TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FAA-AM-72-11	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EFFECTS OF ALCOHOL ON A PROBLEM SOLVING TASK		5. Report Date March 1972
		6. Performing Organization Code
7. Author(s) W. Dean Chiles, Ph.D. Alan E. Jennings, B.A.		8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P. O. Box 25082 Oklahoma City, Oklahoma 73125		10. Work Unit No.
		11. Contract or Grant No.
		13. Type of Report and Period Covered OAM Report
2. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S. W. Washington, D. C. 20591		
		14. Sponsoring Agency Code

5. Supplementary Notes

This research was conducted under Task No. AM-A-71-PSY-13.

6. Abstract

Twenty subjects were tested on two separate days on a simple problem-solving task. Half of the subjects received alcohol on the first day of testing and half on the second day of testing. A control group of 11 subjects was also tested on two days and they were given a placebo on the first day of testing. All 31 subjects were also serving in a vestibular stimulation experiment.

A significant effect was found for alcohol with five of the eleven measures analyzed; four of the measures were time measures and one was an error measure. Analysis of the simple effects indicated that alcohol had a greater effect on the group that had alcohol on the first session than on the group that had alcohol second. There was also suggestive evidence of a residual effect of the vestibular stimulation on the problem-solving performance of the control group. In general, the findings provide supportive evidence of the potential deleterious effects of alcohol on a skill of importance to aviation operations.

. Key Words Alcohol Problem Solving Vestibular Stimulation	18. Distribution Statement Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.

. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	9	$3.00

:m DOT F 1700.7 (8-69)

EFFECTS OF ALCOHOL ON A PROBLEM SOLVING TASK

Introduction.

In a previous study (Chiles and Jennings, 70) we found alcohol (an average blood ɔohol level of 105 mg%) to produce significant crements in skills important to flying. Spe- ically, both monitoring and two-dimensional ıcking performance suffered, although decre- ›nts were not found in the performance of a ıple mental arithmetic task with subjects who ·re given substantial practice before testing. .e tasks were performed in different combina- ns which required time sharing, and we con- .ded that the subjects probably tended to place ıigher priority on the arithmetic task and thus ›tected their performance of that task.

Carter, Jones, Simpson, and Vega (1971) re- ·ted decrements in performance on a variety tasks with (Breathalyzer) blood alcohol els of 80 mg%; included were tests of short- m memory (WAIS Digit Span and dichotic sentation of digits), simple and choice visual ction time, and abstracting and conceptual lity (Shipley-Hartford). However, with re practiced subjects, alcohol effects were nd only on one of these tasks—3-choice reac- ı time.

Similarly, Carpenter and Ross (1959) reported rements in short-term memory with an alcohol e of 1 ml/kg of body weight. (Blood alcohol ›ls were not specified.) Again, this effect was ͅgely mitigated by increased practice.

The present study examines the effect of a lerately high level of blood alcohol on a ple problem-solving task. Basically, the : required the subject to discover the correct ıence in which to push five buttons in order urn on a green light; a red light provided ır feedback to the subject. The solution ob- ed had to be remembered for 10 seconds and ı re-entered. Thus, performance of the task primarily dependent on short-term memory perceptual-motor speed, both of which are ortant elements in aviation operations.

II. Method.

A. *Subjects.* Thirty-one paid volunteer male subjects were tested; they were college students in their twenties who described themselves as "moderate social drinkers." The subjects served concurrently in another experimental study that involved rotational stimulation of vestibular mechanisms. (The testing schedule in that other experiment was such that the subjects could serve in the problem-solving study without additional subject costs.)

