AD-A064 777 OKLAHOMA UNIV HEALTH SCIENCES CENTER OKLAHOMA CITY F/G 5/11
EFFECTS OF ALCOHOL ON HUMAN INFORMATION PROCESSING.(U)
OCT 76 H L WILLIAMS, B K LESTER, O H RUNDELL DAMD17-76-C-6001

UNCLASSIFIED NL

| OF |
AD
A064777

END
DATE
FILMED
4 -79
DDC

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

LEVEL II

AD A064777

DDC FILE COPY

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
Effects of Alcohol on Human Information Processing	Final Scientific Report · July 1975 - Oct 1976
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Harold L. Williams, Ph.D., Boyd K. Lester, M.D., and O. H. Rundell, Ph.D.	DAMD 17-76-C-6001
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
University of Oklahoma Health Sciences Center P. O. Box 26901 Oklahoma City, Oklahoma 73190	62758A 3A762758A833 00 012
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
U.S. Army Medical Research and Development Command Fort Detrick, Frederick, Maryland 21701	October 1976 13. NUMBER OF PAGES 63
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
12 63p.	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DDC RECEIVED FEB 22 1979 A

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Alcohol
Information processing
Memory

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Although the three investigations supported by this contract are independent studies, each examined the effects of alcohol on cognitive processes associated with information processing or memory. The principal aim of the first project was to analyze the effects of alcohol on organizational processes in human memory. The aim of the second project was to investigate the effects of alcohol on speed-accuracy tradeoff functions in auditory choice reaction time performance. The third project employed visual choice reaction time tasks to study the

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

407464

79 02 16 084

20. (cont.)
differential effects of alcohol on hypothetical stages of information processing and the mediation of alcohol deficit by extended practice. Recently our studies have investigated alcohol effects from the perspectives afforded by contemporary theories in cognitive psychology.

During the report period we completed the fourth in a series of studies assessing the effects of acute alcohol intoxication on memory processes in normal, young adult men. The study employed 46 subjects and three experimental tasks in an attempt to confirm and extend earlier findings with regard to the vulnerability of several hypothetical memory processes to moderate levels of intoxication (blood alcohol content, BAC ≈ 100 mg%). The paradigm assessed performance on free recall, multi-trial free recall, and recognition tasks. The results confirmed earlier findings of (1) an alcohol-related deficit in recall from both short-term store and long-term store, and (2) an alcohol-related impairment of organizational processes, as assessed by various measures of subjective and objective organization. In addition, the correlations between the organizational measures and measures of recall were substantial ($\bar{r}$ = .76), thus confirming previous findings.

Alcohol produced nearly equal decrements in recognition and free recall performance. This finding suggests that the memory scanning function of the retrieval process is unimpaired by alcohol. Recall stability, however, was markedly reduced by alcohol. This suggests that the intoxicated subject may have little difficulty locating an item in memory, but may be severely impaired in the ability to decide whether the item located is appropriate for emission. Signal detection analyses of the recognition tasks indicated both an alcohol-related decrease in the d' statistic and an increase in β. Thus, the moderately intoxicated individual clearly is experiencing an impairment of memory and may be attempting to compensate for the deficit by increased caution. Although caution was not assessed in the free recall tasks, one would expect that a result of increased caution would be a decrease in the number of words "recalled".

Objective organization, as assessed in the present study, requires the subject to analyze the to-be-remembered items at the level of meaning. Therefore, the alcohol-related impairment seen in measures of organizational processes very likely is a reflection of impaired encoding. Unfortunately, the task designed to assess level of encoding produced inconclusive results. Overall, the results of the present study were consistent with the hypothesis of a disruption of encoding process in moderately intoxicated individuals; but a definitive test of the hypothesis is yet to be made.

The second project examined the combined effects of alcohol and task difficulty on speed-accuracy tradeoff in auditory choice reaction time. The results confirmed those found by the Walter Reed group, showing that alcohol produces a dose-related decrease in the slope parameter of the speed-accuracy tradeoff function but has no systematic effect on the intercept parameter. Thus in speeded choice tasks, the moderately intoxicated subject can sustain high accuracy but does so with considerable loss of speed.

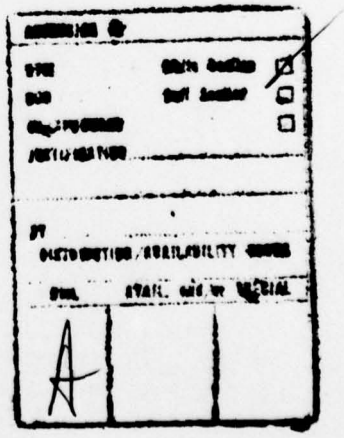
Task difficulty was manipulated in this study by varying the rule for mapping the response on the stimulus. The side-discrimination task required the subject to respond according to a highly compatible left-right position rule. The pitch-discrimination task required the subject to disregard position (ear stimulated) and respond to pitch according to a left/right rule. Reaction times were longer for the pitch than for the side task. The task difficulty variable influenced the intercept but not the slope of the speed accuracy tradeoff function, and its effects were independent of those of alcohol. The isolation of the task effect on the intercept parameter probably reflects increased requirements

20. (cont.)
for stimulus processing in the pitch discrimination task, and the absence of a task-by-alcohol interaction effect is consistent with our earlier conclusion that alcohol influences output cognitive processes associated with response decisions rather than input cognitive processes such as stimulus encoding.

The third project employed two visual choice reaction time tasks (Digit-Key and Light-Key) and simple reaction time to investigate the effects of alcohol on information processing at two levels of practice. Correct responding in the Digit-Key task requires the subject to translate from a numerical to a spatial code, whereas for the highly compatible Light-Key task the stimulus and response codes are identical. Employing the two visual choice tasks with simple reaction time, subtraction procedures are used to obtain estimates of the durations of two hypothetical stages of information processing, translation and response selection.

In both the short (100 trials per task) and long (2,000 trials per task) practice groups, alcohol slowed performance on both of the choice tasks. At both levels of practice, alcohol produced significant increases in the estimated duration of both hypothesized stages of information processing, translation and response selection. In the short practice group, alcohol had no effect on simple reaction time but in the long practice group simple reaction time was slowed. Although practice improved speed in all three tasks, it did not prevent alcohol-related deficit on any task. With repeated alcohol doses spaced 48 hrs. apart, there was evidence that the subject does not "habituate" to alcohol effects such that impairment is reduced in a second alcohol session. In fact, there were trends in the data suggesting that alcohol interferes with the beneficial effects of practice.

The results are consistent with our earlier conclusion that alcohol effects are targeted upon output cognitive processes associated with selecting and organizing the response. They extend this work by showing that alcohol also causes slowing of a more central cognitive process, stimulus to response translation.



AD_____

EFFECTS OF ALCOHOL ON HUMAN INFORMATION PROCESSING

Final Scientific Report
October 1976

Harold L. Williams, Ph.D., Boyd K. Lester, M.D., and O.H. Rundell, Ph.D.

Supported by

U.S. Army Medical Research and Development Command

Fort Detrick, Frederick, Maryland 21701

Contract No. DAMD 17-76-C-6001

University of Oklahoma Health Sciences Center
Oklahoma City, Oklahoma

Table of Contents

Effects of Alcohol on Human Information Processing

List of Tables

List of Illustrations

EFFECTS OF ALCOHOL ON HUMAN INFORMATION PROCESSING

Summary

Although the three investigations supported by this contract are independent studies, each examined the effects of alcohol on cognitive processes associated with information processing or memory. The principal aim of the first project was to analyze the effects of alcohol on organizational processes in human memory. The aim of the second project was to investigate the effects of alcohol on speed-accuracy tradeoff functions in auditory choice reaction time performance. The third project employed visual choice reaction time tasks to study the differential effects of alcohol on hypothetical stages of information processing and the mediation of alcohol deficit by extended practice.

