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16. Abstract

Eight private pilots (four men, four women) were trained to perform on a two-dimensional tracking task (joystick control of a localizer/glideslope instrument) and to respond as quickly as possible to the onset of a red pinlight, appended to the tracking instrument, by depressing a button on the joystick. Tracking and reaction time scores were obtained under both static (stationary) and dynamic conditions (during angular acceleration), at ground level and at a simulated altitude of 12,000 ft. Subjects were tested in pairs one night per week for 3 consecutive weeks (alcohol, placebo, and sleep control sessions). Sessions began at about 1700, continuing through midnight to about 1100 the next day. Subjects performed in the evening after a monitored dinner, drank prepared beverages from 2100 to midnight, and were tested again. Subjects slept 4-5 hours, were awakened around 0645, were fed, and performed the tasks again, beginning about 0730. Ground level test sessions always preceded ascent in the altitude chamber and sessions included completion of several questionnaires and rating forms by the subjects.

At midnight following alcohol ingestion (3.25 ml of 100-proof alcohol per kg of body weight), peak breath alcohol levels averaged 91 mg percent. Impairment in tracking performance and in visual reaction time occurred during midnight sessions following alcohol ingestion. While ratings of hangover and other questionnaire data indicate awareness of hangover symptoms, no hangover-related performance impairment was recorded during morning sessions. In addition, no significant altitude/alcohol interactions on performance were obtained during either acute intoxication or hangover periods. These results offer no evidence contrary to the "8-hour rule."

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PERFORMANCE EFFECTS OF ALCOHOL INTOXICATION AND HANGOVER AT GROUND LEVEL AND AT SIMULATED ALTITUDE

Introduction.

Impairment of performance due to the ingestion of alcohol depends in part on the blood alcohol levels (BAL) produced and on the ability requirements of the task (18). Acute alcohol intoxication has been demonstrated to have deleterious effects on flying tasks, both in simulators (1,12,13) and in flight (2). These studies (1,2,12,13) and others suggest that decrements not only in the performance of flying tasks but also in the "time of useful consciousness" following acute exposure to high altitude (24) can be anticipated at BALs below 50 mg percent.

Because the oxygen uptake of tissue cells is reduced both by alcohol (histotoxic hypoxia) and in a different way by altitude (hypoxic hypoxia), a synergistic interaction of the effects of alcohol and of altitude on performance might be expected. Based primarily on his own studies (21,22) and one by Newman (25), McFarland (20) concluded, "Thus if an airman ascends to even a moderate altitude with alcohol in his blood, he would be especially vulnerable to the effects. For example, the alcohol in two or three cocktails would have the physiological action of four or five drinks at altitudes of approximately 10,000 to 12,000 ft." Also, "Airmen should be informed that the effects of alcohol are similar to those of oxygen want and that the combined effects on the brain and nervous system are significant at altitudes even as low as 8,000 to 10,000 ft." These conclusions have been perpetuated through physiological training courses of both military and civilian pilots.

However, Higgins et al. (14) assessed performance in an altitude chamber with reaction time and motor coordination tests at ground level, 12,000 ft, and 20,000 ft (the latter with supplemental oxygen) at several intervals during a 4-h period after subjects ingested alcohol (either 1.25 or 2.50 cc of 100-proof bourbon per kg of body weight) with no significant results. The performance tests were insensitive to the main effects of either altitude or alcohol level.

Pearson (26) assessed alcohol-hypoxia effects on performance comparing ground level to 12,000 ft (simulated) over 10-h periods. In a complex design that involved several types of tasks and replications of each condition, there were no significant main effects for alcohol (the mean peak BAL was 85 mg percent) and no significant interactions involving both alcohol and altitude. As noted by Pearson (26), both design and replication factors may have confounded possible effects suggested by trends in the data.

Tests conducted several hours after alcohol ingestion permit an assessment of possible effects of so-called hangover periods on performance. In general, studies designed to assess hangover effects have yielded no effects (7,9,15) or have reported mixed results (16,23,27,29). With regard to the latter, for example, Takala et al. (29) compared performance of four types of tasks (a 3-h test battery) under control, brandy-ingestion, and beer-ingestion conditions. Significant impairment occurred with all tests immediately after the 2½-h period of alcohol consumption, but the following morning (12½ h after drinking), in comparisons with the control condition, scores for the brandy condition were the same while scores for the beer condition were significantly poorer for one test (spatial relations) and better for another (manual dexterity). In contrast, a recent study by Bonte and Volck (3) reports motor performance decrements during hangover periods (16 h after the start of drinking) for three groups of subjects (the groups had mean peak BALs of 144, 165, and 205 mg percent and hangover BALs of 1, 25, and 94 mg percent, respectively). Drinking times ranged from 6 to 8 h. Although the absence of a control group might raise questions about the interpretation of the data for two of the groups, the third group appears clearly to have had performance deficits during hangover, but that group's BAL averaged 94 mg percent at that time.

The possible effects of altitude on performance during hangover periods were specifically investigated by Carroll, Ashe, and Roberts (5), who used pilots aged 23-31 and a task that involved both tracking a moving point source and canceling lights displayed in the peripheral visual field. Subjects were given a premixed orange juice/alcohol mixture, drank it at home within a 1-h period in the evening, and were tested 10 h later in an altitude chamber. Conditions for each subject included three dose levels (35, 70, and 105 cc of 95 percent pure alcohol), a placebo, and 15 min of performance at each of three altitudes (ground level, 8,000 ft, and 12,000 ft). Although no data are presented (and there is no apparent demonstration of the sensitivity of the device to acute alcohol effects), the authors report no statistically significant detrimental effects on performance. Subjective hangover symptoms were noted as having occurred most frequently in the high-dose condition.