B. *Apparatus.* The apparatus consisted of a small metal box (approximately 11 x 18 x 9 cm) on which five push buttons were mounted in a row. The buttons were 8 mm in diameter and were spaced with 2.4 cm between edges; they were labeled with the numbers one through five. The subjects were required to make all responses with the index finger of the preferred hand. Three indicator lights (amber, red, and green) were mounted about 10 cm above the box on a panel in front of the subjects. The lights provided information in the following manner. At the beginning of a problem the red light was illuminated to indicate to the subject that he should begin to search for the problem solution. Whenever any button was pushed, the amber light would come on and remain on until the button was released; this light indicated that the response had been registered by the programming and scoring equipment. Coincident with the onset of the amber light, the red light would go out. When the subject released the button, the red light would come back on if the response were incorrect, but it would remain out if the response were correct. Thus, the number-one button for a given problem was the button that would keep the red light out when the button was released. If the next button pushed after finding the first correct button was the correct second button, the red light would remain out; if it were not the correct second button, the red light would be re-illuminated and the correct first button would have to be pushed again in order to continue the search for the second button. Similarly, if at any time during the search the red light came on, the subject had to re-enter the partial solution he had already discovered before he could continue the search for the next button in the problem sequence. Since the correct solution used each button only once, those buttons which were included in a partial solution were to be eliminated from the search. The onset of the green light indicated that the problem had been solved. Thus, if the solution for a given problem were 3, 5, 1, 4, 2, a subject who used the search sequence would enter the following sequence of button pushes (an *R* representing the onset of the red light): R, 1, R, 2, R, 3, 4, R, 3, 5, 1, 2, R, 3, 5, 1, 4, 2, Green Light. After a 10-second delay, the green light would go out, the red light would come on, and the same problem would be presented a second time. Thus, each problem was solved twice—once by discovering the sequence by a trial-and-error process through application of the search procedure and once by re-entering the already obtained sequence; the error light functioned the same during the second solution as it did for the first solution. The green light was also illuminated for a 10-second interval following the entry of the second solution. Thus, the subject also had to remember whether the onset of the red light meant that he was to repeat the preceding problem solution or that a new problem was present.

The subjects were required to search for the problem solution by trying buttons in a left-to-right sequence; for this purpose, the left hand button was to be considered as following the extreme right hand button. This procedure was chosen because it provided an easily-learned way of simplifying and standardizing the memory load during search. It also provided a means of standardizing error detection during search; specifically, the number of errors (red lights) for a given problem can be predicted exactly for a given problem by relating the problem solution back to the search sequence. For example, the sample problem shown in the preceding paragraph should be solved with only four "errors" if the search sequence is followed properly; of course, it is *possible* to make fewer errors by chance deviations from the search sequence at the risk of forgetting what one has done an thus, making redundant responses.

Responses were recorded on punch tape b means of an automatic scoring system. Th time at which each event occurred with respe to the beginning of the experimental session w recorded to the nearest 1/100 sec. The butto pushed, whether or not it was in the corre sequence, and whether it was associated with a initial or re-entered solution were also recorde The punch tapes were then compiled and a alyzed by computer.

Four time measures were taken separately f the first and second solution phases. These we mean time per response, mean time per corre response, mean time per incorrect response, a mean time per solution. In addition, a me time per problem with first and second soluti data combined was computed.

An error measure for first solution perfor ance was derived by taking the mean differen between the number of incorrect responses a the number of incorrect responses which wou be expected if the search procedure were f lowed correctly. Since the subject should n make any errors during the second solution, error measure for second solution was simply number of incorrect responses.

C. *Procedure.* The 31 subjects were randor divided into three groups; the control group h an N of 11 and two experimental groups had N of 10 each. One experimental group recei alcohol on the first day of testing and the ot received alcohol on the second day of testi The experimental subjects were given alcohol the amount of 2.5 ml of 100-proof Wild Tur bourbon or Smirnoff vodka per kg of b weight. This is equivalent to slightly over absolute alcohol per kg of body weight and calculated to give a peak blood alcohol level about 100 mg%. The vodka or bourbon diluted with orange juice to a total volume about 30 fluid ounces. Control subjects recei a placebo of equal volume with a few drops rum extract added to simulate the addition alcohol. The subjects were given 30 minute which to drink the beverage. Six of the alco first subjects were given bourbon and four w given vodka; in the alcohol-second group, subjects were given bourbon and six were g vodka.

Blood alcohol level (BAL) determinations vere made on all subjects before they were given he alcohol or placebo. In addition, the experiiental subiects had blood samples drawn for 3AL determinations at one and two hours after ley were given the alcohol. Testing on the roblem-solving task occurred about halfway etween the first and second hour BAL deterination. Results of these BAL determinations re summarized in Table 1. The mean BAL cross subjects was 94.5 mg% which approxiated the target figure of 100 mg%.