During the past several years we have directed considerable effort toward explicating the effects of moderate alcohol intoxication on aspects of human performance. Recently these studies have investigated alcohol effects from the perspectives afforded by contemporary theories in cognitive psychology. The work on alcohol and human memory began with the examination of alcohol effects on short- and long-term memory "stores" as postulated in several serial stage models of memory. Subsequently, the emphasis shifted toward the effects of alcohol on such hypothetical processes as encoding, organization, and retrieval of information in memory.

During the report period we completed the fourth in a series of studies assessing the effects of acute alcohol intoxication on memory processes in normal, young adult men. The study employed 46 subjects and three experimental tasks in an attempt to confirm and extend earlier findings with regard to the vulnerability of several hypothetical memory processes to moderate levels of intoxication (blood alcohol content, BAC ≃ 100 mg%). The paradigm assessed performance on free recall, multi-trial free recall, and recognition tasks. The results confirmed earlier findings of (1) an alcohol-related deficit in recall from both short-term store and long-term store, and (2) an alcohol-related impairment of organizational processes, as assessed by various measures of subjective and objective organization. In addition, the correlations between the organizational measures and measures of recall were substantial ($\bar{r}$ = .76), thus confirming previous findings.

Alcohol produced nearly equal decrements in recognition and free recall performance. This finding suggests that the memory scanning function of the retrieval process is unimpaired by alcohol. Recall stability, however, was markedly reduced by alcohol. This suggests that the intoxicated subject may have little difficulty locating an item in memory, but may be severely impaired in the ability to decide whether the item located is appropriate for emission. Signal detection analyses of the recognition tasks indicated both an alcohol-related decrease in the d' statistic and an increase in β. Thus, the moderately intoxicated individual clearly is experiencing an impairment of memory and may be attempting to compensate for the deficit by increased caution. Although caution was not assessed in the free recall tasks, one would expect that a result of increased caution would be a decrease in the number of words "recalled".

Objective organization, as assessed in the present study, requires the subject to analyze the to-be-remembered items at the level of meaning. Therefore, the alcohol-related impairment seen in measures of organizational processes very likely is a reflection of impaired encoding. Unfortunately, the task designed to assess

level of encoding produced inconclusive results. Overall, the results of the present study were consistent with the hypothesis of a disruption of encoding process in moderately intoxicated individuals; but a definitive test of the hypothesis is yet to be made.

The second project examined the combined effects of alcohol and task difficulty on speed-accuracy tradeoff in auditory choice reaction time. The results confirmed those found by the Walter Reed group, showing that alcohol produces a dose-related decrease in the slope parameter of the speed-accuracy tradeoff function but has no systematic effect on the intercept parameter. That is to say, alcohol had no effect on fast but relatively inaccurate performance but produced substantial deficit in relatively slow but accurate performance. Thus in speeded choice tasks, the moderately intoxicated subject can sustain high accuracy but does so with considerable loss of speed.

Task difficulty was manipulated in this study by varying the rule for mapping the response on the stimulus. The side-discrimination task required the subject to respond according to a highly compatible left-right position rule. The pitch-discrimination task required the subject to disregard position (ear stimulated) and respond to pitch according to a left/right rule. Reaction times were longer for the pitch than for the side task. The task difficulty variable influenced the intercept but not the slope of the speed accuracy tradeoff function, and its effects were independent of those of alcohol. The isolation of the task effect on the intercept parameter probably reflects increased requirements for stimulus processing in the pitch discrimination task, and the absence of a task-by-alcohol interaction effect is consistent with our earlier conclusion that alcohol influences output cognitive processes associated with response decisions rather than input cognitive processes such as stimulus encoding.

The third project employed two visual choice reaction time tasks (Digit-Key and Light-Key) and simple reaction time to investigate the effects of alcohol on information processing at two levels of practice. Serial stage models of choice reaction time postulate that the longer reaction times found for the Digit-Key task are due to a translation requirement for that task which is not present in the Light-Key task. Thus, correct responding in the Digit-Key task requires the subject to translate from a numerical to a spatial code, whereas for the highly compatible Light-Key task the stimulus and response codes are identical. Employing the two visual choice tasks with simple reaction time, subtraction procedures are used to obtain estimates of the durations of two hypothetical stages of information processing, translation and response selection.

In both the short (100 trials per task) and long (2,000 trials per task) practice groups, alcohol slowed performance on both of the choice tasks. At both levels of practice, alcohol produced significant increases in the estimated duration of both hypothesized stages of information processing, translation and response selection. In the short practice group, alcohol had no effect on simple reaction time but in the long practice group simple reaction time was slowed. Although practice improved speed in all three tasks, it did not prevent alcohol-related deficit on any task. With repeated alcohol doses spaced 48 hrs. apart, there was evidence that the subject does not "habituate" to alcohol effects such that impairment is reduced in a second alcohol session. In fact, there were trends in the data suggesting that alcohol interferes with the beneficial effects of practice.

The results are consistent with our earlier conclusion that alcohol effects are targeted upon output cognitive processes associated with selecting and organizing the response. They extend our earlier work by showing that alcohol also causes slowing of a more central cognitive process, stimulus to response

translation. Finally, the results indicate that practice up to 2,000 trials, spaced over several days does not protect performance against the impairment associated with moderate intoxication.

ALCOHOL AND MEMORY

Three previously completed experiments using free recall and free recall learning had led to the following tentative conclusions regarding the effects of acute alcohol intoxication on human memory processes:

1. Alcohol intoxication (BAC ≃ 100 mg%) produces a substantial and reliable effect on recall from long-term store (LTS).
2. Intoxication at this level also leads to a smaller and somewhat less reliable impairment of recall from short-term store (STS).
3. A moderate increase in errors of commission (statistically significant in one experiment), and an interaction between the effects of alcohol and a task variable, list length, suggested that the alcohol deficit seen in output from LTS may have resulted from impaired organization of items in LTS and/or from impaired retrieval. Data from the third experiment of the series indicated that intoxicated subjects were impaired in the use of objective organizational aids as indexed by a measure of clustering. In addition, the clustering measure correlated strongly ($r = .87$, $p < .001$) with the criterion measure, total correct recall.
4. In two experiments the task variable, forced inter-item rehearsal (FIR), was employed to load the STS-to-LTS transfer mechanism. The two levels of FIR employed were one or five verbal repetitions of each to-be-remembered item during the 2 second interstimulus interval. Glanzer and Meinzer (1967) have shown that such forced rehearsal impairs output from LTS, but not from STS. Thus, these investigators have hypothesized that FIR interferes with the transfer of items from STS to LTS. In neither of our two experiments employing FIR as a task variable was there an interaction between the effects of FIR and alcohol. Thus, our data do not support the hypothesis that alcohol interferes with STS-to-LTS transfer.

The completed work, reported below, is a fourth study in the series investigating the effects of acute alcohol intoxication on human memory processes. This study was designed to test the following hypotheses derived primarily from the previous experiments in the series:

1. Alcohol (BAC ≃ 100 mg%) impairs recall from two hypothetical memory stores: STS and LTS.
2. Alcohol impairs retrieval processes.
3. Acute intoxication mimics in certain ways alcoholic Korsakoff syndrome. In particular, acute intoxication impairs encoding processes, leading to processing at shallow levels (i.e., at phonemic levels rather than at semantic levels).
4. Alcohol impairs organizational processes and specifically interferes with the use of objective organizational aids present in the to-be-remembered material.

Three groups of subjects participated in the experiment. Subjects assigned to Group 1 came to the laboratory on two successive days. These subjects received a placebo on Day 1 and a moderate dose of alcohol on Day 2. Half of the Group 1 subjects performed Tasks 1a, 2, and 3 on Day 1 and repeated Task 1a on Day 2. The remaining Group 1 subjects performed only Task 1a on Day 1 and Tasks 1a, 2, and 3 on Day 2. Subjects assigned to Group 2 (placebo) and Group 3 (alcohol) came to the laboratory on one occasion only, and performed Tasks 1b, 2, and 3. Thus,

approximately half of the subjects (Group 1) performed Task 1a while the remainder (Groups 2 and 3) performed Task 1b. All subjects performed Tasks 2 and 3. For clarity of presentation the tasks will be reported separately.

