	.905	.452
	CONTROL	MEAN	19.625	19.542	19.458	19.750
		S.D.	.495	.588	.721	.442
Mean Reaction Time (MRT)						
	YOUNGER	MEAN	1837.568	1747.529	1944.973	1923.183
		S.D.	570.767	711.957	764.967	669.160
	MIDDLE	MEAN	2421.777	2329.327	2350.315	2208.900
		S.D.	648.974	748.977	726.561	620.329
	OLDER	MEAN	2905.915	2533.400	2576.863	2546.438
		S.D.	705.252	624.565	552.439	558.675
	CONTROL	MEAN	2289.193	2126.794	2132.152	2121.423
		S.D.	795.120	546.743	583.082	613.566

TABLE 12 (Con't). Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and older, 57-62.

SYMBOL-DIGIT CODING						
Number Correct						
	YOUNGER	MEAN	75.182	69.583	71.417	66.500
		S.D.	17.183	20.690	17.223	14.632
	MIDDLE	MEAN	62.500	63.417	59.583	59.000
		S.D.	17.594	16.407	13.918	12.329
	OLDER	MEAN	47.333	53.800	49.333	46.333
		S.D.	15.084	13.776	17.432	13.640
	CONTROL	MEAN	59.375	62.167	58.167	56.167
		S.D.	16.421	21.508	19.433	13.739
Mean Reaction Time (MRT)						
	YOUNGER	MEAN	1201.775	1186.713	1200.203	1316.399
		S.D.	258.123	236.784	196.747	272.114
	MIDDLE	MEAN	1444.656	1448.291	1482.650	1517.623
		S.D.	435.577	312.890	303.568	304.234
	OLDER	MEAN	2023.386	1674.024	1898.662	969.688
		S.D.	812.831	408.154	634.859	652.531
	CONTROL	MEAN	1533.095	1446.970	1559.152	1584.170
		S.D.	507.759	478.178	556.534	415.928
SYMBOL-DIGIT IMMEDIATE RECALL						
Number Correct						
	YOUNGER	MEAN	5.917	5.854	5.806	5.611
		S.D.	.289	.264	.577	.886
	MIDDLE	MEAN	5.250	5.167	5.917	4.833
		S.D.	.965	1.193	.195	1.403
	OLDER	MEAN	5.417	5.000	5.806	5.500
		S.D.	.900	1.044	.577	1.000
	CONTROL	MEAN	5.531	5.500	5.885	5.458
		S.D.	.928	1.022	.417	1.179

<u>TABLE 12 (Con't).</u> Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and over, 57-62.

Mean Reaction Time (MRT)						
	YOUNGER	MEAN	1201.775	1186.713	1200.203	1316.399
		S.D.	258.123	236.784	196.747	272.114
	MIDDLE	MEAN	1444.656	1448.291	1482.650	1517.623
		S.D.	435.577	312.890	303.568	304.234
	OLDER	MEAN	2023.386	1674.024	1898.662	1969.688
		S.D.	812.831	408.154	734.859	652.531
	CONTROL	MEAN	1533.095	1446.970	1559.152	1584.170
		S.D.	507.759	478.178	556.534	415.928
SYMBOL-DIGIT DELAYED RECALL						
Number Correct						
	YOUNGER	MEAN	6.000	5.666	5.701	5.521
		S.D.	.000	.603	.623	.991
	MIDDLE	MEAN	5.542	4.750	4.833	4.667
		S.D.	.775	1.357	1.586	1.497
	OLDER	MEAN	5.000	4.200	5.431	5.250
		S.D.	1.128	1.335	.786	1.138
	CONTROLMEAN		5.365	5.542	5.833	5.250
		S.D.	1.101	.977	.482	1.260
Mean Reaction Time (MRT)						
	YOUNGER	MEAN	1843.388	2336.125	2215.896	2998.528
		S.D.	654.303	1137.660	1177.434	1301.035
	MIDDLE	MEAN	2487.001	3037.623	2319.098	3089.139
		S.D.	916.394	1418.574	1131.103	1213.103
	OLDER	MEAN	4553.028	4470.251	3978.069	3351.833
		S.D.	2030.976	2288.691	3418.895	1320.821
	CONTROL	MEAN	3197.340	3057.452	2744.944	3047.417
		S.D.	2156.179	2152.110	1853.735	1461.969