TABLE 1.—Blood Alcohol Levels in mg%.

		1 hour after ingestion	2 hours after ingestion	Mean of 1 and 2 hours
roup A	M	99	95	97
	S	25	22	19
roup B	M	96	87	92
	S	22	18	18

The subjects were trained and tested individually with all training and testing sessions llowing essentially the same procedure. Durg training, the task was explained to the subt and the experimenter demonstrated the lution of one complete problem (first and cond solution). Then the experimenter "talked e subject through" one other problem. Addinal instruction was given if necessary until e subject solved one complete problem by folving the correct procedure with essentially no sistance from the experimenter. The subject s then allowed to work five practice problems ile the experimenter observed through a halfvered mirror from the adjoining room. When cessary, the subject was reminded, via intern, to follow the proper procedure.

The testing sessions consisted of 18 problems vo solutions each). The duration of each ting session was dependent on the length of e it took each subject to complete the 18 probs. Prior to each testing session, the subject rked one complete practice problem and the erimenter corrected any errors in procedure. The subject was then reminded to work as idly as possible while trying to avoid making necessary errors. The experimenter then entered the adjoining room and momentarily turned the task off while activating the scoring circuitry. The subject was alerted via the intercom system, and the task device was turned on to start the testing session. Voice contact with the subjects during the testing period was kept to a minimum.

The testing schedule for the three groups is summarized below.

1. Pre-Alcohol Day. Only the alcohol-second group was tested on a pre-alcohol day, and these subjects were not exposed to vestibular stimulation on this day. The subjects were trained on the task and, immediately following training, were tested on 18 problems, with each problem being solved twice.

2. Alcohol Day. First, subjects in all groups had pre-drinking BAL blood samples drawn, immediately after which *S*s in the control group and the alcohol-first group were trained on the problem solving task. Then they were given their drink, either alcohol or placebo. One hour after ingestion, blood samples were drawn on *S*s who had received alcohol and all subjects then experienced a period of rotational vestibular stimulation. Following this, (about 1½ hours after receiving their drink) all subjects were tested on the problem solving task; another blood sample was drawn after code-lock testing was completed, i.e., at two hours after they received alcohol.

3. Post-Alcohol Day. Following a period of rotational vestibular stimulation, control and alcohol-first subjects were again tested on code-lock.

All subjects were tested on the same set of 18 problems on the alcohol day; a second set of 18 problems was used on the post-alcohol sessions; the alcohol-second group was given a third set for their pre-alcohol testing.

III. Results.

The data from the experimental groups were analyzed using a Lindquist Type II design in which day of receipt of alcohol was the Latin square factor. The sources of variance in each of the 11 analyses were: day of testing (first vs. second day); alcohol (vs. no alcohol); group (order of testing with respect to the alcohol/no alcohol conditions); and subjects. The results of these analyses are summarized in Table

2. For each measure, the means for the two levels of each of the variables and the "F" value for the test of the effect are shown.

The order of testing with respect to the day of administration of alcohol is reflected in the difference between groups in this design. In no case was that difference significant.

The practice effect was significant for all but three of the 11 measures. With the exception of those three measures, performance on day 2 was significantly better than on day 1. Two of the measures that did not show a significant difference between day 1 and day 2 were error measures, namely, errors per solution for first solution and errors per solution for second solution. The third measure for which no difference was found was the time per incorrect response for the second solution. However, this latter measure is based on a relatively small number of responses and a reduced number of subjects. Since seven of the 20 subjects made no incorrect responses during the second solutions on one or both testing sessions, the four subjects in the alcohol-first group and the three subjects in the alcohol-second group who made no errors wer dropped from the analysis, along with one sub ject selected at random from the alcohol-secon group. For the remaining six subjects per grou the time per incorrect response for the secon solution was based on an average of only si responses per session. For all of the other tim measures, the difference between day 1 and da 2 was significant with better (i.e., faster) pe formance occurring on day 2. Specifically, tir per response, time per correct response, and tir per solution for both first- and second-solutic phases of performance treated separately differe significantly for the two days of the study; tir per incorrect response differed significantly f the first solution only; and time per proble differed significantly for the two solutions con bined.

