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Effects of Age and Low Doses of Alcohol on Compensatory Tracking During Angular Acceleration

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16. Abstract

Heightened interest in existing FAA regulations regarding alcohol and flying, with emphasis on the potential effects of low blood alcohol levels on performance, indicated a need for research to help define effects of low doses of alcohol on performance. This study was designed to assess the effects of age and three breath alcohol levels (0.04, 0.027, and 0.014%). Performance was assessed while subjects experienced mild angular stimulation. On the day prior to drinking, 48 subjects drawn from three age categories (27-32, 42-47, and 57-62 years) completed four training sessions on a compensatory tracking task (a localizer/glide slope instrument that required compensatory tracking of both a horizontal and a vertical needle) with and without a secondary auditory recognition task, under 1.0 ft L. and 0.1 ft L. illumination conditions. The test day consisted of a pre-drinking session and three experimental sessions conducted at the appropriate times on the descending limb of the alcohol curve, as indicated by breath alcohol measurements. Mean performance scores for the three age groups were compared across the four sessions, (pre-drinking and three levels of alcohol). A Mutivariate Analysis of Variance (MANOVA) test yielded a significant interaction and a significant main effect (age and sessions) for the combined needle errors under the 0.1 ft L. illumination level with the secondary task. The resulting simple effects tests revealed age differences at all post-drinking sessions favoring younger over older subjects, and poorer performance for the older age subjects at the 0.04% BrAC level. When testing individual needle errors, MANOVA tests yielded a significant interaction and main effects in the high illumination condition both with and without the secondary task for vertical needle errors. Resulting simple effects Analysis of Variance tests yielded significant age and alcohol effects for the older age subjects. The 0.04% level accounted for the alcohol effect. The alcohol and age interaction was accounted for by the older age group at the 0.04% BrAC level. This study showed no evidence of performance decrement associated with BrACs below 0.04%.

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EFFECTS OF AGE AND LOW DOSES OF ALCOHOL ON COMPENSATORY TRACKING DURING ANGULAR ACCELERATION

INTRODUCTION

Previous vestibular research (Schroeder, 1971, 1972) has demonstrated that, in darkness, the pattern of alternate slow sweeps and fast return movements of the eye (nystagmus) is depressed after alcohol consumption. However, under conditions where visual fixation is permitted during angular stimulation, nystagmus is increased due to the inhibiting effects of alcohol on the visual fixation mechanism (Collins, Schroeder, Gilson & Guedry, 1971; Gilson, Schroeder, Collins & Guedry, 1971; Schroeder, 1971; Schroeder, Gilson, Collins, & Guedry, 1972). Further, these studies demonstrated that the alcohol-lowered inhibition of nystagmus during angular acceleration results in significantly higher compensatory tracking errors than during static (no motion) conditions. Most of the performance decrements occurred under relatively high dose intoxication; however, one study (Gilson et al., 1971) detected significant impairment at blood alcohol levels (BACs) of 0.027%. In that study, performance on a localizer/glide slope tracking task administered during angular motion resulted in a significant performance decrement under the lower of two levels of instrument illumination; that effect was not obtained when subjects were stationary. The effect found by Gilson et al. (1971) was in part due to the improved performance of the control group across repeated test sessions, while the alcohol group still evidenced some performance impairment when compared to the pre drinking level. These findings suggest that, while an intoxicated person may perform some tasks adequately when stationary, performance can be impaired when motion is added.

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 9 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 for these conclusions.

Billings, Wick, Gerke, and Chase (1972) determined the effects of alcohol on pilot performance during 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. 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 was most evident in recovery from unusual attitudes. In a recent study using four air carrier crew members, Billings, Demosthenes, White, and O'Hara (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 that noted for the 0.025% BAC level.

Few studies in the alcohol literature have included an age variable in their research designs. Collins & Mertens (1988) demonstrated that alcohol-induced impairment resulted in greater performance decrements for older aged subjects. Linnoila, Erwin, Ramm, and Cleveland (1980) demonstrated significant age and alcohol effects, but no significant age by alcohol interaction. With only 10 subjects per group, Linnoila and co-authors believed that their study lacked sufficient power to demonstrate a significant interaction. However, since the interaction trend was strong, t-tests were performed between the two groups and yielded a significant difference in performance at placebo, 0.05%, and 0.08% BACs. They concluded that "age and alcohol have a deleterious synergistic effect on tracking performance" (p.494).

Morrow, Leirer, and Yesavage (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 did not appear to be significantly impacted (e.g., heading errors); however, there was an increase in altitude errors and in a combined-variable summary score for performance errors. These differences were demonstrated more frequently for older, rather than younger, subjects. In a later study, Morrow, Yesavage, Leirier, Dolhert, Taylor, and Tinkenberg (1993) failed to replicate the age-related differences in performance.

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 Aviation Regulations (FARs) was modified to include a rule that no one could act or attempt to act as a 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 difficulty with this regulation is that it may imply to some crew members that it is safe to fly with a BAC that does not exceed 0.04%. Despite the existence of these regulations, a recent postmortem inquiry found 6% of general aviation fatal accidents during 1989 and 1990 involved pilots with a BAC of 0.04% or higher (Canfield, Kupiec, and Huffine, 1992). 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" (Ross, 1988; p. 2). These observations and conclusions raise a number of questions concerning the effects, at all ages, of low doses of alcohol on performance. Therefore, this study was designed to test some effects of low dose alcohol ingestion on visual tracking performance during angular acceleration, both with and without a secondary auditory task.

METHOD

Subjects

Forty-eight men were recruited from each of three age categories, 25 to 32, 40 to 47, and 55 to 62 years old, and assigned to experimental and control groups. All subjects were screened with the Cahalan, Crisin, and Crossley (1967) Quantity-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 requested not to consume any alcoholic beverages, including mixed drinks, beer, and wine on the day prior to participating in the experiment or during the test days. Three alcohol groups, one for each of the three age groups, included six subjects who held a pilot's license, and six subjects who were non-pilots.

Apparatus

Split unit tracking task and rotation device. This task has a divided attention component, and has previously been used to assess alcohol effects on performance in this laboratory (Collins et al., 1971). Components that were unique to this study were the inclusion of a secondary task involving auditory attention and the requirement to track both the horizontal needle, which was in the plane of eye movements; and the vertical needle, which was at a right angle to the horizontal needle. The needles moved independently of one another, and were constantly deflected by sinusoidal forcing functions; subjects were required to correct the deviations of both the horizontal and vertical needles. As the primary task, tracking was required in each of four trials during every session. The subject made compensatory adjustments by use of a joy stick with his dominant hand to keep the needles of the aircraft localizer/glide slope indicator in the center or null position, while experiencing a mild earth vertical axis acceleration in a darkened room. Deviations of the needles were considered errors, and were integrated over one-second intervals. The values were then summed and an average value was obtained for each session.

Illumination for the instrument was provided by a light that was projected through a tube to localize on the display, thereby minimizing reflection in the otherwise light free room. Voltage across the 3vDC light source was adjusted for a luminance of 1.0 ft-L, a level comparable to that recommended for use in aircraft displays at night. The light source calibration was verified using a Minolta Chroma Meter CS100. A second illumination level of 0.1 ft-L was used, which was produced by placing a Kodak Wratten gelatin 1.0 neutral density filter in front of the projected light source.