The present study was a followup to a previous study (7) that assessed tracking performance and several other variables (i) immediately following alcohol ingestion and (ii) 8 h after drinking. That study also assessed possible differential effects of congener vs. noncongener alcoholic beverages. Although subjects showed performance impairment during acute intoxication (average peak BALs were 93 mg percent), there were no hangover effects on performance and no congener vs. noncongener differences. These laboratory results thus offered no evidence contrary to Federal Aviation Regulation 91.11, which states in part that no one may act as a crewmember of a civil aircraft within 8 h after the consumption of any alcoholic beverage or while under the influence of alcohol (the so-called "8-hour rule"). The present study examined the further possibility that performance decrements might be enhanced at a simulated altitude of 12,000 ft during acute alcoholic intoxication and that altitude might interact with hangover malaise to result in impaired performance 8 h or so after drinking.

Method.

Subjects. Eight active general aviation pilots (four men, four women) ranging in age from 22 to 55 years (mean, 39.6 years) served as subjects. All subjects had participated with several other pilots in our previous study described above (7), and so were experienced in performing the task protocol. All represented themselves as light-to-moderate drinkers of alcohol who would have no trouble handling five or so ordinary-sized drinks of liquor in an evening. Their flying time ranged from 160 h to 20,000 h (overall mean = 4,383; mean for men = 6,664; for women = 390) and they were variously certificated as commercial pilots, flight instructors, and private pilots. The subjects volunteered to spend one night a week for several consecutive weeks in the laboratory from 1700 to approximately 1200 the next day.

Alcohol. Two kinds of drinks were provided the subjects. Each drink contained either a 100-proof alcoholic beverage or a trace of rum extract and food coloring (placebo), each mixed with 7-Up. The amounts of alcoholic beverage given were 3.25 ml per kg of body weight which was equally divided into four large drinks. Drinks contained two parts of 7-Up for each part of alcohol; placebo drinks were equivalent in volume but contained only 7-Up diluted by water in place of the alcohol plus a few drops of extract and coloring. Half the subjects received alcohol during the first week and placebo the next week; that order was reversed for the remaining subjects. During the last week (sleep control), all subjects had the placebo drink. Subjects were told that they would be receiving "some" alcohol in every drink.

Breathalyzer readings were taken from an Omicron Intoxilyzer before drinking began (about 1945), immediately after the drinking period ended (midnight), and the following morning (about 0800).

Tracking Task. Each subject performed a two-dimensional compensatory tracking task while exposed to angular acceleration (dynamic mode) and while stationary (static mode). The order in which subjects performed static and dynamic tracking was alternated each day. Tracking was performed at ground level and at 12,000 ft in an altitude chamber. The tracking task system consisted of an aircraft localizer/glide slope indicator and a joystick. The vertical and horizontal needles of the indicator were deflected by individual sinusoidal forcing functions with 15-s periods. The instruction was given to keep the needles in the centered or null positions by compensatory movements of the joystick; the task was similar to that used in previous studies (7,8, 10) but the joystick control was intentionally less sensitive, i.e., there was a slight lag built into the joystick-controlled modification of needle deflections. The integrated tracking errors for localizer and glide slope deviations were recorded on separate channels of a Beckman Type T electroencephalograph.

An enclosed Vertigon rotation device (6) provided the angular stimulation. The rotation was programed by modifying the internal circuitry of the Vertigon to provide a triangular waveform stimulus with a period of 48 s and a peak velocity of $\pm 120^{o}/s$. The chamber was in total darkness throughout the testing session with the exception of a light source that was focused on the tracking instrument to provide 1.0 fL of illumination. Immediately after tracking at ground level and at altitude, subjects rated their effort (0-25 percent, 26-50 percent, 51-75 percent, 76-90 percent, 91-100 percent) and gave a self-appraisal of their performance (very poor, below average, average, very good, excellent) on a 5-point rating scale, separately for static and dynamic conditions.

Reaction Time Task. A small red pinlight was attached to the localizer/glide slope indicator, approximately 6 in from the edge of the instrument at the 2 o'clock position. The light was turned on during the tracking task at random, once in every 30-s interval. A pushbutton control at the top of the joystick enabled the subject to react to the illumination of this light; depressing the button turned out the light. The onset and duration (maximum duration was set at 12 s) of the light were recorded by pen deflections on the electroencephalograph; the time required for the subject to respond by turning out the light could be measured and converted to seconds of reaction time.

Degree of Drunkenness, Hangover, Mood, and Anxiety Ratings. In addition to self-ratings of effort and performance on the tracking task, subjects also provided four other types of ratings.

1) Degree of Drunkenness. During the interval between static and dynamic tracking, subjects were asked to rate how "drunk" they felt (not at all, slightly, moderately, more than moderately, extremely). Ratings were obtained at ground level and at altitude during midnight and morning test sessions and were scored on a 0-4 scale.

2) Hangover Ratings. At midnight and after breakfast both at ground level and at altitude, subjects completed a 20-item hangover questionnaire developed by Gunn (11) and also answered 4 additional items added by the author. The first 23 items comprised a checklist of symptoms (throwing up, stomach ache, hungry, headache, loose bowels, tight bowels, muscle aches, shaking, dizzy, feel hot, feel confused, eyes burn, backache, nose runs, nervous, tired, dry mouth, feel sad or depressed, ringing in ears, hurts to move, thirsty, nauseated, heartburn) to which subjects responded according to one of four categories (not at all, a little, some, quite a bit). Items were scored on a 0-3 scale and a mean score was calculated for each subject. The final item ("rate your hangover") was rated on a 0-4 scale (none, slight, moderate, strong, very strong) and constituted both a separate score and part of the overall hangover rating. The overall rating was obtained by a simple summation of the 24 item scores.