The main effect of alcohol was significant f only one measure taken during the first-soluti phase of testing; that measure was the time-pe correct response. The alcohol effect was signi cant for three second-solution measures—tir per response, time per solution, and errors p

Table 2.—Means and F Ratios for Analysis of Variance.

	Time Per Response	Time Per Correct Response	Time Per Incorrect Response	Time Per Solution	Errors Per Solution	Time Per Problem
First Solution						
Mean Day 1	1.35	1.26	1.46	23.3	.88	14.7
Mean Day 2	1.14	1.11	1.20	18.1	.50	10.9
F (df=1/18)	15.53**	17.23***	23.83***	16.22***	1.19	23.78**
Mean with Alcohol	1.27	1.23	1.36	21.6	.97	13.7
Mean without Alcohol	1.22	1.14	1.30	19.7	.41	11.9
F (df=1/18)	1.07	5.09*	1.09	20.7	2.51	5.09*
Mean Group A	1.27	1.23	1.36	20.7	.74	13.2
Mean Group B	1.21	1.04	1.30	20.6	.64	12.4
F (df=1/18)	X	X	X	X	X	X
Second Solution						
Mean Day 1	.92	.90	1.18	5.5	.46	
Mean Day 2	.77	.77	.88	4.3	.27	
F (df=1/18)	17.53***	15.52***	3.84	5.95**	1.29	
Mean with Alcohol	.89	.86	1.08	5.5	.55	
Mean without Alcohol	.80	.80	.99	4.3	.18	
F (df=1/18)	5.91*	3.40	X	6.39**	5.43**	
Mean Group A	.91	.89	1.06	5.4	.47	
Mean Group B	.78	.77	1.00	4.4	.26	
F (df=1/18)	1.07	1.99	X	1.78	2.83	

* $p<.05$ ** $p<.01$ ***$p<.001$ X $F<1.0$

solution. Time per problem (first and second solutions combined) also showed a significant effect.

The individual cell means for the five measures for which a significant alcohol effect was found are shown in Tables 3 through 7 along with the day-1 and day-2 means for the control group. Individual "t" tests were applied to the differences between days for each of the alcohol groups treated separately. The performance of the alcohol-first group was significantly better on day 2 than on day 1 ($p<.05$) for five of the measures (Tables 3, 4, 5, and 7); only errors on the second solution did not differ significantly across days (Table 6). The only significant difference found across days for the alcohol-second group was in the case of the time per problem measure (both solutions combined). It can be seen in Table 7 that, for this measure, performance on day 2 (the alcohol day) was significantly superior to that on day 1 ($p<.05$); note also that the direction of the effect for this test is opposite that found with the overall "F" test for the effect of alcohol (Table 2). For two of the measures, the performance of the alcohol-second group was faster on their alcohol day (day 2) than on day 1, but the differences were not significant; the measures were time per correct response (first solution) shown in Table 3 and time per response (second solution) shown in Table 4. For time per solution (second solution), the mean performance on the two days was the same for the alcohol-second group (Table). Only the error measure on the second solution (Table 6) was in the direction of better performance on day 1 than on day 2 for the lcohol-second group, but that difference was not gnificant.

ABLE 3.—Cell Means for Time Per Correct Response—First Solution.

	Day	
	1	2
lcohol First	1.35*	1.11
cohol Second	1.17	1.10
ontrol	1.29	1.14

*The value underlined is for the session on which the oup received alcohol.

TABLE 4.—Cell Means for Time Per Response—Second Solution.

	Day	
	1	2
Alcohol First	1.03*	.79
Alcohol Second	.81	.75
Control	.91	.72

*The value underlined is for the session on which the group received alcohol.

TABLE 5.—Cell Means for Time Per Solution—Second Solution.

	Day	
	1	2
Alcohol First	6.6*	4.2
Alcohol Second	4.4	4.4
Control	5.4	4.0

*The value underlined is for the session on which the group received alcohol.

TABLE 6.—Cell Means for Errors Per Solution—Second Solution.