The angular stimulus was provided by a Stille-Werner RS-3 rotation device programmed for continuous motion using a triangular wave form that reached a peak rotation of 15 rpm in either direction at a rate of $15°/sec^2$. The chair was modified to include an enclosure to eliminate breeze cues to motion and was fitted with a head rest, which served as a reminder to the subjects to keep their heads upright and to ensure that the horizontal semicircular canals were positioned in the plane of motion.

Auditory Recognition Task. The secondary task was presented during two of the four primary rotation intervals. It consisted of listening to number strings comprised of three digits (e.g., 5-2-1) followed by a pause and then another string (e.g., 5-2-3). If the subject heard a string that was identical to the previously presented string, the subject pressed a thumb switch held in the non-dominant hand. Subject performance was scored for hits and false alarms. The number strings were created by combining randomly generated single digit numbers. The placement of identical strings was also determined by random numbers. One identical number occurred in each block of five numbers, yielding 12 identical number strings out of the 60 presented on each tape. Six, three-minute tapes were recorded on 3M Scotch AVC 30-minute audio-cassettes, and presented to the subjects in a counterbalanced order on a Califone (Model 5270B) cassette tape recorder/player. The tape recorder/player was attached to an external speaker located in the angular acceleration laboratory and played at a constant volume.

Alcohol Levels Alcohol levels were determined through use of a CMI, Inc. Intoxilyzer 5000, which measures breath alcohol content (BrAC) in terms of grams per 210 liters of air. Since BrACs are known to drop at approximately .004% every 15 minutes (Dubowski, 1985), and since the sessions were approximately 40 minutes in length, initial BrACs of 0.046%, 0.033%, and 0.020% were used in an attempt to have the desired BrACs of 0.04%, 0.027%, and 0.014% at the mid point between the start and completion of each alcohol testing session. Alcohol testing sessions all occurred on the descending limb of the alcohol curve, and were completed during the same afternoon.

Alcohol Consumption. Subjects were given 1.62 milliliters (mls) of 80 proof Smirnoff vodka per kilogram of body weight (.505 mg/kg), mixed with 300 mls of orange juice and divided into two drinks. Two, one-ounce scoops of crushed ice were added and the beverages were stirred immediately before being given to the subject. Each drink was consumed in 7.5 minutes. The alcohol amount was derived by multiplying the Moskowitz et al. (1985) formula by 1.15, after adjusting for using 80 proof instead of 40 proof vodka. There were a few subjects who did not reach the desired BrACs using this formula, in which case they were given a "booster" drink of .081 ml per kg of body weight (.025 mg/kg) — a modification of the Lentz and Rundell (1976) formula, corrected for using 80 proof instead of 95 per cent alcohol. Placebo drinks were the same volume as the alcohol drinks and consisted of an orange juice and water mixture with five mls of vodka floating on the top of each drink to provide an alcohol odor.

Procedure

The design implemented in this study consisted of eight experimental sessions in all, covering 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 tasks involved. They then read and signed a consent form, were weighed, and given breath tests to verify that they were not under the influence of alcohol before beginning the study.

Following sedentary participation in data collection for another study, subjects were returned to the Angular Acceleration Laboratory and entered the rotation device, where they received detailed instructions about this study. Subjects performed the compensatory tracking task in a darkened room, while undergoing mild angular acceleration. This task lasted 15 minutes and consisted of 4, three-minute trials. Two of the four trials were under the 1.0 ft-L illumination condition, the others under the 0.1 ft-L illumination. These trials were presented in a counterbalanced order across the eight experimental sessions. An experimenter entered the darkened room to remove or replace the filter in front of the light source to change illumination levels. Subjects were given one minute to readjust to the dark upon entering the rotation room, and after a change in illumination conditions. A 30-second rest period was given between trials in the same illumination condition. The secondary task was incorporated during one trial under each illumination condition.

Each session on Day 1 was followed by a 15-minute break, during which subjects could read magazines, watch television, or just relax quietly. No one was allowed to eat, drink, or smoke during the testing session on either of the test days.

Following completion of the 4th session, subjects were told to return at the same time the next day, 30 minutes after consuming a moderate lunch. They were also reminded not to consume any alcoholic beverages or medications that evening.

On the second day, each subject completed a baseline breath test upon arrival, followed by compensatory tracking session (pre-drinking). Subjects were then given 15 minutes to consume 2 drinks. Fifteen minutes after the second drink, the breath tests resumed and subjects were tested periodically until they had reached their peak and had dropped to a level of 0.046% on the descending limb of their blood alcohol curve. The initial post-drinking testing session was then administered. Breath tests continued until a BrAC of 0.033% was reached and the second post-drinking session was administered, followed by breath tests until a BrAC of 0.020% 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 BrAC of 0.00% was reached. Shortly thereafter, subjects were permitted to leave the test site.

Design and Analysis

Prior to analysis, all measures were examined through various Statistical Package for the Social Sciences (SPSS) programs for accuracy of data entry, missing values, and fit between their distributions and the assumptions of multivariate analysis. No missing values or outliers were found; therefore, no casewise deletion of scores was necessary. The alpha level was set at .05.

Three categories of age— younger, middle, and older with 12 subjects in each group— two levels of secondary task— absent and present— and two levels of illumination— high and low, were compared with SPSS across a pre-drinking (0.00) session and three levels of intoxication— 0.04, 0.027, and 0.014% BAL— in a mixed factorial doubly repeated multivariate analysis of variance (MANOVA) (Tabachnick and Fidell, 1989). There were four dependent measures: vertical and horizontal tracking error, and number of hits and false alarms on the secondary auditory task.

RESULTS

The data presented in this section are organized according to the type of localizer/glide slope tracking errors: average combined needle errors, vertical needle errors, or horizontal needle errors. Cell means and standard deviations are presented, along with data profiles for all statistically significant interactions and main effects. Detailed MANOVA source of variance tables are also included in this section.

Combined Needle Errors

Error measurements for both the vertical and horizontal needles were averaged creating an average combined error score. Cell means and standard deviations are listed in Tables 1 and 2 for the two levels of illumination. In the 4 groups of sessions (2 tasks by 2 levels of illumination) error increased with increasing

Table 1. Means and standard deviations for average (Avg) combined needle tracking errors under the 1.0 ft L. illumination condition at each of the pre- and post- drinking sessions.

Measure	Group		0.000%	0.040%	0.027%	0.014%
				Without secondary task		
Avg combined Errors	Y	M	102.04	122.65	98.54	93.42
		SD	42.28	50.72	30.62	27.38
	M	M	142.96	153.25	147.75	153.88
		SD	63.69	48.33	73.86	88.21
	O	M	165.70	213.33	159.54	154.88
		SD	51.57	62.82	49.89	50.36
				With secondary task		
Avg combined Errors	Y	M	104.08	120.92	101.96	96.88
		SD	30.52	55.50	37.51	25.56
	M	M	146.33	153.54	151.50	141.42
		SD	66.09	50.33	76.91	81.01
	O	M	179.42	222.70	170.12	165.75
		SD	63.27	83.18	56.44	56.35

Session header spans 0.040%, 0.027%, 0.014% columns.

Table 2. Means and standard deviations for average (Avg) combined needle tracking errors under the 0.1 ft L. illumination condition at each of the pre- and post- drinking sessions.