Tasks 1a and 1b: Free Recall and/or Recognition

Introduction

If alcohol impairs retrieval from LTS, then a task which eliminates retrieval or, at least, reduces the retrieval load should show less impairment than a recall task. Recognition tasks are generally presumed to require either (1) no retrieval at all (i.e., search-free retrieval; see, Anderson & Bower, 1972; Bernbach, 1967; Bower, Clark, Lesgold & Winzens, 1969; Kintsch, 1968, 1970; Murdock, 1972; Norman & Waugh, 1968), or (2) a substantially reduced retrieval load (Shiffrin & Atkinson, 1969; Tulving, 1970; Tulving & Thompson, 1971). In either case, alcohol might be expected to have lesser effects on recognition tasks than on free recall.

Method

Subjects. Forty-six male volunteers (ages 21-30) were recruited from nearby colleges and universities and were paid for their participation. Two subjects became nauseous after receiving alcohol, leaving a total of forty-four subjects from whom data were collected. Subjects were randomly assigned to one of three groups. Group 1 subjects (N = 20) came to the laboratory on two successive days and performed Task 1a (free recall and recognition). They received a placebo on Day 1 and a moderate dose of alcohol on Day 2. Subjects assigned to Groups 2 (N = 11) and 3 (N = 13)[1] came to the laboratory on one occasion and performed Task 1b (recognition). Group 2 received placebo drinks on their single session, and Group 3 received a moderate dose of alcohol. Subjects were tested in groups of three or four.

Alcohol dosage and administration. Subjects were fasted (water excepted) for at least four hours before coming to the laboratory and were requested to refrain from taking any drug for at least 24 hours prior to participation. None of the subjects were currently receiving prescription medication. The alcohol dose consisted of 1 g 95% ethanol per kg body weight mixed 1:4 with orange drink. The total beverage was divided into three drinks and consumed within 30 minutes. Placebo consisted of an identical volume of orange drink (total 4.8 ml/kg) with 4-5 ml ethanol floated on the top of each of the three drinks. Initial Breathalyzer measures of BAC were taken 30 minutes following consumption of the final drink. Two subsequent BAC determinations were made following Task 1 (about 25 minutes later) and Task 3 (about 60 minutes after the initial measurement).

Procedure. Task 1a consisted of free recall of ten 15-word lists, each list being followed by a recognition task. After tests of free recall and recognition, subjects performed a final free recall of the words in all lists. Each list consisted of 15 English words of one syllable. The words were of high frequency

---

[1]Groups 2 and 3 were planned to include 12 subjects each. The unequal sample sizes were the result of a scheduling error.

according to both the Thorndike-Lorge (1944) and Kucera-Francis (1967) norms. Words were projected on a large screen at a two second rate by means of a Kodak Ektagraphic slide projector. End of the list (beginning of the recall interval) was signalled by a blue slide containing five question marks. Subjects were instructed to write as many words as they could remember without regard for order of presentation. The experimenter suggested to subjects that prior research had indicated that the most efficient recall strategy was to first write the last few items and then try to recall items from the first and middle portions of the list. Immediately following each free recall period, subjects were presented a page containing the 15 list words randomly mixed with 30 lures. Subjects responded to each item by circling a number from 1 to 6 to indicate his confidence that the word was or was not a member of the preceding list. Following the tenth presentation-recall-recognition cycle, subjects were asked for written final free recall of all lists. Ninety seconds were allowed for free recall, three minutes for the subsequent recognition task, and five minutes for final free recall. Two sets of 10 lists were used for Task 1a. Half of the Group 1 subjects received Lists 1-10 on Day 1 and Lists 11-20 on Day 2. The remaining subjects in Group 1 received Lists 11-20 on Day 1 and Lists 1-10 on Day 2.

Task 1b (recognition-final free recall) was identical to the foregoing except that subjects performed the task on one occasion only and immediate free recall was omitted. Thus, the recognition subtask immediately followed list presentation. Written final free recall followed the tenth presentation-recognition cycle. Task 1b was performed only by Groups 2 and 3, and these subjects, therefore, served as a control for the time elapsing between list presentation and memory assessment.

Results and Discussion

Blood alcohol concentrations. For the placebo condition (Group 1-Day 1 and Group 2) each subject's maximum BAC was well below 10 mg%. Mean BAC for subjects in the alcohol condition (Group 1-Day 2 and Group 3) averaged 87 mg%. Means and standard deviations for the three BAC determinations are shown in Table 1. During Task 1 the subjects' mean BAC rose from 82 to 96 mg%.

Task 1a: Immediate free recall of 15-word lists. For analysis the 15 serial positions were combined to form five blocks of three positions each (e.g., 1-3, 4-6, etc.). Alcohol produced a reliable decrement in immediate recall (F 1, 19 = 24.15, $p < .001$)†. The serial position curves for both alcohol and placebo conditions were of the typical U shape, and the F ratio for serial position was highly significant (F 4, 76 = 33.17, $p < .001$)†. However, the interaction between drug condition and serial position was nonsignificant (F 4, 76 = 1.13), and the simple main effect of drug was significant for the final three list positions (F 1, 43 = 4.15, $p < .05$). These results confirm the three previous experiments and imply that alcohol impairs the recall of items in both long- and short-term storage.

Mean errors of commission (i.e., words "recalled" that were not members of the list) were 9.85 and 11.30 for placebo and alcohol conditions, respectively. The difference, however, was not significant (t 19 = 1.36). Thus, in three experiments mean errors of commission was consistently higher for intoxicated

---

†Significant at $p < .05$ or better, non-parametric tests.

Table 1

Blood Alcohol Concentration (N = 33)

	Time since consumption of beverage (minutes)		
	30	55	90
BAC (mg%)			
Mean	82	96	83
SD	13	17	14

subjects, but the difference between alcohol and placebo was statistically significant for only one experiment. Across the three experiments the average increase in commission errors from placebo to alcohol conditions was 86%.

Task 1a: Delayed recognition (following free recall). For both sober and intoxicated subjects, nearly twice as many items were correctly identified in the recognition subtask as were recalled in the immediate free recall subtask. However, alcohol reliably reduced the number of correct recognitions (t 19 = 4.10, $p < .001$)†. Intoxicated subjects tended to commit fewer false recognitions (false alarms), although this result was not quite significant at the .05 level. There was no significant difference between the amount of alcohol-related decrement in the immediate free recall task and the recognition task. This was true whether decrement was calculated on the basis of number of words (t 19 = 1.03)* or on proportional change (t 19 = .48)*. Thus, there was no indication that the retrieval operation of memory scanning was the target of the alcohol effect. The signal detection statistics, d' and β were calculated for both alcohol and placebo conditions of the recognition task. The d' estimates were lower in the alcohol condition, again indicating a reduced ability to identify list items ($p < .021$, sign test). A significantly higher β statistic for the alcohol condition ($p < .006$, sign test) indicated that when intoxicated, the subjects were more "cautious", i.e., less willing to identify items as being list items. Conversely, once committed to a response, the subjects tended to have a higher degree of confidence in their responses when intoxicated than when sober (t 19 = 2.07, $p < .10$; $p = .06$, sign test). Indeed, the degree of confidence was significantly higher in the alcohol condition ($p < .05$) for each of three response categories: hits, correct rejections, and misses. Only for false alarms were intoxicated subjects less confident than sober subjects. However, this latter trend was not statistically significant (t 19 = 1.22)*.

Task 1b: Immediate recognition. The possibility remained that the delayed recognition task failed to show a disproportionate improvement over immediate free recall performance in the alcohol condition because recognition followed recall. Therefore, twenty-four additional subjects (Groups 2 and 3) performed the recognition task immediately after list presentation without intervening free recall. The impairment in immediate correct recognitions by the alcohol group (-15%) was similar to that found with recognition following free recall. However, with independent groups and smaller sample sizes, the alcohol effect did not reach statistical significance with the parametric test (t 22 = 1.67)†. As in the delayed recognition task the alcohol group had lower d' and higher β scores, although neither reached significance. When the number of correct recognitions was compared for the immediate and delayed tasks, no significant difference was found for alcohol (t 31 = 1.04)* or placebo (t 29 = .95)* conditions. Thus, the data support rejection of the first hypothesis (viz., that alcohol interferes with the memory scanning aspect of retrieval).