	Day	
	1	2
Alcohol First	.66*	.16
Alcohol Second	.16	.35
Control	.44	.16

*The value underlined is for the session on which the group received alcohol.

TABLE 7.—Cell Means for Time Per Problem—First Plus Second Solution.

	Day	
	1	2
Alcohol First	32.0*	20.8
Alcohol Second	26.8	22.8
Control	29.4	20.0

*The value underlined is for the session on which the group received alcohol.

In addition to the above "across-days tests," individual "t" tests were applied to the differences between groups for each day treated separately. For the day-1 comparisons, significant differences between groups were found only in the case of the time per response measure (second solution). For this measure, shown in Table 4, the performance of the alcohol-first group was significantly poorer than that of both the alcohol-second ($p<.05$) and the control groups ($p<.05$). And the performance of the control group was significantly poorer than that of the alcohol-second group ($p<.05$). (Note that the control group underwent vestibular stimulation immediately prior to testing whereas the alcohol-second group did not). For the day-2 comparisons, no significant differences were found. However, for the errors per solution (second solution), the differences between the alcohol-second group and the other two groups approached significance ($.10>p>.05$) with the performance of the alcohol-second group being inferior to that of the other two groups (Table 6). Since the control group and the alcohol-first group did not differ on this meansure, these two groups were combined and an "F" test was applied to the difference between the combined groups and the alcohol-second group. This difference was significant at the .05 level of confidence.

IV. Discussion.

The significant practice effect for time but not error measures suggests that subjects followed a strategy of trying to minimize errors by holding their speed of performance to a value that would permit achievement of that goal. The subjects apparently followed the search procedure rather carefully on the first solution as seen by the very small number of surplus errors when a correction is made for the expected errors for a given problem. And the errors were even less frequent for the second solution. The error-minimization strategy is also revealed by the fact that between-subject variance accounted for about 40% of the total variance for the error measures whereas it accounted for about 70% of the variance on the time measures. This finding that individual differences on this task are measured primarily by time measures is consistent with the findings of an earlier study by Chiles and Smith (1971) in which significant correlations with the Otis test of mental abilities were found for the time measures but not for the error measures.

Although a significant main effect of alcohol was found for five of the measures, the interpretation of the findings with respect to the effects of alcohol on problem-solving performance is rather complicated. First, the fact that the study here "attached to" the vestibular stimulation study creates a problem. Specifically, in the comparisons on day 1 between the alcohol first and the alcohol second groups, the effects of the two variables (alcohol and vestibular stimulation) are confounded. The alcohol-first group was exposed to vestibular stimulation prior to testing on day 1 whereas the alcohol-second group was not. Similarly, on day 2 there is partia confounding of the two variables in that the alcohol-second group was exposed to the vestibular stimulation for the first time on that day. Second, of the five significant F-ratios fo the alcohol effect, in only one case was the performance of the alcohol-second group actuall poorer with than without alcohol, and even i that case (errors on the second solution), performance was not significantly poorer unde alcohol.

The simple effects of alcohol on day 1 for th time per response measure (second solution) ar relatively clear-cut. For this analysis, there i both a significant effect of alcohol and a signifi cant effect of the vestibular stimulation and/o the placebo. The alcohol-second group responde the fastest, the control group (placebo and ves tibular stimulation) second fastest, and th alcohol-first group (their alcohol day) responde the slowest, all of these differences being signif cant. The possibility that it was the vestibula stimulation that produced the significant effe on the performance of the control group make interpretation of the day-2 findings for secon solution errors rather difficult. Although th alcohol-second group differed significantly fro the combined control and alcohol-first group this was the first exposure of the alcohol-secon group to the vestibular stimulation. Considerin the performance of the control group, the in proved performance of those subjects on day is probably reflective of practice effects but may also be reflective of some kind of adaptatic to the vestibular stimulation. Thus, the great number of second-solution errors made on day by the alcohol-second group relative to the oth two groups may have been in part a result of an alcohol effect, in part a residual of this having been their first exposure to vestibular stimulation, and in part an interaction of the two variables. The significant differences on this measure between the alcohol-first and the alcohol-second groups on day 1 is even less clear. The control group was also poorer than the alcohol-second group but better than the alcohol-first group, though not significantly so in either case. Thus, again, the apparent effect cannot be unambiguously attributed to any one of the experimental variables.