Measure	Group		0.000%	0.040%	0.027%	0.014%
				Without secondary task		
Avg Combined Errors	Y	M	186.67	190.29	167.25	148.00
		SD	75.96	78.25	78.24	52.13
	M	M	234.12	259.29	230.54	214.46
		SD	68.65	95.16	83.60	85.17
	O	M	260.54	296.54	257.83	250.75
		SD	75.77	83.70	81.21	70.03
				With secondary task		
Avg Combined Errors	Y	M	178.50	190.62	169.33	161.04
		SD	79.48	62.39	73.75	66.22
	M	M	239.54	245.17	227.33	216.50
		SD	59.37	88.03	85.30	96.19
	O	M	257.46	277.29	265.29	235.70
		SD	71.10	77.95	81.61	66.88

age in all cases. The younger age group evidenced lower mean error scores and less variablity than the older age group in all post-drinking sessions. Combined error means reached their peak in 11 of the 12 cases (2 tasks by 2 illumination levels by 3 age groups) at the 0.04% BrAC level.

1.0 ft L Level. Contrasting of the pre- and post-drinking sessions for 1.0 ft L illumination means, as depicted in Figures 1 and 2, suggests main effects on both session and age, but no age by session interaction. As seen in Table 3, main effects for both the age and session variables were revealed both with and without the secondary task. However, no statistically significant interaction was found either with or without the secondary task.

When tested for simple effects, the age variable without the secondary task yielded significant differences for all sessions. Using Tukey's Honestly Significant Mean Difference (HSD) posthoc analysis, mean differences were detected between the younger and older subjects at all pre- and post- drinking sessions, and between the younger and middle age subjects at the final session, the 0.014% level. Simple effects tests for sessions without the secondary task yielded statistically

Table 3. MANOVA source of variance table for averaged combined needle error under 1.0 ft L. illumination.

			SecondaryTask			
		Absent			Present	
Measure	MS	df	F	MS	df	F
			Main Effects			
Age	108141.12	2	5.22*	88508.89	2	4.50*
Between Error	2722.68	33		19643.13	33	
Session	12385.39	3	10.30**	6807.97	3	5.84**
Within Error	1202.79	99		1241.37	99	
			Interaction Effect			
Age X Session	681.38	6	.56	385.01	6	.31
Within Error	1202.79	99		1241.37	99	
			Simple Effects			
Session						
Younger	1969.71	3	2.63	1303.10	3	2.13
Error	748.40	33		611.71	33	
Middle	316.21	3	.38	355.69	3	.45
Error	830.22	33		796.56	33	
Older	8756.23	3	44.07**	8175.68	3	18.69**
Error	198.67	33		437.32	33	
Age						
0.00%	12490.36	2	4.41*	17109.36	2	5.52**
Error	2874.39	33		3100.49	33	
0.04%	25551.80	2	8.66**	32419.92	2	7.76**
Error	2951.74	33		4177.24	33	
0.027%	12563.01	2	4.24*	14895.92	2	4.25*
Error	2959.98	33		3502.63	33	
0.014%	14866.67	2	4.03*	14639.67	2	4.23*
Error	3689.32	33		3463.87	33	

* Significance level p<.05
** Significance level p<.01

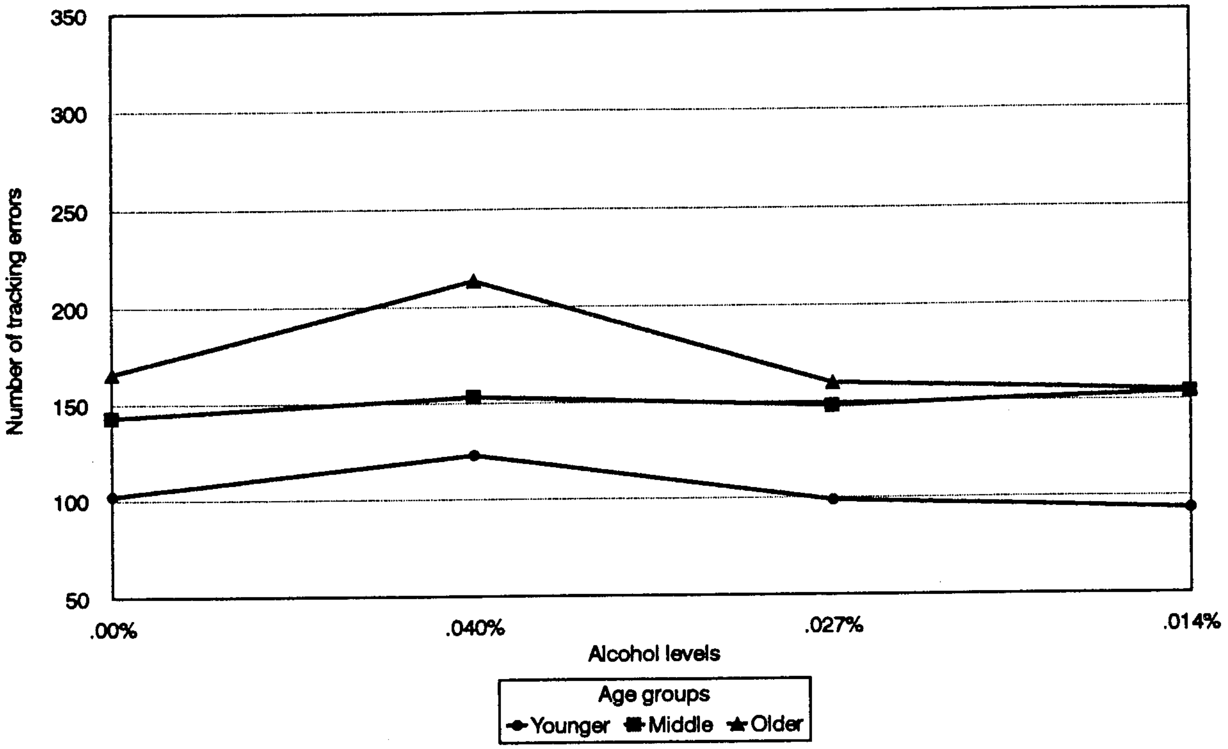

Figure 1. Average combined needle tracking error under 1.0 ft L illumination without the secondary task at each of the pre- and post- drinking sessions by age group