3) Mood. A list of 15 items from the 80-item Composite Mood Adjective Check List (CMACL) developed by Malmstrom (19) was devised on the basis of previous work in this laboratory with alcohol effects. The list comprised 15 adjectives (active, drowsy, dull, sluggish, tired, sleepy, bored, lazy, leisurely, nonchalant, energetic, vigorous, fatigued, happy, and annoyed)

which the subject rated on a 9-point scale ranging from "not at all" descriptive through "moderately," to "definitely" descriptive of the subject's current feelings. Five mood scores were calculated, viz, fatigue, nonchalance, vigor, sleepy, and affect tone; the first four scores were determined according to Malmstrom (19) while affect tone was derived from the two final items on our checklist. This modification (mCMACL) of Malmstrom's list was administered at ground level and at altitude after drinking and after breakfast under all conditions.

4) Anxiety. The State-Trait Anxiety Inventory (STAI) developed by Spielberger and his associates (28) was used to assess anxiety (or psychological arousal). One section of the STAI measures predisposition (Trait) toward anxiety or how the subject generally feels; the other section measures current anxiety level (State) or how the subject feels at that moment. Each section has 20 statements (e.g., I tire quickly, I feel content) and four response categories (almost never, sometimes, often, almost always, for Trait; not at all, somewhat, moderately so, very much so, for State). The Trait section was completed by all subjects during the week of practice. The State section was completed at ground level and at altitude before and after drinking and after breakfast.

Procedure. All subjects had been exposed initially to several 3-h training sessions following which they had participated in a study (7) immediately preceding the present one in which they gained experience in all of the tasks to be performed. Since the tracking device used in this study differed slightly from the device used in the previous study, additional practice was provided for all subjects before data collection was begun.

The experiment began at 1700 on each test day (see Table 1). Subjects were tested in four groups of two. Test days were Monday evening through Tuesday morning, Tuesday evening through Wednesday morning, Wednesday evening through Thursday morning, and Thursday evening through Friday morning. Following a monitored dinner (subjects were not allowed to have coffee or beverages containing caffeine between dinner and breakfast, but they were allowed to smoke), subjects at ground level completed the STAI and mCMACL, took a breathalyzer test, and performed static and dynamic tracking with the reaction time task. Subjects were then taken to 12,000 ft in the altitude chamber where they repeated all tasks. Drinking time was from 2100 to midnight. Each subject had four large drinks with 45 min to finish each drink. Subjects watched television and played ping pong, cards, and table hockey to create a party-like atmosphere. The first postdrinking session was run at midnight immediately following drinking with subjects rating their degree of drunkenness, taking the breathalyzer test, completing the STAI, mCMACL, and hangover questionnaires, and performing the tracking and reaction time tests. After completing all tasks at ground level and at altitude, subjects were put to bed around 0230 in the Civil Aeromedical Institute's clinic facilities. The subjects were awakened at 0645 for breakfast and began their final testing session at 0730. Subjects returned for 2 more weeks (totaling 3 weeks) on the same day of the week for retesting. The "sleep

Table 1. Procedural Schedule

1700	Predrinking session (PRE): Evening
	Dinner
	Breathalyzer, static and dynamic tracking tasks with reaction time, State-Trait Anxiety Inventory, Modified Composite Mood Adjective Check List
1900	Ascent in altitude chamber
1905	Reach 12,000 feet in chamber
1955	State-Trait Anxiety Inventory, Modified Composite Mood Adjective Check List, static and dynamic tracking tasks with reaction time
2035	Descent in altitude chamber
2100	Drinking
0000	Postdrinking session I (PI): Midnight
	Breathalyzer, State-Trait Anxiety Inventory, Modified Composite Mood Adjective Check List, drunkenness rating, Hangover Questionnaire, static and dynamic tracking tasks with reaction time
0050	Ascent in altitude chamber
0055	Reach 12,000 feet in chamber
0145	State-Trait Anxiety Inventory, Modified Composite Mood Adjective Check List, drunkenness rating, Hangover Questionnaire, static and dynamic tracking tasks with reaction time
0225	Descent in altitude chamber
0230	To bed
0645	Awakened
0715	Breakfast
0730	Postdrinking session II (PII): Morning
	Breathalyzer, State-Trait Anxiety Inventory, Modified Composite Mood Adjective Check List, drunkenness rating, Hangover Questionnaire, static and dynamic tracking tasks with reaction time
0805	Ascent in altitude chamber
0810	Reach 12,000 feet in chamber
0900	State-Trait Anxiety Inventory, Modified Composite Mood Adjective Check List, drunkenness rating, Hangover Questionnaire, static and dynamic tracking tasks with reaction time
0940	Descent in altitude chamber

control" week was the last week of the experiment. The differences in this week in relation to the preceding weeks were the absence of alcoholic beverages (subjects drank the same mixture as the placebo drinks) and elimination of the midnight test session. The absence of the latter permitted the assessment of possible effects due to the abbreviated sleep periods in the placebo and alcohol conditions. In this sleep control condition, subjects were in bed no later than midnight.