Task 1a: Final free recall. Final free recall was performed by all subjects. However, Group 1 (Task 1a) represents a within subjects design, while Groups 2 and 3 (Task 1b) require between subjects analyses. For Group 1 alcohol reduced the number of words recalled from a mean of 26.4 to 10.3 (t 19 = 6.03, $p < .001$)†, and increased the number of errors of commission from 10.0 to 13.5 (t 19 = 2.48, $p < .05$)†.

---

*Nonsignificant by non-parametric test.

A set of curves was constructed by calculating the mean recall for each list and arranging the lists in order of presentation. These data are displayed in Figure 1. Main effects were significant for drug (F 1, 19 = 54.3, $p < .001$)† and serial position (F 9, 171 = 13.3, $p < .001$)†, as was the drug by serial position interaction (F 9, 171 = 3.91, $p < .001$)†. Differences between the curves were significant at the .01 level or better (F tests) for the following list positions, 2, 4, 7, 8, 9, and 10. Examination of Figure 1 reveals that the placebo condition's advantage over alcohol steadily increased from List 6 to 10. An hypothesis that alcohol interferes with consolidation processes might predict that alcohol-placebo differences would be greatest for the initial list and least for the final list. In other words, if alcohol interferes with consolidation processes, those lists undergoing consolidation for the longest period should be the most affected. Of course, such a prediction assumes a consolidation process lasting several minutes or longer. The present data are contrary to such an interpretation. However, note that the interval separating presentation of the initial list and final free recall test was only about 45 minutes, and the number of words recalled by the intoxicated subjects was small (mean = 10.3 words). These data, therefore, do not represent a stringent test of a consolidation interference hypothesis.

Task 1b, Groups 2 and 3: Final free recall. For final free recall the placebo and alcohol groups recalled an average of 15.4 and 5.3 words, respectively (t 22 = 4.01, $p < .001$)†. Unlike the results with Group 1, however, Group 2 (placebo) subjects tended to have more commission errors than did the Group 3 (alcohol) subjects. Both Group 2 and Group 3 recalled significantly fewer words than Group 1 ($p < .01$, t tests)†. The relatively superior recall by subjects in Group 1 probably reflects the facilitating effects of immediate recall. Serial position curves were not analyzed because of the very low scores (mode = 0) among the alcohol subjects.

Task 2: Intra-List Recognition

Introduction

Tasks 1a and 1b examined the effects of reduced retrieval load on alcohol-impaired memory. The results suggested that the memory scanning aspect of retrieval is not disrupted by alcohol. Perhaps, then, the memory deficits experienced by intoxicated individuals result from storage difficulties. The source of the deficit may lie in the manner in which intoxicated subjects organize (or fail to organize) new items in memory. A second related possibility is that intoxicated persons may not encode the TBR items efficiently. Task 2 was designed to test the latter notion.

When a TBR item is stored in LTS, a certain amount of ancillary information must be stored with the item (Anderson & Bower, 1972; Shiffrin & Atkinson, 1969; Tulving, 1970). The amount and nature of the ancillary information stored probably has a strong effect on the item's retrievability. Storage of ancillary information with the TBR item is commonly termed "coding". If alcohol intoxication impaired coding processes, recall would be adversely affected.

Several of the possible encoding dimensions are known and their effect on retrievability has been demonstrated (Tulving, 1970; Underwood, 1965). A number of investigators have hypothesized a hierarchy of encoding dimensions for verbal material, and have shown that these dimensions affect recall (see, Craik & Lockhart, 1972; Gardiner, 1974; Hyde & Jenkins, 1969; Posner & Warren, 1972; Wickens, 1970). Three dimensions on which words may be encoded are listed in

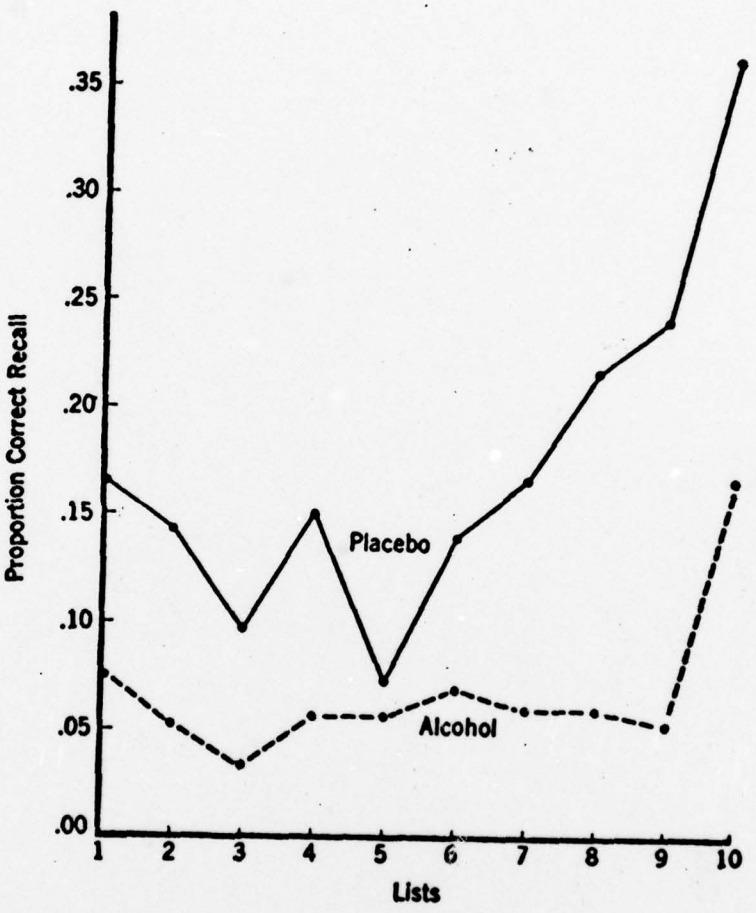


Figure 1. Task 1a, Final Free Recall. Effect of alcohol on delayed recall of each list ($p < .001$).

order of increasing effectiveness: (1) acoustic (phonemic), (2) associative, and (3) semantic characteristics. There is, in addition, some evidence that as the level of encoding effectiveness increases, the difficulty of encoding likewise increases (Cermak & Butters, 1973).

An intra-list recognition (ILR) task, developed by Shepard and Techtsoonian (1961), has been shown to differentiate normal and brain-damaged groups on dimension of coding (Butters & Cermak, 1974; Cermak & Butters, 1973). The ILR task consists of a long list of words presented singly. As each word is presented, subject responds according to whether the word has appeared previously in the list. Typically, the list is composed of pairs of repeated words, homonyms, high frequency associates, and synonyms (e.g., Anisfield & Knapp, 1968). If subject encodes words on the acoustic dimension, false recognition of homonyms would be expected. Associative encoding would lead to false recognition of associates, and so forth. If alcohol leads to encoding at the less effective levels, then the intoxicated subject should have increased false alarms to homonyms and associates. This is precisely what Cermak and Butters found with sober alcoholic Korsakoff patients. Incidentally, such patients have been shown to have intact STS but grossly impaired LTS (Baddeley & Warrington, 1970; Warrington, 1971).

Method

All 44 subjects performed the ILR task on one occasion. Half of the Group 1 subjects performed the task on Day 1 (placebo), and the remaining Group 1 subjects performed the task on Day 2. Subjects in Groups 2 and 3 came to the laboratory on one occasion only and performed the task at that time.