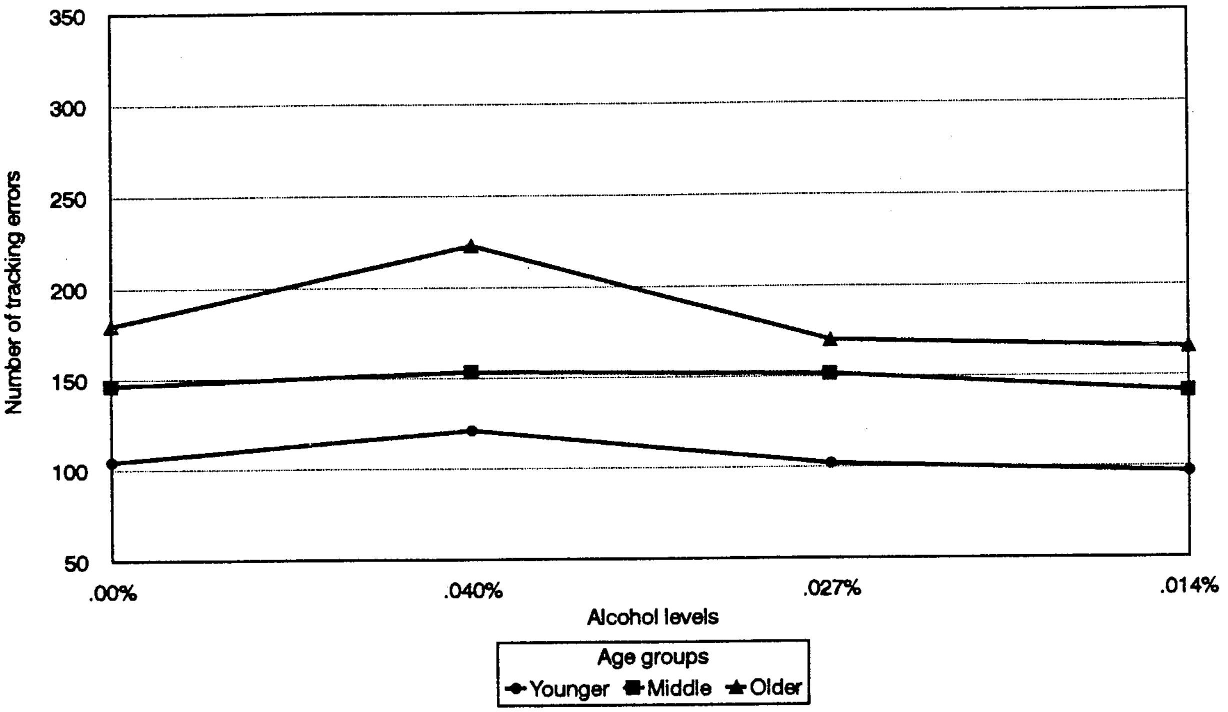

Figure 2. Average combined needle tracking error under 1.0 ft L illumination with the secondary task at each of the pre- and post- drinking sessions by age group.

significant differences for the older subjects only. Additional posthoc tests yielded significantly poorer performance for the 0.04% session when compared with all other sessions (see Figure 1).

The age variable with the secondary task, when tested for simple effects, demonstrated statistically significant differences at all pre- and post- drinking sessions. This was accounted for by statistically significant mean differences between the younger and older subjects for all sessions. The session variable with the secondary task was tested for simple effects, and revealed statistical significance only for the older age subjects. Further posthoc analysis yielded a significant mean difference between the 04% level (poorest performance) and all other pre- and post- drinking sessions (see Figure 2).

Table 4. MANOVA source of variance table for averaged combined needle error under 0.1 ft L. illumination.

			Secondary Task			
		Absen			Present	
Measure	MS	df	F	MS	df	F
			Main Effects			
Age	59308.65	2	5.56*	88508.89	2	4.50*
Between Error	10658.54	33		19643.13	33	
Session	6933.35	3	11.70**	6568.90	3	10.68**
WithinError	592.43	99		615.20	99	
			Interaction Effect			
Age X Session	2054.39	6	3.47*		1632.78	6
2.65*						
Within Error	592.43	99		615.20	99	
			Simple Effects			
Session						
Younger	4575.32	3	4.57**	1933.10	3	1.79
Error	1002.00	33		1078.87	33	
Middle	4128.24	3	2.30	1968.77	3	.97
Error	1791.55	33		2032.90	33	
Older	5044.60	3	6.19**	3676.13	3	6.00**
Error	814.82	33		612.37	33	
Age						
0.00%	16815.30	2	3.11	20563.02	2	4.14**
Error	2874.39	33		3100.49	33	
0.04%	34875.25	2	4.72*	4965.84	2	3.90**
Error	7395.02	33		5906.00	33	
0.027%	25912.02	2	3.94*	28025.67	2	4.34*
Error	6568.69	33		6458.34	33	
0.014%	32582.72	2	6.57**	18039.40	2	2.99*
Error	4958.64	33		6037.01	33	

* Significance level $p <$ 05
** Significance level $p <$ .01

Figure 3. Average combined needle tracking error under 0.1 ft L. illumination without the secondary task at each of the pre- and post- drinking sessions by age group.

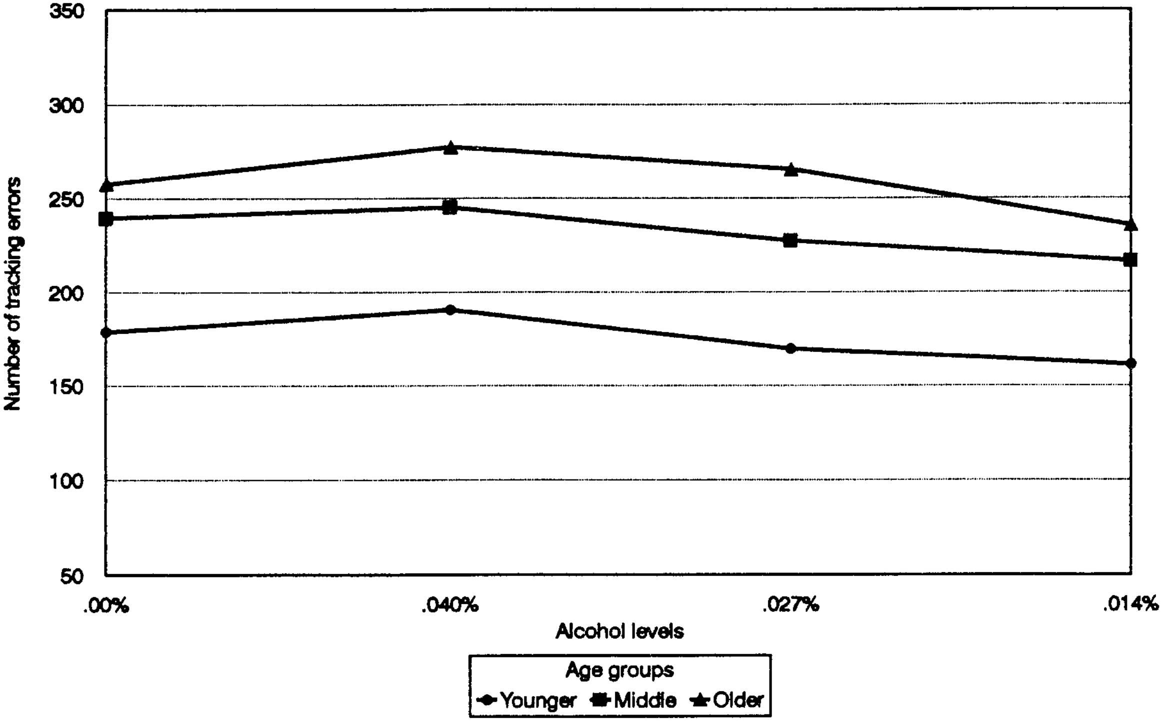

Figure 4. Average combined needle tracking error under 0.1 ft L. illumination with the secondary task at each of the pre- post- drinking sessions by age group.

Table 5. Means and standard deviations for vertical needle tracking error under the 1.0 ft L. illumination condition at each of the pre- and post-drinking sessions.