All measures were obtained in the morning irrespective of the experimental condition and all measures were obtained at midnight for the placebo and alcohol conditions. During the predrinking session in the evening, all measures were obtained for each condition except those from the Hangover Questionnaire and the drunkenness rating. Analyses of variance (17) were conducted as follows: (i) for evening and morning scores from all three conditions, to assess overall hangover effects; (ii) for scores from all three sessions for the placebo and alcohol conditions, to assess the effects of acute intoxication and the relationship of those scores to scores obtained in the hangover period; (iii) morning scores on the Hangover Questionnaire and the drunkenness rating for all conditions; and (iv) midnight and morning scores on the Hangover Questionnaire and the drunkenness rating for placebo and alcohol conditions. Significant F ratios were treated first by simple effects tests and then by Tukey's HSD test (17). Because of the increased variability in postdrinking (midnight) scores, evening and morning comparisons with midnight scores for each measure (for the alcohol and placebo conditions) were additionally checked with the Wilcoxon Signed-Ranks test (4) (the latter yielded no major differences from results obtained by the initial analyses and, therefore are not reported).

Results.

Breathalyzer. The mean breathalyzer level was .091 percent (SD .021) immediately after drinking alcohol and .012 percent (SD .018) during the morning session, 8 h later.

Reaction Time. Reaction times (RT) to the illumination of the red pinlight are presented in Table 2. The data show no obvious differences within or between evening and morning sessions among all conditions, and analyses of variance yielded no significant effects for these sessions. Longer RTs occurred at midnight for all trials in the alcohol condition (static and dynamic, ground and altitude); these sessional differences were significant for static scores ($p < .01$) for the alcohol condition, with RTs at midnight being significantly poorer than either evening or morning scores in every case ($p < .05-.01$). Differences at midnight between alcohol and placebo conditions were significant for both ground ($p < .05$) and altitude ($p < .01$) in the static mode and for both ground ($p < .001$) and altitude ($p < .05$) in the dynamic mode. No effects of altitude or the hangover period were demonstrated.

Table 2. Means and Standard Deviations for Reaction Time (RT) in Seconds to the Onset of a Peripheral Light During Static and Dynamic Tracking

		PLACEBO			ALCOHOL			CONTROL		
		EVE	MID	MORN	EVE	MID	MORN	EVE	MID	MORN
Ground Level										
Static RT	M	1.6	1.6	1.6	1.6	2.0	1.6	1.5	-	1.5
	SD	0.3	0.2	0.3	0.2	0.5	0.2	0.2	-	0.1
Dynamic RT	M	1.6	1.5	1.5	1.5	1.7	1.5	1.4	-	1.5
	SD	0.3	0.2	0.3	0.2	0.3	0.2	0.1	-	0.2
Altitude (12,000')										
Static RT	M	1.6	1.7	1.6	1.7	2.2	1.6	1.5	-	1.5
	SD	0.2	0.6	0.3	0.4	0.7	0.2	0.1	-	0.2
Dynamic RT	M	1.5	1.5	1.5	1.5	1.7	1.5	1.5	-	1.5
	SD	0.2	0.2	0.3	0.2	0.3	0.2	0.2	-	0.1

Tracking Performance. The vector sums of tracking error were calculated (Table 3). The data show that (i) morning scores were numerically better (less error) than evening scores with one exception, dynamic tracking at altitude in the alcohol condition; (ii) midnight sessions in the alcohol condition yielded the poorest performance; and (iii) midnight scores in the placebo condition were intermediate between evening and morning scores at ground level, but better than evening and morning scores at altitude. Regardless of the condition or session, subjects performed with less tracking error in the static as compared with the dynamic mode.

Statistical analyses yielded the following results. For the control and the placebo conditions, there were no significant differences across sessions at either ground or altitude for static or dynamic tracking scores. For the alcohol condition, the midnight (postdrinking) scores were significantly poorer than both predrinking and morning scores for static and for dynamic tracking (at ground level, $p < .05$ and .01 for static tracking and $p < .001$ for dynamic tracking; at altitude, $p < .001$ in all cases). However, in evening vs. morning comparisons, there was an overall significant effect of sessions for both static and dynamic tracking ($p < .05$ in both cases). This overall effect can be attributed to better morning than evening scores in 11 of the 12 comparisons for the two modes of tracking. As noted above, the effect was not strong enough to reach statistical significance in any single condition.

Table 3. Means and Standard Deviations for the Vector Sums of Tracking Error in the Static and Dynamic Modes

Tracking Measure		PLACEBO EVE	PLACEBO MID	PLACEBO MORN	ALCOHOL EVE	ALCOHOL MID	ALCOHOL MORN	CONTROL EVE	CONTROL MID	CONTROL MORN
Ground Level										
Static Error	M	209	207	202	226	283	203	205	-	195
	SD	52	47	63	85	109	63	54	-	53
Dynamic Error	M	234	225	212	246	366	221	223	-	201
	SD	51	60	57	92	155	76	62	-	51
Altitude (12,000')										
Static Error	M	218	239	196	210	315	195	195	-	190
	SD	63	89	51	80	165	64	54	-	54
Dynamic Error	M	225	260	223	220	402	224	212	-	200
	SD	47	105	85	69	182	89	57	-	59

In comparisons of ground level scores with scores at altitude, no significant differences were obtained within or between any conditions for either static or dynamic tracking.

Ratings of Effort and Performance. Mean ratings for tracking effort and performance are presented in Table 4. Effort was consistently rated at a high level, particularly during ground level tests (no less than a mean of 4.8 on a 5-point scale); during altitude tests ratings were similar with three exceptions, viz, a mean rating of 4.6 for static tracking during the placebo morning session and mean ratings of 4.4 at midnight during the alcohol condition for both modes of tracking. Performance ratings were more variable, ranging from 2.8 to 3.5 (on a 5-point scale) for all sessions except that at midnight for the alcohol condition. In the latter case, performance ratings ranged from 2.0 to 2.6 ("below average" performance).