Subjects were given a 10 minute rest period after completing Task 1, and the second Breathalyzer measure was taken. The ILR task was then begun. Following instructions and a short practice list, a single list of 80 words was presented by means of a Kodak Ektagraphic slide projector at a three-second rate. Following presentation of each word, subject responded by circling either "yes" or "no" according to whether the word had appeared previously in the list. The 80-word list was composed of four sets of 10 word-pairs. Set 1 consisted of 10 words, each repeated once in the list. Sets 2-4 consisted of pairs of homonyms, high frequency associates, and synonyms, respectively. The words were randomly shuffled with the constraint that there be two, three, or more than seven items intervening between the members of each pair. This arrangement was designed to allow the separate assessment of the level of encoding of words held in STS and LTS. High frequency associates were presented in forward order only. All words were of relatively high frequency of occurrence according to the Thorndike-Lorge (1944) and Kucera-Francis (1967) norms, and none of the words had been presented previously in the experiment.

Results and Discussion

As shown in Table 1, the mean BAC of subjects in the alcohol condition was 96 mg% at the beginning of Task 2. The final BAC determination was made 35 minutes later (after completion of Task 3), and had fallen to 83 mg% at that time. Thus, Tasks 2 and 3 were performed during a period of declining intoxication. All subjects in the placebo condition had zero blood alcohol.

If the intoxicated subject were to encode at less effective levels, one would expect a decrease in the hit rate. In addition, encoding at the acoustic level

Table 2

Task 3. Effects of Alcohol and Task Variables on Proportion Correct Recall

Drug		Placebo	Alcohol
	Mean	.56	.30
	SD	.19	.12
Trials		One	Two
	Mean	.34	.52
	SD	.16	.20
List Arrangement		Random	Blocked
	Mean	.38	.48
	SD	.13	.20
		Drug	
Trial 1		Placebo	Alcohol
	Mean	.45	.23
	SD	.14	.08
Trial 2			
	Mean	.67	.37
	SD	.16	.11
		Drug	
List Arrangement		Placebo	Alcohol
Random	Mean	.49	.27
	SD	.08	.08
Blocked	Mean	.63	.32
	SD	.17	.09

rather than the semantic level would produce a confusion of homonyms. Thus, the subject would tend to make more false positive responses to the second member of a pair of same-sounding words (e.g., "bear" and "bare"). Likewise, encoding on an associative dimension would lead to more false positive responses to high frequency associates. Therefore, if the encoding hypothesis were correct, one would expect, as a minimum, fewer hits and more false alarms in the alcohol condition. The alcohol group did have fewer correct identifications ($p < .05$)* but only marginally more false alarms than did placebo subjects. However, since the false alarm rate was very low for both groups (placebo = 9.3%, alcohol = 11.3%), this task may not have provided a sensitive test. Indeed when false positives to the first member of each word-pair are added to the false alarms for second members of word-pairs, the alcohol subjects had substantially worse scores ($p < .001$, U test).

The d' statistic was nonsignificantly smaller in the alcohol group (t 19 = 1.46, $p < .20$)* and the β statistic was marginally larger (t 19 = 1.78, $p < .10$)*. Since the prediction of decrease in hit rate is not unique to the encoding hypothesis, the data from Task 2 cannot be said to support (or contradict) the notion of less efficient encoding by intoxicated subjects.

Task 3: Multi-Trial Free Recall of Categorized Lists

Introduction

Data from an earlier experiment indicated that intoxicated subjects have difficulty in using associative information, particularly on the initial trial. One interpretation of this finding was that alcohol impaired subject's ability to generate a plan for organizing items in memory. The difficulty of organizing the list items may have been exacerbated by their random arrangement within the lists and by scrambling the lists from trial to trial.

When the members of a TBR list are composed of items from a few categories, and the items from a given category are presented together (blocked presentation), organizational difficulty is greatly decreased. For example, Bower and associates (1969) structured 112-word lists into hierarchical categories and found mean perfect recall by the third presentation of the list. When the same list items were presented in random order, mean recall after three trials was about 53 words. Their experiments are an outstanding example of the facilitative effect of organization.

If alcohol primarily impairs subject's ability to develop an organizational scheme then the difference in recall of blocked and random categorized lists should be greater for intoxicated subjects than for sober subjects. In other words, blocked presentation preorganizes the list and thereby reduces or eliminates the requirement for subject to develop an organizational scheme. On the other hand, if alcohol impairs the ability to carry out an organizational plan (either in storage or retrieval), then the difference in recall of blocked and random lists may be greater for the sober subjects, i.e., blocking will be more beneficial for sober than intoxicated subjects. Thus, an interaction between the drug and the grouping variable was predicted. The form of the interaction should differentiate the two hypotheses.

Method

Task 3 stimuli were two 64-word lists, each comprised of four category names and 15 members of each category (e.g., vehicles: truck, bus, etc.). The 64 words were presented on four typewritten pages with 16 words to a page. Subjects were allowed 32 seconds study time per page (2 seconds/word). Following study of the entire list subjects were given six minutes for written free recall. The study-test cycle was ten repeated once with the identical list. Each subject performed the task on one day only (following completion of the ILR task) and received only one of the lists. Twenty-one subjects (one-half of Group 1 and Group 2) performed the task while sober. The remaining 23 subjects performed the task while intoxicated. For 23 of the subjects the words were blocked by category (i.e., each study page began with the name of a category, 15 members of the category following). For the remaining 21 subjects the entire list of words was randomly shuffled with the constraint that no category name appear in the top position on any page. The resulting experimental design was a 2 x 2 factorial with subjects nested in the cells.

Results and Discussion

Task 3 was performed on the descending limb of the blood alcohol curve. As shown in Table 1, 15 minutes before the start of Task 3, mean BAC of subjects in the alcohol condition was 96 mg%. By the conclusion of Task 3, mean BAC had fallen to 83 mg%.

Correct recall. A three-way analysis of variance was performed on correct recall scores. Each main effect was significant in the predicted direction: drug (F 1, 36 = 55.06, $p < .001$)†, trials (F 1, 36 = 187.9, $p < .001$)†, and list arrangement (F 1, 36 = 7.31, $p < .05$)*. Cell means and standard deviations are given in Table 2. As shown in Figure 2, the present experiment replicated (F 1, 36 = 8.58, $p < .01$)† the interaction of drug and trials found in a previous experiment. Although the means were in the predicted direction, the interaction of drug and list arrangement did not reach statistical significance. The trend was for the blocked arrangement to benefit the sober subjects more than the intoxicated subjects. As compared with random presentation, the blocked list arrangement led to a 28% improvement in recall for the placebo subjects and an 18% improvement for the alcohol subjects. These data tend to support the hypothesis that alcohol impairs the ability to carry out an organizational plan. None of the other interactions approached statistical significance.

Stability of recall. Stability of recall was calculated as the proportion of items recalled on Trial 1 that were also recalled on Trial 2 and was analyzed in Experiment 3 to assess subjects' difficulty in locating the appropriate storage locations in LTS. Two interpretations of the stability measure are possible. If LTS storage is permanent, then recall of an item on Trial 1 with a subsequent recall failure on Trial 2 suggests a retrieval failure. Thus, lowered stability of recall would implicate an impairment of retrieval processes. On the other hand, if LTS storage is impermanent--even over a matter of minutes--then reduced recall stability suggests an increase in the rate of loss from LTS. This latter interpretation would be consistent with the notion of impaired consolidation. Although either interpretation of recall stability is plausible, the former is more consistent with the storage model.