				Session		
Measure	Group		0.000%	0.040%	0.027%	0.014%
				Without secondary task		
Vertical Errors	Y	M	114.42	136.17	110.08	104.33
		SD	46.12	65.48	36.84	37.45
	M	M	145.42	161.08	137.00	139.25
		SD	75.74	66.59	59.74	77.97
	O	M	164.17	228.67	163.50	162.58
		SD	66.34	59.85	61.96	58.90
				With secondary task		
Vertical Errors	Y	M	114.58	140.50	114.83	106.83
		SD	37.14	69.49	46.63	29.41
	M	M	150.83	161.50	146.41	127.33
		SD	72.81	63.52	60.84	64.61
	O	M	178.08	244.00	173.42	179.08
		SD	78.55	93.93	70.19	73.25

Table 6. Means and standard deviations for vertical needle tracking error under the 0.1 ft L. illumination condition at each of the pre- and post- drinking sessions.

				Session		
Measure	Group		0.000%	0.040%	0.027%	0.014%
				Without secondary task		
Vertical Errors	Y	M	211.17	206.42	185.58	166.00
		SD	86.89	91.40	92.48	64.90
	M	M	247.75	273.33	241.91	225.42
		SD	95.27	118.03	101.94	95.72
	O	M	272.25	328.92	256.92	256.75
		SD	87.85	120.03	91.83	79.69
				With secondary task		
Vertical Errors	Y	M	190.17	201.75	185.17	174.92
		SD	80.44	66.28	82.28	77.76
	M	M	264.25	249.17	227.42	213.58
		SD	101.68	100.54	83.62	84.49
	O	M	256.08	294.83	265.08	244.50
		SD	80.09	85.04	85.37	81.95

0.1 ft L. level. Comparing the combined needle error profiles for the 0.1 ft L. illumination condition, depicted in Figures 3 and 4, an interaction between the age and session variables is suggested both with and without the secondary task. This illumination condition yielded significant main effects for the variables age and session, and a statistically significant interaction effect for the same variables, both with and without the secondary task, as listed in Table 4.

Simple effects test without the secondary task for the age variable yielded statistically significant age differences at all of the post-drinking levels. The Honestly Significant Differences test revealed statistically significant mean performance differences favoring the younger over the older subjects at all post-drinking levels.

Simple effects tests performed for the session variable showed statistically significant sessions effects for both the younger and older age groups. However, further HSD posthoc analysis revealed no significant mean differences for either age groups at any individual session.

Simple effects tests performed for the age variable with the secondary task present revealed statistically significant age differences at all pre- and post- drinking levels. Mean differences favored the younger over the middle and older age subjects at all pre- and post-drinking levels.

Simple effects tests for the sessions variable yielded statistically significant differences in the older age group. Further HSD posthoc analysis revealed statistically significant mean differences between the 0.04% level (poorest performance) and all other pre- and post- drinking levels

Vertical Needle Errors

Cell means and standard deviations for vertical needle errors under both illumination conditions are listed in Tables 5 and 6. Comparisons of the pre- and post- drinking sessions for 1.0 ft L illumination means, as depicted in Figure 5, suggest an age by alcohol interaction.

1.0 ft L. level. As seen in Table 7, statistically significant main effects for both age and session and an age by session interaction were revealed under 1.0 ft L. illumination without the secondary task. Simple effects tests yielded statistically significant age differences for the .04% alcohol level, whereas all other sessions showed no statistically significant age effects. HSD post hoc analysis yielded statistically significant mean performance differences favoring both the younger and middle age groups over the older age group (see Figure 5). Although the younger and middle-age groups did not differ in average vertical needle tracking error under the 1.0 ft L. illumination conditions, in the 8 groups of sessions (2 tasks by 4 sessions), errors increased consistently with increasing age in all cases; simple effects tests showed a statistically significant sessions effect in the older age group. HSD post hoc tests revealed a statistically significant increase in error at the 0.04% alcohol level when compared to all other pre- and post- drinking alcohol level means for the older age group. While Figures 5 and 6 reveal that the average tracking error scores at the .04% alcohol level for each group were above the respective pre-drinking level, the older age group exhibited the greatest change in performance and accounted for the age by alcohol interaction effect.

As seen in Table 7, the MANOVA results for the 1.0 ft L. illumination condition plus the secondary task are consistent with results obtained in the absence of the secondary task, with statistically significant main effects on both age and session and an age by session interaction. Simple effects tests yielded statistically significant age effects at both the 0.04% and 0.014% alcohol levels. At the 0.04% alcohol level, HSD posthoc analysis showed statistically significant mean performance differences favoring both the younger and middle age groups over the older group. At the 0.014% alcohol level, HSD post hoc analysis yielded statistically significant mean performance differences only between the younger and older age group means (see Figure 5).

Simple effect tests indicated statistically significant session effects for both the middle and older age groups. HSD post hoc tests showed statistically significant increases in error at the 0.04% level when compared to all other pre- and post- drinking session means for the older age group. However, post hoc analysis failed to reveal any statistically significant mean differences across pre- and post- drinking alcohol levels for the middle age group. The older age group means at

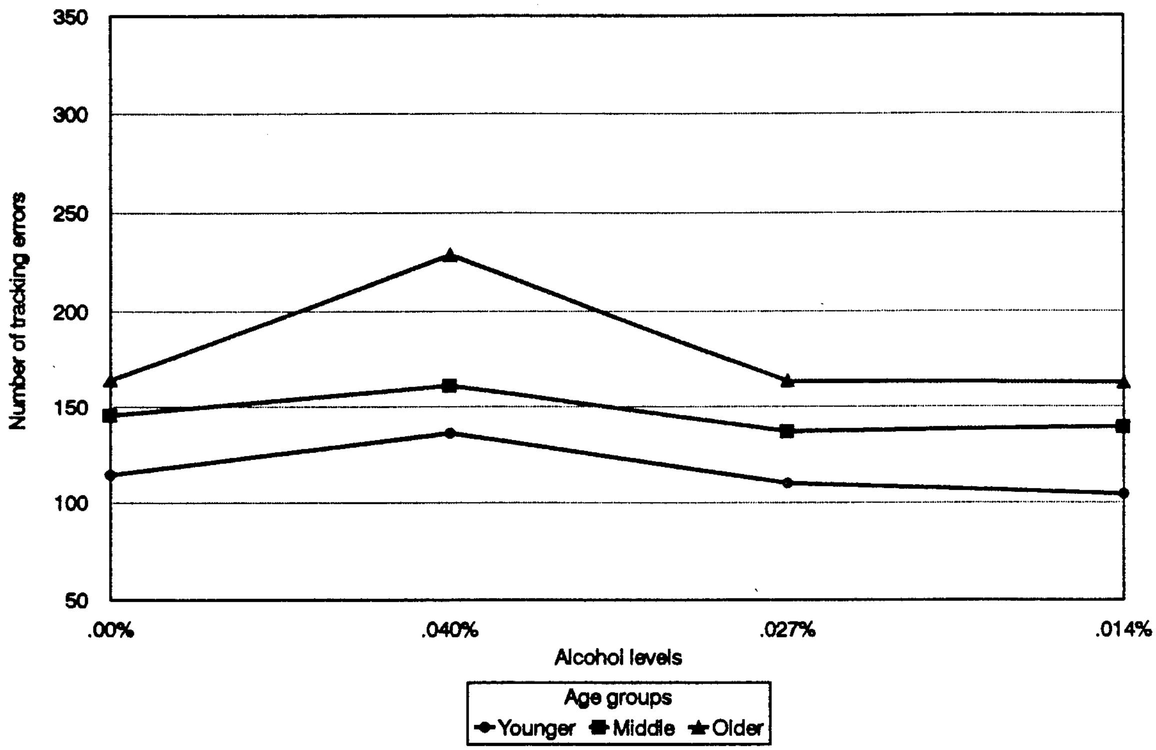

Figure 5. Vertical needle tracking error under 1.0 ft L illumination without the secondary task at each of the pre- and post- drinking sessions by age group.