TABLE 12 (Con't). **Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and over, 57-62.**

MATCHING TO SAMPLE					
Number Correct					
YOUNGER	MEAN	19.250	19.250	19.333	19.750
S.D.	.866	.866	.492	.452	
MIDDLE	MEAN	19.250	18.545	18.833	19.417
	S.D.	.866	1.076	1.467	1.240
OLDER	MEAN	17.854	17.200	17.583	18.917
	S.D.	1.487	1.335	2.314	1.165
CONTROL	MEAN	18.292	18.625	18.167	18.813
	S.D.	1.429	1.610	1.465	1.538
Mean Reaction Time (MRT)					
YOUNGER	MEAN	1484.621	1647.704	1570.513	1343.382
	S.D.	245.783	393.497	328.829	293.749
MIDDLE	MEAN	1661.852	1925.700	1931.758	1750.877
	S.D.	424.472	432.254	545.113	495.985
OLDER	MEAN	2085.979	2118.508	2027.700	1784.270
	S.D.	432.678	365.031	427.859	310.452
CONTROL	MEAN	1727.116	1714.883	1769.149	1564.472
	S.D.	339.252	332.145	414.538	351.267
DIVIDED ATTENTION					
Number Correct					
YOUNGER	MEAN	18.833	17.417	18.583	19.056
	S.D	.718	1.443	1.832	.679
MIDDLE	MEAN	18.333	17.500	17.750	18.500
	S.D.	1.371	1.679	1.215	1.087
OLDER	MEAN	17.833	18.550	17.417	16.750
	S.D.	.718	1.066	1.311	2.050
CONTROL	MEAN	18.375	18.458	17.458	16.438
	S.D	1.173	1.444	1.744	2.786

TABLE 12 (Con't). Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and over, 57-62.

Mean Reaction Time (MRT)						
	YOUNGER	MEAN	1985.907	2072.767	2255.454	2118.349
		S.D.	752.454	960.141	1113.937	1055.230
	MIDDLE	MEAN	2466.270	2688.218	2560.442	2509.174
		S.D.	719.394	910.505	782.317	821.248
	OLDER	MEAN	2534.991	2672.565	2484.678	2463.873
		S.D.	569.069	582.056	496.356	565.421
	CONTROL	MEAN	2238.798	2219.439	2167.703	2260.358
		S.D.	571.961	701.346	649.520	695.746
DUAL TASKING						
Number Correct						
	YOUNGER	MEAN	16.833	17.910	18.667	16.333
		S.D.	5.006	5.373	5.883	5.033
	MIDDLE	MEAN	19.500	20.667	19.833	18.800
		S.D.	3.497	3.939	3.834	3.511
	OLDER	MEAN	18.200	19.400	18.917	19.250
		S.D.	3.352	2.670	3.232	3.194
	CONTROL	MEAN	17.138	18.583	17.694	14.542
		S.D.	2.782	4.452	3.837	4.969
DUAL TASKING						
Mean Reaction Time						
	YOUNGER	MEAN	498.010	639.603	588.688	602.268
		S.D.	146.586	239.640	131.297	180.776
	MIDDLE	MEAN	524.222	714.149	739.307	706.192
		S.D.	169.881	250.444	264.487	165.973
	OLDER	MEAN	730.780	949.798	882.365	786.447
		S.D.	183.574	291.599	245.037	185.617
	CONTROL	MEAN	737.416	694.780	740.266	797.955
		S.D.	279.993	202.277	288.845	306.626

TABLE 12 (Con't). Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and over, 57-62.