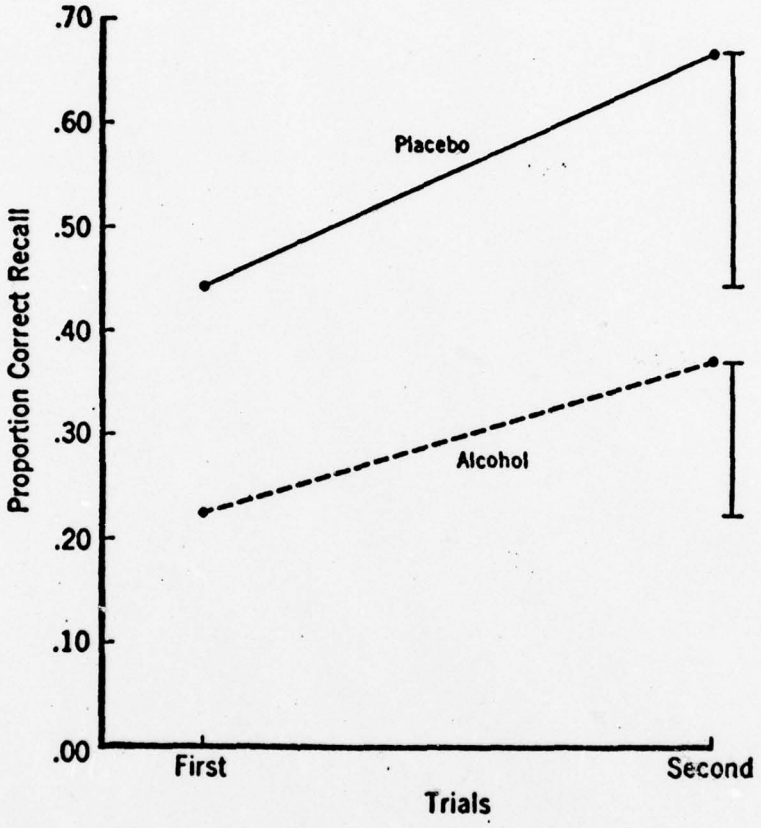


Figure 2. Task 3. Interaction of drug and trials on immediate free recall ($p < .01$).

For a previous experiment, alcohol reduced stability of recall, but associative strength had no effect. For the present experiment a two-way analysis of variance was performed on the arcsin transforms of the proportions. Means and standard deviations of the untransformed proportions are shown in Table 3. As found previously, alcohol reliably reduced the stability of recall measure (F 1, 36 = 18.58, $p < .001$)†. The main effect for list arrangement was nonsignificant ($F = .03$)*, but an interaction occurred between drug and list arrangement (F 1, 36 = 8.10, $p < .01$). For the placebo subjects stability of recall was higher in the blocked than the random arrangement. The reverse was true for the intoxicated subjects. However, simple effects analysis revealed a significant effect of list arrangement for the placebo subjects only (F 1, 36 = 4.57, $p < .05$).

There was a significant overall correlation of the stability measure with total recall ($r = .49$, $p < .01$).

Sequential organization of recall: Inter-trial repetitions. This measure of the sequential properties of recall was developed by Bousfield and Bousfield (1966). The underlying assumption of the inter-trial repetition statistic is that the degree of subjective organization in memory is reflected in the recall order of item emission. In an earlier experiment, alcohol decreased ITRs, while increasing associative strength increased ITRs. These data were interpreted as indicating that alcohol impaired organization in memory while the presentation of high frequency associates increased organization.

For the present experiment (as before), the observed ITRs were corrected for chance occurrence by subtracting the expected ITRs. Means and standard deviations of the resulting scores are shown in Table 4. Because of the high correlation between cell means and variances, the scores were subjected to a square root transformation before the two-way analysis of variance was performed. Again, alcohol decreased sequential organization (F 1, 36 = 10.90, $p < .01$)†, while the blocked arrangement led to increased organization (F 1, 36 = 7.81, $p < .01$)†. The rather striking interaction between drug and list arrangement (illustrated in Figure 3) did not reach significance at the .05 level (F 1, 36 = 2.89, $p < .10$). Nevertheless, a posteriori tests revealed a significant effect of list arrangement for the placebo subjects only ($p < .01$, Tukey's HSD)†. Thus the data support the notion that both alcohol and the objective organization of the list affect the degree to which items are organized in memory. The corrected ITR measure showed a high correlation with total correct recall on trial 2 ($r = .73$, $p < .001$). The correlations were higher for placebo ($r = .81$, $p < .001$) than alcohol subjects ($r = .63$, $p < .01$) and higher for blocked ($r = .82$, $p < .01$) than random presentation ($r = .50$, $p < .05$).

Subjective organization of recall: Clustering. Clustering was expressed as the number of runs of items from a given category present in the recall list, and Z scores were derived (see Frankel & Cole, 1971) and subjected to a three-way analysis of variance. Main effects for drug†, trials†, and the list arrangement variable† were significant at the .001 level in the predicted directions. Thus, clustering scores were higher (1) for the placebo group, (2) on trial 2, and (3) for blocked presentation. Cell means and standard deviations are given in Table 5. None of the interactions were significant, although the means for the drug by list arrangement interaction were in the direction of the expected positive interaction. A posteriori tests revealed increased clustering in the blocked

Table 3

Task 3. Effects of Alcohol and List Arrangement on Stability of Recall (Proportion of Items Recalled on Trial 1 That Were Also Recalled on Trial 2).

Drug		Placebo	Alcohol
	Mean	.80	.61
	SD	.10	.19
List Arrangement		Random	Blocked
	Mean	.72	.70
	SD	.14	.21

		Drug	
List Arrangement		Placebo	Alcohol
Random	Mean	.75	.68
	SD	.10	.17
Blocked	Mean	.86	.55
	SD	.07	.19

Table 4

Task 3. Effects of Alcohol and List Arrangement on Sequential Organization of Recall. Scores are Based on Inter-Trial Repetitions Corrected for Chance Occurrence.

Drug		Placebo	Alcohol
	Mean	4.74	1.24
	SD	5.78	1.15
List Arrangement		Random	Blocked
	Mean	1.47	4.50
	SD	1.46	5.85

		Drug	
List Arrangement		Placebo	Alcohol
Random	Mean	2.06	0.89
	SD	1.63	1.04
Blocked	Mean	7.41	1.58
	SD	7.20	1.20

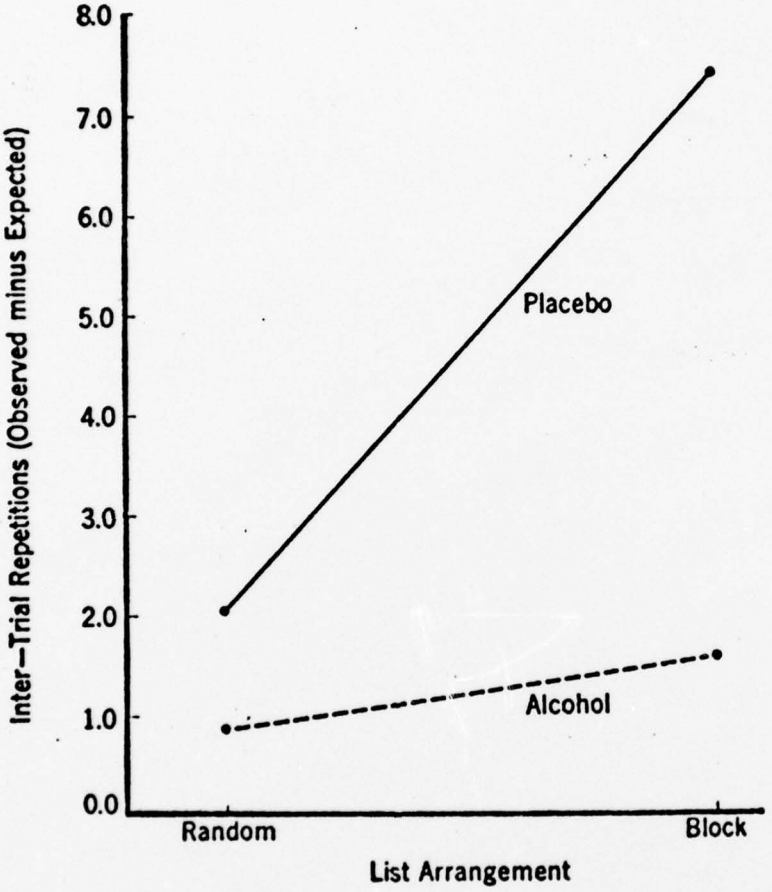


Figure 3. Task 3. Interaction of drug and list arrangement on inter-trial repetitions (corrected for chance). Although the interaction did not reach statistical significance ($p < .10$), the simple effect of list arrangement was significant only for the placebo group (HSD < .01).