Figure 6. Vertical needle tracking error under 1.0 ft L illumination with the secondary task at each of the pre- and post- drinking sessions by age group.

the 0.04% level accounted for most of the age by sessions interaction effect under 1.0 ft L. illumination with the secondary task.

0.1 ft L. level. Cell means and standard deviations for vertical needle tracking errors under 0.1 ft L. illumination were presented in Table 6. Figures 7 and 8 depict the pre- and post- drinking changes in tracking errors under the 0.1 ft L. illumination condition both with and without the secondary task.

MANOVA results for vertical needle tracking error under 0.1 ft L. illumination without the secondary task, as displayed in Table 8, yielded statistically significant age and session main effects. However, no age by session interaction was shown.

Simple effects tests conducted on the age variable indicated statistically significant effects at the 0.04% and 0.014% alcohol level. HSD posthoc analysis

Table 7. MANOVA source of variance table for vertical needle error under 1.0 ft L. illumination.

	Secondary Task					
	Absent			Present		
Measure	MS	df	F	MS	df	F
Main Effects						
Age	48432.55	2	3.95*	68095.36	2	4.78*
Between Error	12273.67	33		14254.61	33	
Session	12814.43	3	15.45**	13991.90	3	14.02**
Within Error	829.46	99		997.98	99	
Interaction Effect						
Age X Session	1835.61	6	2.21*	2318.39	6	2.32*
Within Error	829.46	99		997.98	99	
Simple Effects						
Session						
Younger	2320.28	3	2.07	2588.02	3	2.55
Error	1121.28	33		1014.78	33	
Middle	1387.64	3	2.28	2444.58	3	3.85*
Error	608.35	33		634.70	33	
Older	12777.74	3	16.84**	13596.08	3	10.11**
Error	758.74	33		1344.47	33	
Age						
0.00%	7575.25	2	1.85	12177.75	2	2.84
Error	4088.47	33		4283.50	33	
0.04%	27498.19	2	6.70**	35919.00	2	6.09**
Error	4101.19	33		5895.88	33	
0.027%	8561.58	2	2.93	10317.03	2	2.86
Error	2921.90	33		3600.95	33	
0.014%	10313.36	2	2.82	16636.75	2	4.80*
Error	3650.48	33		3468.22	33	

* Significance level p < .05

** Significance level p < .01

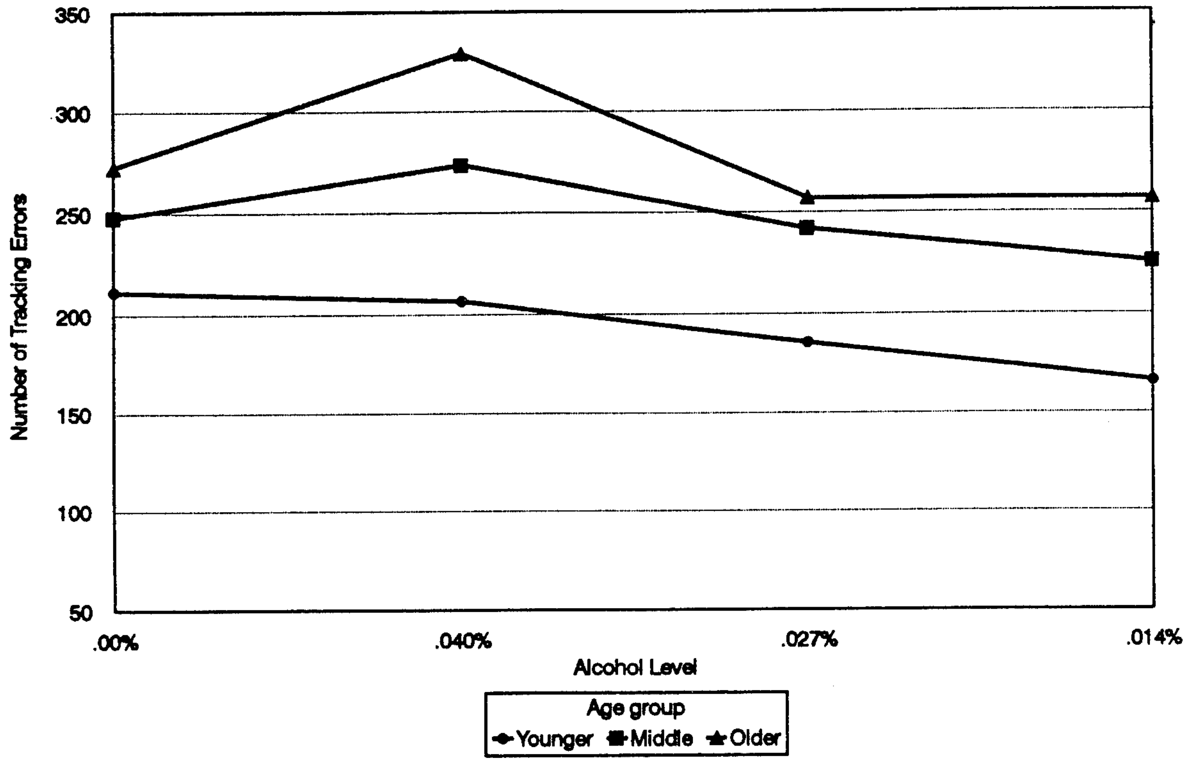

Figure 7. Vertical needle tracking error under 0.1 ft L illumination without the secondary task at each of the pre- and post- drinking sessions by age group.