Alcohol vs. placebo comparisons yielded no significant effects for effort ratings. However, for static performance ratings, significant effects ($p <$ .05 in all cases) were obtained for conditions, sessions, altitude, and the conditions-by-sessions interaction. Also, significant effects for sessions and the conditions-by-sessions interaction were determined for dynamic performance ratings ($p <$ .001 in both cases). With respect to these results, (i) midnight ratings for static tracking performance in the alcohol condition were significantly lower than both evening and morning ratings at ground level (they were also lower, but not significantly, at altitude); (ii) static

Table 4. Means and Standard Deviations for Ratings by the Subjects of the Effort They Expended (1-5 scale) and the Quality of Their Performance (1-5 scale) for Static and Dynamic Tracking

Rating Condition		PLACEBO			ALCOHOL			CONTROL		
		EVE	MID	MORN	EVE	MID	MORN	EVE	MID	MORN
Ground Level										
Effort										
Static Tracking	M	4.9	4.8	4.8	4.8	4.8	4.9	5.0	-	4.8
	SD	0.4	0.5	0.5	0.5	0.5	0.4	0.0	-	0.5
Dynamic Tracking	M	4.9	4.8	4.8	4.9	4.8	4.8	4.9	-	4.9
	SD	0.4	0.5	0.5	0.4	0.5	0.5	0.4	-	0.4
Performance										
Static Tracking	M	2.9	3.1	3.1	3.0	2.1	3.0	2.9	-	3.1
	SD	0.8	1.0	0.8	0.8	0.6	0.8	1.0	-	1.1
Dynamic Tracking	M	2.8	3.4	3.1	3.4	2.0	3.4	3.5	-	3.1
	SD	0.9	0.9	0.6	0.9	0.5	0.5	0.8	-	1.0
Altitude										
Effort										
Static Tracking	M	4.9	4.9	4.6	4.9	4.4	4.8	5.0	-	4.9
	SD	0.4	0.4	0.5	0.4	0.5	0.5	0.0	-	0.4
Dynamic Tracking	M	4.9	4.9	4.8	4.9	4.4	4.8	4.9	-	4.9
	SD	0.4	0.4	0.5	0.4	0.7	0.5	0.4	-	0.4
Performance										
Static Tracking	M	3.1	3.1	3.5	3.3	2.6	3.1	3.5	-	3.1
	SD	0.4	0.6	0.9	0.7	1.1	0.6	1.2	-	1.1
Dynamic Tracking	M	3.4	2.9	2.9	3.3	2.3	3.4	3.5	-	3.5
	SD	0.5	1.0	0.8	0.5	0.9	0.7	0.9	-	0.9

performance ratings at altitude were higher overall than the same ratings at ground level; and (iii) at ground level for both static and dynamic tracking, midnight performance ratings under the alcohol condition were significantly poorer than midnight ratings under the placebo condition (these differences accounted for significant sessions and sessions-by-conditions effects for both modes of tracking).

Analyses of variance of the two types of ratings across all three conditions yielded only one significant effect for evening vs. morning comparisons; in static performance ratings, subjects rated their performance better ($p < .05$) at altitude than they did at ground level.

Drunkenness and Hangover Ratings. Mean ratings of drunkenness and of hangover and mean overall scores on the Hangover Questionnaire for the midnight and morning sessions appear in Table 5 for the placebo and alcohol condition; only morning scores are listed for the control condition. All subjects gave "0" ratings for drunkenness in morning sessions at both ground level and altitude with the exception of one subject in the alcohol condition at ground level. Comparison of alcohol and placebo scores at midnight showed that only one subject under placebo rated his drunkenness level above "0" (while at altitude). During the alcohol condition, subjects' midnight ratings averaged 1.5 at both ground level and altitude.

Analysis of variance yielded no significant differences across conditions for morning scores. Comparisons of alcohol and placebo conditions yielded significant conditions, sessions, and conditions-by-sessions effects ($p < .001$ in all cases). Simple effects tests showed that (i) midnight ratings in the alcohol condition yielded significantly higher scores than morning ratings at both ground level and altitude, and (ii) drunkenness ratings at midnight were significantly higher after alcohol than after placebo ($p < .001$ and .01 for ground and altitude, respectively).

The Hangover Rating item was "0" only at midnight for the placebo treatment at ground level, and in the morning for the control treatment at altitude. One subject self-rated above "0" during each of the other placebo and control sessions. The alcohol condition yielded mean ratings of about 1.0 at midnight and between 1.1 to 1.4 during morning sessions for both altitude and ground level. Analysis of variance yielded only a significant conditions effect ($p < .01$); alcohol produced higher ratings than either the control or placebo condition. Thus, this rating showed no effect of altitude and indicated no significant differences in scores between acute intoxication and hangover in the alcohol condition.

Overall scores on the Hangover Questionnaire were lowest for the control condition, intermediate for the placebo condition, and highest for the alcohol condition. Analysis of variance of morning scores yielded a significant conditions effect ($p < .01$) accounted for by significantly lower control scores than both placebo ($p < .05$) and alcohol ($p < .001$) scores by HSD tests. These findings suggest that a main component of the poorer scores

Table 5. Means and Standard Deviations for Single-Item Ratings by the Subjects of Their Degree (0-4) of Drunkenness and Degree (0-4) of Hangover, and for Their Overall Scores on the Hangover Questionnaire