Table 5

Task 3. Effects of Alcohol, List Arrangement, and Trials on Subjective Organization of Recall. Scores are Z Scores Representing Clustering. (See, Frankel & Cole, 1971).

Drug		Placebo	Alcohol
	Mean	7.38	3.65
	SD	2.93	2.74
List Arrangement		Random	Blocked
	Mean	4.01	7.02
	SD	2.58	3.46
Trials		One	Two
	Mean	4.47	6.56
	SD	3.11	3.37

		Drug	
List Arrangement		Placebo	Alcohol
Random	Mean	5.54	2.48
	SD	1.94	2.23
Blocked	Mean	9.22	4.82
	SD	2.60	2.76

presentation condition for the placebo subjects (HSD < .01)†, but the increase for the alcohol subjects was not reliable (HSD > .05)†. Thus, there was a strong trend for blocking to increase clustering in the placebo subjects, but the results for the intoxicated subjects were more variable.

Overall, clustering scores correlated well with recall scores (r = .78, p < .001). As with the previous measures, the correlations were higher in the placebo group (r = .86, p < .001) than in the alcohol group (r = .68, p < .001) and higher for blocked presentation (r = .85, p < .001) than for random presentation (r = .64, p < .01). There was little difference in the correlations on Trials 1 and 2 for the placebo subjects (r = .87 and r = .84, respectively). In contrast, the intoxicated subjects showed a substantial increase (p < .03) in the correlation between clustering and recall from Trial 1 (r = .42, p < .10) to Trial 2 (r = .84). Thus, for the alcohol subjects, there was little initial association between clustering and recall, but by Trial 2 the correlation for alcohol and placebo subjects were nearly identical (approximately .84).

General Discussion

The outcome of Tasks 1a and 1b do not support the hypothesis that the memory scanning operation of the retrieval process is affected by alcohol. These tasks showed nearly identical alcohol deficits for immediate free recall, and immediate or delayed recognition. Analysis of Task 1a data strongly supported previous indications that both STS and LTS are impaired by alcohol. The results of the final free recall task showed greater alcohol deficits with delayed recall than with immediate recall. This finding confirmed earlier work by Jones (1972), but did not support his consolidation-interference hypothesis. Perhaps the final free recall task presents a challenge equivalent to a very long list. Recall that previous studies had found an interaction between list length and alcohol.

Data from Task 2 were not conclusive with regard to the encoding-impairment hypothesis. There is a hint in both Tasks 1b and 2 that alcohol may affect the decision process such that the intoxicated subjects were applying a more stringent criterion (higher β statistic); but the data are not strong. An increase in β might account, in part, for the decrease in stability of recall found in intoxicated subjects in Task 3. Of the initial hypotheses the third (i.e., that alcohol produces an organizational deficit) was most strongly supported. The data suggest that the deficit results from an inability to carry out a coherent organizational plan rather than an inability to formulate a plan. Data from Task 3 also showed alcohol impairment of recall stability and of two measures of organization: ITRs and clustering. In general, the organizational data from Task 3 are similar to the data from Experiment 3 where the organization variable was associative strength. The correlations between recall and the organization measures were reasonably high. Alcohol seems to undermine this association, at least for initial presentation and recall.

Altogether, four studies of acute alcohol effects on human memory have been completed with the support of the Surgeon General, Department of the Army. The series of experiments began (Experiments 1 and 2) with a focus on the effects of alcohol on the structural ("hard-wired") aspects of the typical serial store models (e.g., Glanzer's 1972 storage model). A variable of secondary interest in those experiments was one which may relate to LTS organization (viz., list length). Although the procedures were somewhat different in the first two experiments, both employed free recall tasks; and the outcomes were remarkably consistent.

The task variables generally performed as expected with list length and forced inter-item rehearsal affecting only recall of the early and middle portion of the lists (LTS) and the interpolated task affecting only the last few items (STS). Alcohol produced a reliable and substantial overall reduction in recall performance and had nonadditive effects in combination with list length.

In terms of serial store models, the preliminary experiments gave little evidence for a differential sensitivity of STS and LTS to alcohol. There was no indication of an impairment of STS-to-LTS information transfer, but alcohol did produce greater impairment for the longer lists. The initial conclusions, therefore, were that alcohol probably interferes with recall from both STS and LTS and that the LTS impairment may be related to an organizational deficiency. However, at that point, support for the organizational impairment hypothesis was not strong, and other explanations were possible (e.g., retroactive inhibition).

Given the data from Experiments 1 and 2, the succeeding experiments centered less on the structural components of the storage model and more on control processes. Note, however, that attempts to differentiate alcohol effects on recall from STS and LTS were made in both Experiment 3 (a free recall learning study) and in the experiment reported here (Experiment 4).

The principal hypothesis tested in Experiment 3 was that one alcohol effect on LTS was to interfere with organization along the lines of associative linkages. For this experiment association value was varied between three lists, and subjects were given six presentation-recall trials with each list. As expected, the placebo group showed a substantially higher rate of learning than did the alcohol group. A three-way interaction between drug, association value, and trials suggested that alcohol interferes with the associative structuring of memory. Two measures of subjective organization (ITRs and clustering) were derived from the data, and both were reliably impaired by alcohol. In addition, both measures correlated significantly with recall. Thus, the data clearly supported the hypothesis that alcohol interferes with organization along the lines of associative linkages. Alcohol also interfered with stability of recall, suggesting an impairment of retrieval operations. However, the net (partial) correlation of recall stability and total recall, holding clustering and ITRs constant, was nonsignificant ($\underline{r}$ = .27).

Three main hypotheses were tested in Experiment 4 using three tasks. The hypothesis that alcohol interferes with the memory scanning process of the retrieval operation was tested with free recall and recognition tasks (Tasks 1a and 1b) and was not confirmed. Instead, alcohol produced nearly identical decrements in free recall and recognition performance. The levels of processing hypothesis (namely, that alcohol interferes with efficient encoding) was tested with an intra-list recognition task (Task 2) and was neither confirmed nor disconfirmed. The hypothesis that alcohol disrupts organization in LTS was supported in a free learning task using random and blocked arrangement of categorized lists (Task 3). Data from the free learning task supported the notion that the organizational impairment was not simply an inability on the part of the intoxicated subject to develop an organizational scheme. Rather, the greatest relative alcohol impairment was seen with blocked presentation (i.e., when the lists were preorganized for the subjects). Both ITRs and clustering were impaired by alcohol, and both measures correlated significantly with recall. These results support the data from Experiment 3 and strengthen the notion that alcohol impairs

organizational processes in LTS. As in Experiment 3, alcohol reduced the stability of recall, but the partial correlation of stability and total recall, holding clustering and ITRs constant, was nonsignificant (r = .07). Thus, whatever the factor reflected by the stability measure, that factor makes little unique contribution to recall. On the other hand, the second order correlations of total recall with ITRs or with clustering were significant (r = .41, p < .01; and r = .52, p < .001, respectively).

In summary, alcohol produced reliable (p < .001) decrements in four independent tests of memory function. In every case recall from LTS was substantially reduced. Intoxication also impaired recall from STS in each experiment, but the effect was less reliable than for LTS. In contrast to the present results, Jones (1972) found no effect of alcohol on recall of words from the final four list positions (STS). These conflicting results are somewhat disturbing since they cannot readily be ascribed to differences in BACs, instructions, or procedures.

Overall, the present experiments consistently supported the notion that alcohol produces an impairment of organizational processes in memory (see, also, Parker et al., 1974). The combination of alcohol and those task variables presumably influencing organization generally produced nonadditive effects on recall performance. Two measures of subjective organization were derived in both Experiments 3 and 4, and these measures invariably showed deterioration in the alcohol groups. Additionally, these measures of organization correlated rather substantially and consistently with the basic measure of memory, total correct recall. Nevertheless, a causal relationship between organizational impairment and impaired memory has not been conclusively established.