Number Premature Responses						
	YOUNGER	MEAN	1.917	2.114	1.750	1.917
		S.D.	2.314	1.366	1.765	1.564
	MIDDLE	MEAN	2.400	2.500	2.083	2.067
		S.D.	2.054	1.784	1.929	1.207
	OLDER	MEAN	1.875	3.000	2.750	1.333
		S.D.	1.334	2.449	1.765	1.435
	CONTROL	MEAN	2.042	2.208	2.458	2.250
		S.D.	1.429	2.187	1.688	1.775
SHIFTING ATTENTION						
Number Correct						
	YOUNGER	MEAN	49.750	47.583	50.091	48.500
		S.D.	2.221	3.029	2.109	3.030
	MIDDLE	MEAN	37.917	38.417	37.250	39.917
		S.D.	13.249	10.122	10.481	9.249
	OLDER	MEAN	38.333	41.275	37.917	40.333
		S.D.	14.462	6.240	12.631	11.665
	CONTROL	MEAN	41.542	42.042	42.792	41.292
		S.D.	10.974	9.355	9.926	9.742
SHIFTING ATTENTION						
Mean Reaction Time (MRT)						
	YOUNGER	MEAN	664.511	648.380	634.893	610.458
		S.D.	143.985	119.825	101.379	123.419
	MIDDLE	MEAN	870.506	812.009	849.438	804.659
		S.D.	359.641	279.112	404.147	380.891
	OLDER	MEAN	992.426	1026.779	1016.911	1035.316
		S.D.	503.229	228.634	416.723	405.455
	CONTROL	MEAN	903.573	842.377	814.298	759.825
		S.D.	360.237	359.343	320.418	248.671

TABLE 12 (Con't). Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and over, 57-62.

Number of Lost Rules						
	YOUNGER	MEAN	1.417	1.333	2.273	2.000
		S.D.	1.084	1.557	1.135	.953
	MIDDLE	MEAN	3.583	3.417	4.689	3.417
		S.D.	2.429	2.712	2.898	1.881
	OLDER	MEAN	2.250	2.200	3.417	2.500
		S.D.	1.545	1.991	2.746	1.732
	CONTROL	MEAN	2.583	2.583	2.667	3.063
		S.D.	2.244	2.104	1.685	1.794
DUAL TASKING						
Tracking Alone						
Mean Reaction Time						
	YOUNGER	MEAN	396.110	363.209	335.338	298.047
		S.D.	186.154	173.632	162.700	158.012
	MIDDLE	MEAN	561.859	527.475	505.611	446.729
		S.D.	164.223	310.414	273.546	139.241
	OLDER	MEAN	622.134	579.516	500.037	488.848
		S.D.	180.795	162.315	180.098	145.336
	CONTROL	MEAN	541.220	518.060	423.289	469.849
		S.D.	251.975	265.134	230.972	245.903
Average Absolute Error						
	YOUNGER	MEAN	17.671	8.572	12.541	12.505
		S.D.	14.638	3.764	13.516	11.255
	MIDDLE	MEAN	13.672	16.798	13.542	11.905
		S.D.	14.117	21.015	15.470	5.850
	OLDER	MEAN	16.698	24.350	13.090	18.538
		S.D.	19.629	17.244	6.737	18.126
	CONTROL	MEAN	19.899	20.833	19.527	24.210
		S.D.	15.384	20.139	16.031	23.200

TABLE 12 (Con't). **Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and over, 57-62.**