MEASURE		PLACEBO MID	PLACEBO MORN	ALCOHOL MID	ALCOHOL MORN	CONTROL MID	CONTROL MORN
Ground Level							
Drunkenness Rating	M	0.00	0.00	1.50	0.12	-	0.00
	SD	0.00	0.00	0.76	0.35	-	0.00
Hangover Rating	M	0.00	0.13	0.88	1.38	-	0.13
	SD	0.00	0.35	0.99	0.92	-	0.35
Hangover Questionnaire	M	5.1	6.6	5.9	9.3	-	3.4
	SD	3.3	3.5	3.9	3.0	-	3.2
Altitude							
Drunkenness Rating	M	0.12	0.00	1.50	0.00	-	0.00
	SD	0.35	0.00	0.93	0.00	-	0.00
Hangover Rating	M	0.13	0.13	1.00	1.13	-	0.00
	SD	0.35	0.35	1.07	0.99	-	0.00
Hangover Questionnaire	M	5.5	6.5	7.6	8.4	-	2.1
	SD	2.0	3.2	2.9	5.3	-	2.8

on the questionnaire could be attributed to sleep loss effects in both the placebo and alcohol conditions. Analysis of placebo and alcohol conditions yielded significant overall effects for sessions and conditions ($p < .05$ in both cases) but only one simple effects test reached significance (the higher morning vs. midnight score for the alcohol condition at ground level).

Anxiety and Mood. Scores on the Trait section of the STAI averaged 29.09, which is a lower mean anxiety score on this test than the norm for college undergraduates (28). With regard to State scores (see Table 6), there were no significant differences between sessions, altitudes, or conditions. However, the two highest mean scores were obtained under the alcohol condition at midnight (31.8) and in the morning (33.4).

Mood scores for the five factors assessed are presented in Table 6. At ground level, the poorest scores for the placebo and control conditions

Table 6. Means and Standard Deviations for "State" Scores on the State-Trait Anxiety Inventory (STAI) and for Five Moods Assessed by the Modified Composite Mood Adjective Check List (mCMACL)

		PLACEBO			ALCOHOL			CONTROL		
		EVE	MID	MORN	EVE	MID	MORN	EVE	MID	MORN
Ground Level										
STAI	M	28.4	29.6	30.6	31.5	31.8	33.4	26.8	30.4	27.5
	SD	4.7	3.6	2.6	10.4	8.4	8.6	4.4	4.1	4.1
(mCMACL)										
Fatigue	M	23.8	41.6	35.6	23.4	47.0	32.9	19.9	43.0	24.8
	SD	9.5	15.5	7.9	11.0	11.2	10.2	9.7	14.4	10.4
Nonchalance	M	9.5	9.3	9.5	9.5	9.6	8.3	8.5	10.6	8.4
	SD	3.4	2.8	2.6	4.4	3.3	2.1	3.9	3.4	2.0
Vigor	M	17.4	9.8	11.5	16.9	11.9	11.4	18.6	11.0	17.9
	SD	4.2	3.8	3.2	4.9	4.9	4.2	5.9	3.6	4.3
Sleepy	M	11.9	24.3	20.1	14.0	26.9	17.6	9.0	23.5	12.1
	SD	5.6	11.4	7.0	7.0	7.6	7.9	4.7	8.2	5.4
Affect Tone	M	8.4	7.0	7.0	7.9	8.3	8.0	8.4	8.4	8.4
	SD	1.9	2.1	2.5	1.7	3.1	2.3	1.6	2.5	2.1
Altitude (12,000')										
STAI	M	30.1	33.1	31.0	32.0	35.3	33.9	27.9	-	26.3
	SD	5.1	3.7	4.0	10.3	12.9	8.4	4.7	-	4.2
(mCMACL)										
Fatigue	M	28.8	46.9	39.5	30.5	45.4	41.9	28.6	-	30.9
	SD	8.5	16.7	9.3	8.2	16.0	11.3	13.2	-	8.2
Nonchalance	M	9.3	9.8	9.4	8.6	9.4	9.1	10.3	-	9.8
	SD	2.6	3.8	2.1	2.5	2.3	2.6	2.8	-	2.5
Vigor	M	15.6	10.4	11.0	13.5	7.5	10.4	17.3	-	15.1
	SD	3.7	2.7	2.7	5.1	4.6	3.1	3.8	-	5.1
Sleepy	M	14.9	26.8	22.8	16.0	27.0	22.8	13.8	-	13.9
	SD	4.5	10.8	6.7	7.2	8.9	6.7	7.1	-	4.4
Affect Tone	M	7.6	7.4	7.6	7.6	6.8	7.1	8.1	-	8.3
	SD	1.7	2.5	1.5	1.9	2.2	1.7	2.2	-	1.7

occurred at midnight for fatigue, vigor, sleepy, and affect tone (the latter yielded identical midnight and morning scores for both conditions); nonchalance was also poorest at midnight for the placebo condition. In the alcohol condition at ground level, nonchalance, vigor, and affect tone yielded poorest scores during the hangover session, while fatigue and sleepy scores were poorest at midnight. With the exception of nonchalance, the best morning scores occurred in the control condition (which provided the most sleeping time).

With a few exceptions, mood scores at altitude were poorer than at ground level under all conditions. However, morning scores for the control condition at altitude (no midnight control scores were obtained) were uniformly better than the altitude scores for either the placebo or alcohol condition.

Statistical tests indicated no significant effects in any case for the nonchalance and affect tone mood factors. In comparing the alcohol-placebo conditions across all sessions for the remaining three factors, altitude scores were regularly poorer ($p < .05$). Fatigue, vigor, and sleepy scores yielded significant sessions effects ($p < .001$ in all cases) and were each poorer during midnight sessions at ground level and at altitude ($p < .05$-$.001$) as compared with evening scores following both placebo and alcohol. Midnight scores for these three factors also differed significantly from morning scores in several comparisons, and morning scores most often differed from evening scores. Thus, the dominant effect on these scores was the time of day of the assessments.