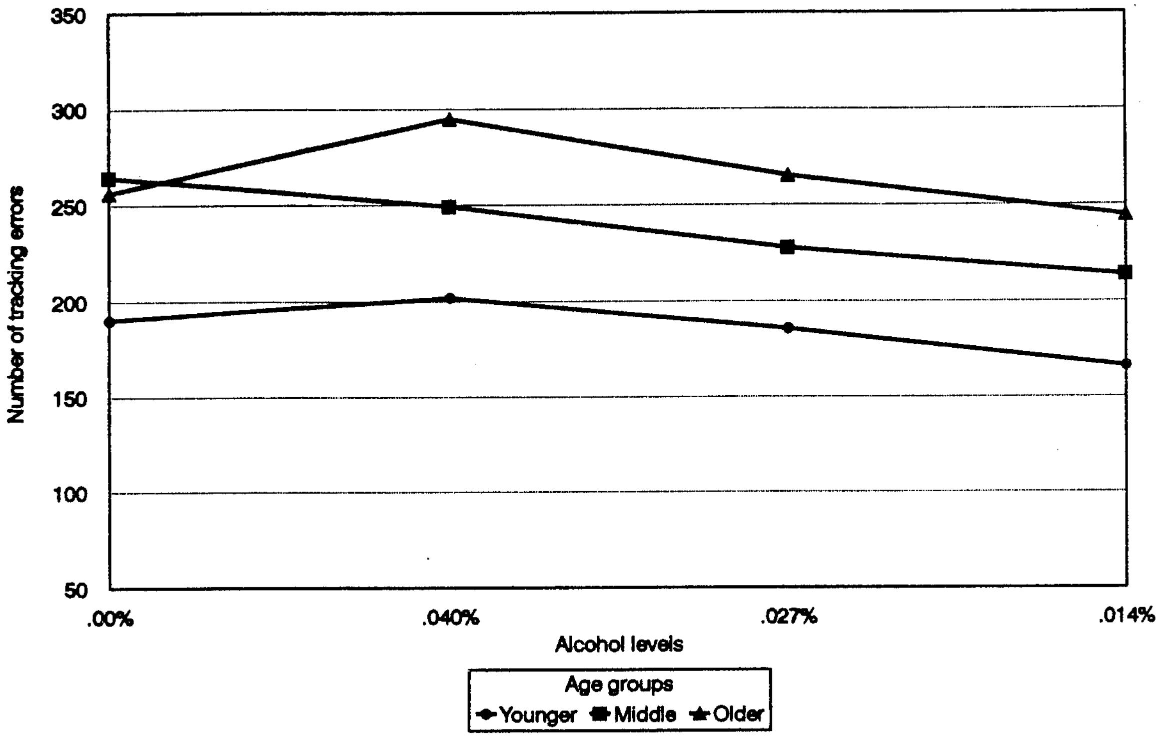

Figure 8. Vertical needle tracking error under 0.1 ft L illumination with the secondary task at each of the pre- and post-drinking sessions by age group.

showed statistically significant mean performance differences favoring younger over the older age group for both sessions.

Simple effects analysis of pre- and post drinking sessions revealed statistically significant effects for the younger and older age groups. However, due to within subject variability, HSD posthoc analysis failed to detect any significant mean session differences for either the younger or older age group means (see Figure 7). It is noteworthy that for the younger and middle age groups, the highest error scores were recorded during the 0.04% session.

As shown in Table 8, the MANOVA results for vertical needle tracking error under 0.1 ft L. illumination with the secondary task showed significant main effects for both age and session. However, no significant age by session interaction was detected. Simple effects analysis revealed significant sessions effects at the

Table 8. MANOVA source of variance table for vertical needle error under 0.1 ft L. illumination.

	Secondary Condition					
	Absent			**Present**		
Measure	MS	df	F	MS	df	F
			Main Effects			
Age	91768.59	2	3.10*	73699.21	2	3.10*
Between Error	29616.36	33		23722.97	33	
Session	19197.73	3	8.96**	9223.28	3	5.63**
Within Error	2143.20	99		1638.05	99	
			Interaction Effect			
Age X Session	2395.76	6	1.12	1954.69	6	1.19
Within Error	2143.20	99		1638.05	99	
			Simple Effects			
Session						
Younger	5168.14	3	3.78*	1491.83	3	1.16
Error	1365.79	33		1286.80	33	
Middle	4742.58	3	2.05	6081.93	3	2.65
Error	2308.65	33		2294.76	33	
Older	14078.53	3	5.11**	5558.92	3	4.17*
Error	2755.15	33		1332.58	33	
Age						
0.00%	11339.53	2	1.39	19800.08	2	2.56
Error	8114.79	33		7741.42	33	
0.04%	45147.19	2	3.69*	25996.58	2	3.58**
Error	12230.08	33		7244.41	33	
0.027%	16973.78	2	1.86	19181.03	2	2.73
Error	9126.43	33		7017.26	33	
0.014%	25495.36	2	3.87*	14585.58	2	2.19
Error	6574.94	33		6634.02	33	

* Significance level p < .05
** Significance level p < .01

Table 9. Means and standard deviations for horizontal needle tracking error under the 1.0 ft L. illumination condition at each of the pre- and post-drinking sessions.

				Session		
Measure	Group		0.000%	0.040%	0.027%	0.014%
				Without secondary task		
	Y	M	89.67	109.08	87.00	82.50
		SD	40.59	40.25	28.55	22.24
Horizontal Errors	M	M	140.50	145.41	158.08	168.50
		SD	112.80	72.27	133.08	143.06
	O	M	167.25	198.00	155.58	147.17
		SD	88.08	84.76	84.50	54.83
				With secondary task		
	Y	M	93.58	101.33	89.08	86.92
		SD	30.10	44.34	30.97	44.34
Horizontal Errors	M	M	141.83	145.58	156.58	155.50
		SD	115.58	75.21	148.61	146.29
	O	M	180.75	201.42	166.83	137.50
		SD	99.60	88.43	88.11	70.73

Table 10. Means and standard deviations for horizontal needle tracking error under the 0.1 ft L. illumination condition at each of the pre- and post- drinking sessions.

				Session		
Measure	Group		0.000%	0.040%	0.027%	0.014%
				Without secondary task		
	Y	M	162.17	174.17	148.92	130.00
		SD	68.37	67.96	66.70	46.77
Horizontal Errors	M	M	220.50	245.25	219.17	203.50
		SD	86.14	83.79	131.31	122.43
	O	M	248.83	264.17	258.75	244.75
		SD	77.07	83.06	103.91	83.38
				With secondary task		
	Y	M	166.83	179.50	153.50	147.17
		SD	83.25	62.68	70.25	59.32
Horizontal Errors	M	M	214.83	241.17	227.25	219.42
		SD	86.57	117.37	148.83	157.33
	O	M	258.83	259.75	265.50	265.50
		SD	87.10	83.14	106.21	92.36

0.04% alcohol level. HSD posthoc tests showed significant mean performance differences favoring the younger over the older age group, similar to that obtained without the secondary task.

Simple effects tests showed significant session effects for the older age group. However, due to within subject variability, HSD posthoc tests failed to detect any significant mean differences between sessions (see

Figure 8), although the highest error scores were detected for both the older and younger groups, during the 0.04% session.

Horizontal needle errors

Error measurements for the horizontal needle alone, when analyzed using a MANOVA, yielded no significant results for any of the comparisons (i.e., neither 1.0 or 0.1 ft L. illumination, with or without the secondary task). Since no significant main effects were obtained, no further analysis was performed on the horizontal error measurements. Cell means and standard deviations are listed in Tables 9 and 10. In the 16 groups of sessions (2 levels of illumination by 2 tasks by 4 sessions), error consistently increased with increasing age in 13 cases. The younger age group consistently evidenced lower mean tracking error scores and less variability in performance than either the middle or older age groups. Mean tracking error scores for the older subjects were also generally higher than those of the middle age subjects. Horizontal error means reached their peak at the 0.04% BrAC level in 9 of 12 cases (4 sessions by 3 age groups), which, although not statistically significant, suggests an alcohol effect trend in the direction similar to that obtained for the vertical needle. Despite the lack of statistical significance for these measures, the trends in the data, with respect to the main effects of session and age, were consistent with those evident for the vertical needle.

Secondary Task

Tables 11 and 12 display the complete cell means and standard deviations for secondary task measures. The difference in group means was less than 1 for all sessions on both hits and false alarms. No statistically significant results were evident in the MANOVA.