The effect of the order of testing with respect to the administration of alcohol could not be measured with any great degree of sensitivity in this study. Since this was a between-subjects comparison, 10 subjects per group does not afford much statistical power for the direct test of the order effect. However, there were indications in the individual tests of the simple effects of alcohol and the simple effects of practice that suggest that there was in fact an interaction between the two variables. For one measure, time per problem (first and second solutions combined), the alcohol-second group performed significantly faster on day 2 (with alcohol) than on day 1 despite the fact that the overall effect of alcohol was significant and in the other direction for this measure. This suggests the possibility that subjects who are motivated to do well on a task will adjust their speed to take account of what they perceive to be possible effects of alcohol on their performance. And it also suggests that the amount of adjustment (reduction in speed) will be greater on a relatively new task (alcohol-first group) than on a task with which the subject has become somewhat familiar (alcohol-second group). It may well be that this is an important aspect of the increased errors for the alcohol-second group on day 2. They incorrectly perceived the potential for disruption caused by the alcohol and, as a result, went too fast to avoid making second-solution errors. One is tempted to conclude that their judgment was impaired by the alcohol, but that conclusion would be an unwarranted extrapolation in view of the confounding noted previously.

There are three primary mechanisms in the performance of the code-lock task that might be affected by the blood alcohol levels found with these subjects, namely, perceptual-motor skill, short-term memory, and "memory-response" encoding. Although the first solution phase of the code-lock task is ostensibly a problem-solving situation, performance generally becomes a rather simple, repetitive process that is fairly automatic when the subject has a small amount of practice. The limiting factors on performance during this phase are motor skill in pressing buttons, speed of reaction to the error feedback light, short-term memory, and memory-response encoding. Short-term memory is clearly important in re-entering partial solutions following an error. It is also important in executing the search sequence, since any button that is a member of the already-discovered partial solution must be eliminated from the search sequence.

Short-term memory is perhaps even more important in the second solution phase; the subject must remember the correct sequence discovered in the first solution phase and, after a 10-second delay, re-enter that sequence. Speed of response to the feedback lights was generally not important since the subjects tended to enter the second solution without reference to the lights. Since the lights were separated from the push-buttons by a vertical distance of about 10 cm (4 inches), it was possible to determine by observation where many of the subjects were focusing their attention. They seemed not to be looking at the feedback lights during the second-solution phase. This can also be inferred from the fact that it was not uncommon for a subject to enter a complete 5-button sequence even though intermediate responses were incorrect.

The pattern of significant effects on the code-lock measures suggests that the most likely mechanism for an effect of alcohol was interference with short-term memory and/or the memory-to-response encoding mechanism. During the first solution phase, only time per correct response and solution time were affected by alcohol. The number of correct responses during this phase of the task is constituted primarily of responses made in re-entering partial solutions, a process that depends heavily on short-term memory. Solution time for a given problem is a function of both speed of response and the number of surplus errors, but, because relatively few surplus errors were made (an average of less than one error per problem), speed of response in re-entering partial solutions is the dominant component. Hence, short-term memory and/or memory-to-response encoding are also implicated for this measure.

Efficient performance during the second solution is almost entirely dependent on short-term memory and the memory-to-response encoding process. However, the occurrence of errors during the second solution could also be the result of motor involvement. Although this study does not afford a means for clearly distinguishing between these two possibilities, the separation between buttons (2.4 cm) would seem to make "aiming" a relatively small factor. Thus, we are inclined to conclude that the obtained effects are in the informational rather than the motoric domains.