Analysis of variance applied to the evening and morning mood scores yielded significant effects for fatigue ($p < .01$), vigor ($p < .001$), and sleepy ratings ($p < .01$), all of which were uniformly poorer in the morning; analyses by conditions indicated that the evening-morning differences were not significant for any of these mood factors in the control condition, were uniformly significant for placebo ($p < .05$-$.01$), and reached significance following alcohol only for vigor at ground level and for fatigue and sleepy at altitude ($p < .05$ in all cases). Fatigue and sleepy scores were each poorer ($p < .01$) at altitude than at ground level, and the uniformly better morning scores for vigor and for sleepy in the control condition (compared with alcohol and placebo) produced a significant conditions effect ($p < .05$) for these two factors. The reduced sleeping time associated with the placebo and alcohol conditions thus appeared to have a major effect on these scores.

Sex Differences. Analyses of variance of the 17 sets of evening-morning (hangover) scores across the control, placebo, and alcohol conditions for the four men and the four women yielded no significant main effects due to sex. Moreover, among the interaction terms involving sex, (i) no four-way interactions were significant, (ii) only two (dynamic RT, $p < .01$, and static effort rating, $p < .05$) of the 51 three-way interactions were significant, and (iii) none of the 51 two-way interactions was significant. Although there were no significant overall sex differences, men tended to have better scores on tracking, reaction time, and the fatigue and sleepy mood factors; women tended to have generally higher ratings for the nonchalance and affect tone mood factors.

Effects of Smoking. Two each of the four men and four women were smokers. Analyses of variance of possible evening-morning (hangover) effects attributable to smoking yielded no significant main effects across the 17 performance, rating, and questionnaire variables for the three conditions. Of all the interaction terms involving smokers vs. nonsmokers, (i) no four-way interactions were significant, (ii) only two (STAI, $p < .001$, and sleepy mood, $p < .05$) of 51 three-way interactions reached signifiance, and (iii) four of 51 two-way interactions (three of the latter were for mood ratings, $p < .05-.001$, and the other involved dynamic tracking, $p < .05$) reached significance. However, on the average, nonsmokers generally had better scores for tracking and reaction time; they had lower STAI scores and generally higher scores for sleepy mood, hangover, and drunkenness ratings.

Discussion.

In this study, significant impairment occurred for tracking performance and visual reaction time in both static (stationary) and dynamic (motion) modes during midnight sessions immediately following the ingestion of alcohol. Morning scores, however, showed no deleterious performance effects of the hangover period, and, in fact, an overall circadian effect of better morning performance was obtained for tracking scores. Thus, while the performance tests were sensitive to acute alcohol intoxication and the tracking task additionally showed small but consistent time-of-day effects, no hangover-related performance impairment was recorded. The higher hangover ratings and Hangover Questionnaire scores for the morning session following alcohol ingestion attest to the awareness of symptoms from the previous night's drinking, but the subjects were successful in not allowing those negative experiences to influence their performance. Similarly, the poorer mood ratings in the morning (as compared with evening scores) for fatigue, vigor, and sleepy due to the reduced sleeping periods in the alcohol and placebo conditions were not reflected in the subjects' morning performance at either tracking or reaction time tasks. Thus, no hangover effects on performance were demonstrated, although it is possible that the subjects had to expend more effort to maintain performance.

A consistent finding related to altitude was the increased error at midnight for both modes of tracking under both the placebo and alcohol conditions. It would appear that the fatigue, sleepiness, and reduced vigor that subjects uniformly reported at both ground level and altitude during this session may have interacted with the mild hypoxia of the altitude situation to produce these increased error rates. However, the interaction of altitude and alcohol yielded no statistically significant performance effects although the poorest average scores for both modes of tracking occurred during the midnight session at altitude in the alcohol condition. A substantial part of these increases in error for both the static and dynamic tracking modes was due to a single subject (his peak BAL was third highest among the subjects) whose error rates following alcohol were markedly above his ground level score (about 75 percent higher in both cases). Actually, following alcohol ingestion, half the subjects performed better at altitude than at ground level during static tracking and three of the eight subjects were better at altitude in the dynamic mode.

We found no general or differential effects of alcohol and/or of altitude on performance or on hangover symptoms that could be related either to sex or to the habitual smoking of cigarettes.

The results obtained in this study show clear performance decrements during acute intoxication. However, no deleterious performance effects were obtained during the hangover period and there were no significant altitude/alcohol interactions on performance during eit' acute intoxication or hangover periods. While these findings thus offer no contradictions to the "8-hour rule," they should be interpreted cautiously since (i) our subjects were particularly well motivated and interested in the outcome of the research and (ii) additional aviation stressors such as engine noise were not present. While it appears likely that higher altitudes, higher BALs, longer periods at altitude, or a combination of these conditions would produce some significant interactions, it seems clear with regard to effects on performance, that there is no generalizeable relationship between mild hypoxia produced by about an hour of exposure to 12,000 ft and BALs under 100 mg percent.

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REFERENCES

1. Aksnes, E. G.: Effect of Small Dosages of Alcohol Upon Performance in a Link Trainer. JOURNAL OF AVIATION MEDICINE, 25:680-688 & 693, 1954.

2. Billings, C. E., R. L. Wick, R. J. Gerke, and R. C. Chase: Effects of Ethyl Alcohol on Pilot Performance. AEROSPACE MEDICINE, 44(4):379-382, 1973.

3. Bonte, W. and J. Volck: Untersuchungen zum Problem der Alkoholnachwirkungen. BLUTALKOHOL, 15:35-46, 1978.

4. Bruning, J. L. and B. L. Kintz: Computational Handbook of Statistics. Dallas, Texas: Scott, Foresman, and Company, 1968.