DISCUSSION

Tracking Performance. The present study introduced an additional (i.e., glide slope) needle to the tracking task used in previous studies in this laboratory (Collins, Schroeder, Gilson & Guedry, 1971; Gilson, Schroeder, Collins & Guedry, 1971; Schroeder, 1971; Schroeder, Gilson, Collins, & Guedry, 1972). The subjects were free to choose a strategy as to how they would attend to the simultaneously moving needles. Subjects' performance errors seemed to indicate that they alternated attention between the needles. Analyses were performed on combined needle errors and on individual needle errors.

The 0.1 ft L. illumination condition appeared to present a significant challenge for subjects in this study, especially those in the middle and older age groups. This was the only condition to evidence a significant session and age interaction for the averaged combined needle errors. When investigating vertical needle error, the increase in error rates and variability associated with the task under these conditions tended to reduce the potential significance of any findings. Several subjects reported that the horizontal needle was easier to see and indicated that they had difficulty tracking the vertical needle, perhaps due to acceleration-induced ocular nystagmus in that plane of motion.

The influence of the secondary task appeared to be limited. Subjects demonstrated slightly higher average tracking errors when asked simultaneously to track and perform the secondary task. However, there was little evidence that alcohol had a more profound effect when workload was increased in this manner. It may be that the auditory task was sufficiently distinct with regard to the basic eye-hand coordination task, or that accuracy on the secondary task could be maintained at the expense of speed of response. Since our measures for the secondary task all involved simply the detection of the repeated number string, we are unable to determine if any response slowing had occurred.

Age. Combined needle tracking errors demonstrated differences in the performance rate between the younger and older age groups in all pre- and post-drinking sessions. Younger age subjects performed better than the middle age group at all pre- and post drinking sessions under the low illumination level condition with the secondary task.

Separate analyses were conducted on the individual needle errors. The vertical needle errors yielded statistically significant results. Vertical needle error outcomes are also supportive of findings by Collins and

Table 11. Means and standard deviations for hits and false alarms on secondary task under the 1.0 ft L. illumination condition at each of the pre- and post- drinking sessions by age group.

			Alcohol Condition			
Measure	Group		0.000%	0.040%	0.027%	0.014%
Hits	Y	M	10.50	10.50	10.83	10.58
		SD	1.38	1.51	1.75	1.44
	M	M	10.50	10.25	10.00	10.67
		SD	2.02	1.76	2.34	1.92
	O	M	10.83	10.25	10.75	10.83
		SD	1.34	1.76	1.38	1.27
False Alarms	Y	M	.33	.58	.50	.67
		SD	.65	.79	.67	1.07
	M	M	.17	.50	.67	.33
		SD	.40	1.00	1.03	.88
	O	M	.83	.33	.58	.83
		SD	1.19	.78	.90	1.40

Table 12. Means and standard deviations for hits and false alarms on secondary task under the 0.1 ft L. illumination condition at each of the pre- and post- drinking sessions by age group.

			Alcohol Condition			
Measure	Group		0.000%	0.040%	0.027%	0.014%
Hits	Y	M	10.57	10.25	10.08	11.00
		SD	.77	1.71	1.44	.95
	M	M	9.75	10.50	9.92	10.50
		SD	1.91	9.92	2.71	1.68
	O	M	10.17	10.08	10.50	11.33
		SD	1.80	1.83	1.68	.78
False Alarms	Y	M	.83	1.00	.92	.67
		SD	.71	1.04	1.08	.65
	M	M	.50	.42	.42	.33
		SD	.80	.90	.90	.49
	O	M	1.33	.58	1.00	.33
		SD	1.61	.79	1.35	.49

Mertens (1988) and Linnoila, et al., (1980), indicating that there are age-related differences in the effects of alcohol on performance. While there was evidence of an alcohol effect on performance of each of the three age groups (younger, middle, and older), the effects associated with vertical needle tracking were more prominent for older subjects. Differences in the effects of alcohol on performance as a function of age were evident under both illumination conditions. Although no significant findings were obtained on the horizontal needle errors, the trend of the results was in the same direction as that obtained for the vertical needle.

Alcohol. These data support previous research (Collins et al., 1971; Gilson and Guedry, 1971; and Gilson, et al., 1971) in demonstrating that compensatory tracking performance during motion is impaired at 0.04% blood alcohol levels. The current findings were evidenced on averaged combined needle errors under the 0.1 illumination condition with the secondary task, and under both the 1.0 and 0.1 ft L. illumination conditions both with and without the secondary task for vertical needle errors. The results failed to support a previous finding (Gilson et al., 1971) of tracking performance impairment at blood alcohol levels below 0.04%.

The alcohol effect for the averaged combined needle errors was demonstrated by older age subjects, under the 0.1 ft L. illumination level with the secondary task, and at the highest BrAC level, 0.04%, in the study. An alcohol effect on the same task was demonstrated generally by the younger subjects; however, their within group variability eliminated any statistically significant mean differences. This may suggest that at .04% BrAC the performance of individuals within the same age group may vary to the point that potential alcohol effects are obscured in group data. These alcohol related findings were similar under the 1.0 ft L. illumination condition, in that significant alcohol effects were found at the 0.04% level involving the older subjects, but only with the secondary task present. Moreover, although not statistically significant, the poorest performance for the younger and middle age groups also occurred during the 0.04% session in all but one case.

Although we did not obtain eye movement measures of alcohol related changes in the nystagmus associated with the angular motion, performance outcomes for vertical needle errors are supportive of the role of increased nystagmus, which occurs in response to angular motion following alcohol consumption. This was inferred from the findings that, while there was a significant increase in compensatory tracking errors associated with deviations of the vertical needle on the instrument, tracking errors associated with deviations of the horizontal needle did not demonstrate significant impairment. However, an alcohol trend was evident on horizontal needle outcomes in that mean performance errors on the 0.04% post-drinking session were consistently above the respective pre-drinking level.

Age by alcohol interaction. An age by alcohol interaction was present in four of the eight cases considered for combined and vertical needle tracking. In three of those cases, (all related to vertical needle error), no age effects were present for the pre-drinking session. All cases where an age by alcohol interaction was present, were accounted for by the 0.04% alcohol level and the older age group. The 0.04% alcohol level had more of an effect on performance in older age subjects, when compared to middle age or younger subjects.

Summary. This study demonstrated statistically significant main effects of age and alcohol. Older subjects performed more poorly than younger or middle age group subjects on the combined localizer/glide slope tracking; the 0.04% alcohol level session was found to be the most difficult for all subjects, particularly older subjects. Vertical needle errors yielded similar statistically significant main effects and an interaction effect, with and without the secondary task under 1.0 ft L. illumination conditions, when instrument needle movement was in the plane of the horizontal eye movements (vertical needle), but not when needle movement occurred at a 90 degree angle to the eye movement (horizontal needle). While eye movement measures were not gathered in this study, in earlier reports (Gilson and Guedry, 1971; Gilson et al., 1971) angular motion following alcohol ingestion resulted in an increase in horizontal eye movements (nystagmus) that increased blurring of the instrument, resulting in a degradation in tracking performance. It seems reasonable to infer that the same mechanism was present in this study and played a significant role in the increased tracking error. The presence of a secondary task slightly strengthened the effect seen; however, it was statistically significant only when needle errors were combined under the 0.1 ft L. illumination condition. The number of tracking errors increased with the subjects' age and BrAC levels. The older age group at the 0.04% level accounted for most of the age and sessions effects. For subjects in these three groups, there was little evidence of performance decrement associated with BrACs below 0.04%.

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