Several factors that are present in the aviation environment were not included in this experiment. Three of these are of direct relevance to the interpretation of the findings in relation to flying skills. First, the problem-solving task can be thought of as involving a homogeneous set of behaviors. In contrast, the pilot is required to exercise a variety of behaviors, and, of even greater importance, he is required to time share their performance. Thus, as suggested by our previous study (Chiles and Jennings, 1970), if time sharing were added to the situation, the detrimental effects of alcohol would be expected to be enhanced. Second, the nature of the problem solving task is such that the subject can adjust his speed of response as a way of avoiding errors if he interprets the potential effects of alcohol to be likely to lead to errors; this is in fact what the subjects in this study did. In the operation of an aircraft, the pilot has rather limited freedom in making such adjustments and, in emergencies, may have no room for adjustment of his "speed of response." And, third, the pilot is subjected to a variety of potentially disturbing motions of the aircraft which, as reported by Collins, Gilson, Schroeder, and Guedry (1971), tend to enhance the effects of alcohol on performance. Factors such as these are undoubtedly the reason that Billings, Wick, Gerke, and Chase (1971) found significant decrements in pilot performance at blood alcohol levels that were substantially lower than those used in the present study.

V. Summary and Conclusions.

Three groups of subjects were tested on two separate days on a simple problem-solving task which required them to discover the correct sequence in which to push five buttons in order to turn on a green light; the correct sequence was then re-entered after a 10-second delay. One group of subjects (N=10) received alcohol on the first day and nothing the second; a second group (N=10) received nothing the first day and alcohol the second; the third group (N=11) received a placebo the first day and nothing the second. The group that received alcohol the first day and the placebo group were also subjected to vestibular stimulation on both days; the alcohol-second group received vestibular stimulation only on the second day of testing. The average blood alcohol level for the experimental groups was about 94.5 mg%.

Alcohol as a main effect was significant for five of the 11 measures analyzed; three of the significant effects found were for second-solution performance, one was for first-solution performance, and one was for the solution time per problem which included both solutions. One of the measures that was affected by alcohol was errors on the second solution; the other four were time measures. Analysis of the simple effects showed that alcohol has a greater effect during the time when the task is still being mastered than after a day's practice (18 problems) has been given. However, there is suggestive evidence from the error measure, second solution performance, that the performance of practiced subjects may also be adversely affected by alcohol. There was also suggestive evidence of a residual effect of the vestibular stimulation on the problem-solving performance of the control group.

We conclude that alcohol does have an effect on problem solving of the sort used in the present study and that the effect is greater on subjects when they are less practiced than when they are more experienced on the task. We also tentatively conclude that there may be a residual effect of vestibular stimulation per se on performance even though some time has elapsed since the rotational experience. Further research is required to clarify this point, but, if the finding does prove reliable on replication, then the implications with respect to recovery times in the case of pilots could be very important.

REFERENCES

1. Billings, Charles E., Robert L. Wick, Jr., Ralph J. Gerke, and Robert C. Chase: The Effects of Alcohol on Pilot Performance During Instrument Flight. Final Report, FAA Contract No. FA68AC-6089-2, Project No. RF-2626, Office of Aviation Medicine, Washington, D.C., 1971.
2. Carpenter, John A., and Bruce M. Ross: Effect of Alcohol on Short Term Memory, QUARTERLY JOURNAL OF STUDIES ON ALCOHOL, 26:561-579, 1965.
3. Chiles, W. Dean, and Alan E. Jennings: Effects of Alcohol on Complex Performance, HUMAN FACTORS, 12:605-612, 1970.
4. Chiles, W. Dean, and Roger C. Smith: A Non-Verbal Technique for the Assessment of General Intellectual Ability in Selection of Aviation Personnel. FAA Office of Aviation Medicine Report No. FAA-AM-71-28, 1971.
5. Collins, William E., Richard D. Gilson, David J. Schroeder, and Frederick E. Guedry, Jr.: Alcohol and Disorientation-Related Responses. III. Effects of Alcohol Ingestion on Tracking Performance During Angular Acceleration. FAA Office of Aviation Medicine Report No. FAA-AM-71-20, 1971.
6. Lindquist, E. F.: *Design and Analysis of Experiments in Psychology and Education*, Houghton Mifflin Company, Boston, 1953.
7. Tarter, Ralph E., Ben M. Jones, C. Dene Simpson, and Arthur Vega: Effects of Task Complexity and Practice on Performance During Acute Alcohol Intoxication, PERCEPTUAL AND MOTOR SKILLS, 53:307-318, 1971.