5. Carroll, J. R., W. F. Ashe, and L. B. Roberts: Influence of the After-effects of Alcohol Combined With Hypoxia on Psychomotor Performance. AEROSPACE MEDICINE, 35(10):990-993, 1964.

6. Collins, W. E.: Effective Approaches to Disorientation Familiarization for Aviation Personnel. FAA Office of Aviation Medicine Report No. AM-70-17, 1970.

7. Collins, W. E. and W. D. Chiles: Laboratory Performance During Acute Intoxication and Hangover. FAA Office of Aviation Medicine Report No. AM-79-7, 1979.

8. Collins, W. E., D. J. Schroeder, R. D. Gilson, and F. E. Guedry, Jr.: Effects of Alcohol Ingestion on Tracking Performance During Angular Acceleration. JOURNAL OF APPLIED PSYCHOLOGY, 55(6):559-563, 1971.

9. Dowd, P. J., J. W. Wolfe, and R. L. Cramer: Aftereffects of Alcohol on the Perception and Control of Pitch Attitude During Centripetal Acceleration. AEROSPACE MEDICINE, 44(8):928-930, 1973.

10. Gilson, R. D., D. J. Schroeder, W. E. Collins, and F. E. Guedry, Jr.: Effects of Different Alcohol Dosages and Display Illumination on Tracking Performance During Vestibular Stimulation. AEROSPACE MEDICINE, 43(6):656-660, 1972.

11. Gunn, R. C.: Hangovers and Attitudes Toward Drinking. QUARTERLY JOURNAL OF STUDIES ON ALCOHOL, 34:194-198, 1973.

12. Henry, P. H., J. A. Flueck, J. F. Sanford, H. N. Keiser, R. C. McNee, W. H. Walter III, K. H. Webster, B. O. Hartman, and M. C. Lancaster: Assessment of Performance in a Link GAT-1 Flight Simulator at Three Alcohol Dose Levels. AEROSPACE MEDICINE, 45(1):33-44, 1974.

13. Henry, P. H., T. Q. Davis, E. J. Engelken, J. H. Triebwasser, and M. C. Lancaster: Alcohol-Induced Performance Decrements Assessed by Two Link Trainer Tasks Using Experienced Pilots. AEROSPACE MEDICINE, 45(10): 1180-1189, 1974.

14. Higgins, E. A., A. W. Davis, J. A. Vaughan, G. E. Funkhouser, and E. M. Galerston: The Effects of Alcohol at Three Simulated Aircraft Cabin Conditions. FAA Office of Aviation Medicine Report No. AM-68-18, 1968.

15. Idestrom, C. M. and B. Cadenius: Time Relations of the Effects of Alcohol Compared to Placebo. PSYCHOPHARMACOLOGIA, 13:189-200, 1968.

16. Karvinen, E., M. Miettinen, and K. Ahlman: Physical Performance During Hangover. QUARTERLY JOURNAL OF STUDIES ON ALCOHOL, 23:208-215, 1962.

17. Kirk, R. E.: Experimental Design: Procedures for the Behavioral Sciences. Belmont, California: Brooks/Cole Publishing Company, p. 577, 1968.

18. Levine, J. M., G. G. Kramer, and E. N. Levine: Effects of Alcohol on Human Performance: An Integration of Research Findings Based on Abilities Classification. JOURNAL OF APPLIED PSYCHOLOGY, 60(3):285-293, 1975.

19. Malmstrom, E. J.: Composite Mood Adjective Check List. Unpublished manuscript, Los Angeles, California, University of California, 1968.

20. McFarland, R. A.: Human Factors in Air Transportation. New York: McGraw-Hill, 1953.

21. McFarland, R. A. and A. L. Barach: The Relationship Between Alcohol Intoxication and Anoxemia. AMERICAN JOURNAL OF MEDICAL SCIENCE, 192(2): 186-198, 1936.

22. McFarland, R. A. and W. H. Forbes: The Metabolism of Alcohol in Man at High Altitudes. HUMAN BIOLOGY, 8(3):387-398, 1936.

23. Myrsten, A. L., M. Kelley, A. Neri, and U. Rydberg: Acute Effects and After-Effects of Alcohol on Psychological and Physiological Functions. Reports from the Psychological Laboratories, University of Stockholm, No. 314, December 1970.

24. Nettles, J. L. and R. N. Olson: Effects of Alcohol on Hypoxia. JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION, 194(11):135-136, 1965.

25. Newman, H. W.: The Effect of Altitude on Alcohol Tolerance. QUARTERLY JOURNAL OF STUDIES ON ALCOHOL, 10:398-403, 1949.

26. Pearson, R. G.: Alcohol-Hypoxia Effects Upon Operator Tracking, Monitoring, and Reaction Time. AEROSPACE MEDICINE, 39(3):303-307, 1968.

27. Seppala, T., T. Leino, M. Linnoila, M. Huttunen, and R. Ylikahri: Effects of Hangover on Psychomotor Skills Related to Driving: Modification by Fructose and Glucose. ACTA PHARMACOLOGICA ET TOXICOLOGICA, 38:209-218, 1976.

28. Spielberger, C. D., R. L. Gorsuch, and R. E. Lushene: STAI Manual. Palo, Alto, California: Consulting Psychologists Press, 24 pp., 1970.

29. Takala, M., E. Siro, and Y. Toivainen: Intellectual Functions and Dexterity During Hangovers; Experiments After Intoxication With Brandy and With Beer. QUARTERLY JOURNAL OF STUDIES ON ALCOHOL, 19(1):1-29, 1958.