Previous Numbers Alone Correct						
	YOUNGER	MEAN	39.833	39.750	40.833	42.417
		S.D.	5.474	6.482	5.306	5.869
	MIDDLE	MEAN	34.500	35.917	35.333	36.667
		S.D.	4.777	7.403	6.329	4.355
	OLDER	MEAN	30.667	32.300	32.917	35.083
	S.D.	6.706	6.354	6.855	4.542	
	CONTROL	MEAN	33.625	35.583	37.792	36.625
		S.D.	8.139	7.824	6.833	7.027
Alone MRT						
	YOUNGER	MEAN	396.110	363.209	335.338	298.047
	S.D.	186.154	173.632	162.700	158.012	
	MIDDLE	MEAN	561.859	527.475	505.611	446.729
	S.D.	164.223	310.414	273.546	139.241	
	OLDER	MEAN	622.134	579.516	500.037	488.848
		S.D.	180.795	162.315	180.098	145.336
	CONTROL	MEAN	541.220	518.060	423.289	469.489
		S.D.	251.975	265.134	230.972	245.903
DUAL TASKING						
Previous Numbers Correct						
	YOUNGER	MEAN	30.583	33.667	36.167	33.667
		S.D.	7.329	8.038	7.457	8.500
	MIDDLE	MEAN	28.583	30.583	31.083	33.667
		S.D.	5.869	6.445	5.435	4.559
	OLDER	MEAN	21.917	23.200	23.417	25.167
		S.D.	6.097	4.152	7.513	5.271
	CONTROL	MEAN	25.333	27.917	29.792	30.708
		S.D.	9.964	9.297	8.506	9.248

TABLE 12 (Con't). **Means and Standard deviations of performance measures for baseline (.00) and three levels of alcohol intoxication — .00, .040, .027, and .0135— by a mixed age control group and three age groups — younger, 25-27; middle, 42-47; and over, 57-62.**

DUAL TASKING						
MRT						
	YOUNGER	MEAN	616.717	534.302	455.52	536.218
		S.D.	210.526	222.120	206.561	295.772
	MIDDLE	MEAN	710.152	652.036	604.422	533.764
		S.D	232.339	209.475	186.538	159.938
	OLDER	MEAN	824.796	858.223	801.495	717.440
		S.D	212.567	133.670	200.025	190.368
	CONTROL	MEAN	753.540	713.495	647.615	581.070
		S.D.	317.066	304.600	283.582	270.930
Average absolute error						
	YOUNGER	MEAN	40.576	36.482	39.643	39.406
		S.D.	28.554	26.139	28.627	33.066
	MIDDLE	MEAN	52.306	46.729	43.465	45.978
		S.D.	30.061	26.415	24.442	29.955
	OLDER	MEAN	72.054	78.014	76.578	73.798
		S.D.	20.347	16.220	20.224	17.940
	CONTROL	MEAN	61.315	63.999	58.362	59.608
		S.D.	28.048	29.525	30.699	29.382

Appendix C

Table 13. Changes in 9 measures by BrAC level that yielded significant age differences at baseline and the post-drinking sessions during which those age differences became non-significant. (MRT = Mean Reaction Time.) Six measures (not listed) showed significant age main effects at baseline and maintained those significant levels throughout the subsequent sessions.

Significant Baseline Measure	Non-significant at BrAC level	Change in Younger Age Group Performance: Decrement	Change in Younger Age Group Performance: Improvement	Change in Older Age Group Performance: Decrement	Change in Older Age Group Performance: Improvement	Elevation in Within-subject variability
Visual Comparison MRT	.040%					✓
	.027%				✓	
Visual Comparison with Dual Task MRT	.040%					✓
	.027%					✓
	.014%	✓		✓ (Less than younger age group)		
Symbol Digit Coding Number Correct	.040%	✓			✓	
Symbol Digit Coding Immediate Recall MRT	.040%	✓			✓	
	.014%	✓			✓	
Matching to Sample Number Correct	.040%					✓
	.014%				✓	
Symbol Digit Coding Delayed Recall Correct	.027%	✓			✓	
	.014%	✓			✓	
Symbol Digit Coding Delayed Recall MRT	.027%	✓			✓	
	.014%	✓			✓	
Shifting Attention Number of Lost Rules	.040%	✓			✓	
	.027%					✓
	.014%	✓			✓	
Previous Number Alone Correct	.040%				✓	
Previous Number Alone MRT	.040%					✓
	.027%	✓		✓ (Less than younger age group)		

(N=36 alcohol subjects)

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