Some of the data suggested that retrieval operations may be vulnerable to intoxication, but the evidence is not strong. For example, stability of recall was impaired by alcohol in Experiments 3 and 4. These results suggest a retrieval failure. However, inefficient organization could produce retrieval failures even though the retrieval processes were intact. Perhaps more importantly, the net correlations between recall stability and total recall were nonsignificant.

Experiment 4 provided some evidence that intoxicated subjects apply a more stringent criterion for identifying previously presented items (increased β). Thus, the decision function of the retrieval operation may be altered in intoxicated subjects; but, here again, the data are equivocal with significance levels ranging from .006 to .20. Finally, data from Experiment 4 did not confirm the hypothesis that memory scanning is impaired by alcohol (see also Tharp et al., 1974).

Alcohol and the Storage Model

So far the discussion has centered on the question of alcohol effects on memory as viewed from the perspective of the storage model. Perhaps some attention should be focused on the model itself. Two points are of particular interest: (1) How well did the model stand up when applied to intoxicated subjects?, and (2) Retrospectively, what was the utility of conducting the studies within the framework of the model?

In answer to the first question, the model was quite robust to the effects of alcohol. The patterns of interactions between task-related variables and serial

position were consistent for both sober and intoxicated subjects. For example, list length affected only the first and middle portions of the serial position curves in both alcohol and placebo conditions. Thus, alcohol intoxication seemingly did not alter the hypothesized relationship between STS and LTS or between the memory stores and those task variables which uniquely affect one or the other. On the other hand, the robust quality of the model may reflect an insensitivity of the paradigms employed or of the model itself. As mentioned above, through four independent experiments there was little evidence of a differential vulnerability of STS and LTS to alcohol intoxication. Thus, for these experiments, the multiple stage aspect of the storage model provided little utility for understanding alcohol effects. The present data, therefore, suggest that a single store model might adequately describe alcohol effects on human memory.

With regard to the hypothesized control processes the data were, perhaps, more enlightening; and this relates to the overall utility of carrying out the studies within the framework of a model. Although it was not possible to isolate a particular stage especially sensitive to intoxication, the storage model suggests a number of likely processes to examine.[2] Experiments 3 and 4 examined several of the hypothetical control processes, and organization or structuring of memory was implicated as a primary target for alcohol. Thus, the use of a broad model of human memory lent some coherence to the series of experiments without unduly constricting the range of hypotheses.

---

[2]One may note that such processes as memory scanning, item encoding, and subjective organization are not uniq[illegible] serial stage models. Nevertheless, such processes are easily incorporated into [illegible] storage model; and in many cases, the difference between one theorist's positi[illegible] and that of another is largely a matter of emphasis.

References

Anderson, J.R., and Bower, G.H. Recognition and retrieval processes in free recall. Psychological Review, 79: 97-123, 1972.

Anisfield, M., and Knapp, M. Association, synonymity, and directionality in false recognition. Journal of Experimental Psychology, 77: 171-179, 1968.

Baddeley, A.D., and Warrington, E.K. Amnesia and the distinction between long- and short-term memory. Journal of Verbal Learning and Verbal Behavior, 9: 176-189, 1970.

Bernbach, H.A. Stimulus learning and recognition in paired-associate learning. Journal of Experimental Psychology, 75: 513-519, 1967.

Bousfield, A.K., and Bousfield, W.A. Measurement of clustering and of sequential constancies in repeated free recall. Psychological Reports, 19: 935-942, 1966.

Bower, G.H., Clark, M.C., Lesgold, A.M., and Winzenz, D. Hierarchical retrieval schemes in recall of categorized word lists. Journal of Verbal Learning and Verbal Behavior, 8: 323-343, 1969.

Butters, N., and Cermak, L.S. The role of cognitive factors in the memory disorders of alcoholic patients with the Korsakoff syndrome. Annals of the New York Academy of Sciences, 233: 61-75, 1974.

Cermak, L.S., and Butters, N. Information processing deficits of alcoholic Korsakoff patients. Quarterly Journal of Studies on Alcohol, 34: 1110-1132, 1973.

Craik, F.I.M., and Lockhart, R.S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11: 671-684, 1972.

Frankel, F., and Cole, M. Measures of category clustering in free recall. Psychological Bulletin, 76: 39-44, 1971.

Gardiner, J.M. Levels of processing in word recognition and subsequent free recall. Journal of Experimental Psychology, 102: 101-105, 1974.

Glanzer, M. Storage mechanisms in recall. In, G.H. Bower (Ed.), The psychology of learning and motivation, Advances in research and theory, Vol. 5, New York: Academic Press, 1972, pp. 129-194.

Glanzer, M., and Meinzer, A. The effects of intralist activity on free recall. Journal of Verbal Learning and Verbal Behavior, 6: 928-935, 1967.

Hyde, T.S., and Jenkins, J.J. Differential effects of incidental tasks on the organization of recall of a list of highly associated words. Journal of Experimental Psychology, 82: 472-481, 1969.

Jones, B.M. The effects of alcohol on memory during the ascending and descending limb of the blood alcohol curve. Unpublished doctoral dissertation, University of Oklahoma, 1972.

Kintsch, W. Recognition and free recall of organized lists. Journal of Experimental Psychology, 78: 481-487, 1968.

Kintsch, W. Models for free recall and recognition. In, D.A. Norman (Ed.), Models of Human Memory, New York: Academic Press, 1970, pp. 333-374.

Kucera, H., and Francis, W.N. Computational analysis of present-day American English. Providence, R.I.: Brown University Press, 1967.

Murdock, B.B. Short-term memory. In G.H. Bower (Ed.), The psychology of learning and memory: Advances in research and theory, Vol. 5. New York: Academic Press, 1972, pp. 67-127.

Norman, D.A., and Waugh, N.C. Stimulus and response interference in recognition memory experiments. Journal of Experimental Psychology, 78: 551-559, 1968.

Parker, E.S., Alkana, R.L., Birnbaum, I.M., Hartley, J.T., and Noble, E.P. Alcohol and the disruption of cognitive processes. Archives of General Psychiatry, 31: 824-828, 1974.

Posner, M.I., and Warren, R.E. Traces, concepts, and conscious constructions. In, A.W. Melton & E. Martin (Eds.), Coding processes in human memory. New York: Wiley, 1972, pp. 25-43.

Shepard, R.N., and Teghtsoonian, M. Retention of information under conditions approaching a steady state. Journal of Experimental Psychology, 62: 302-309, 1961.

Shiffrin, R.M., and Atkinson, R.C. Storage and retrieval processes in long-term memory. Psychological Review, 76: 179-193, 1969.

Tharp, V.K., Rundell, O.H., Lester, B.K., and Williams, H.L. Alcohol and information processing. Psychopharmacologia, 40: 33-52, 1974.

Thorndike, E.L., and Lorge, I. The Teacher's Word Book of 30,000 Words. New York: Teacher's Coll. Bur. Publ., Columbia University, 1944.

Tulving, E. Short- and long-term memory: Different retrieval mechanisms. In, K.H. Pribrim & D.E. Broadbent, (Eds.). Biology of Memory, New York: Academic Press, 1970, pp. 7-9.

Tulving, E., and Thomson, D.M. Retrieval processes in recognition memory: Effects of associative context. Journal of Experimental Psychology, 87: 116-124, 1971.

Underwood, B.J. False recognition produced by implicit verbal responses. Journal of Experimental Psychology, 70: 122-129, 1965.

Warrington, E.K. Neurological disorders of memory. British Medical Bulletin, 27: 243-247, 1971.

Wickens, D.D. Encoding categories of words: An empirical approach to meaning. Psychological Review, 77: 1-15, 1970.

ALCOHOL AND SPEED-ACCURACY TRADEOFF

This research had two major aims: (a) to replicate and extend studies of choice reaction time (CRT) by Jennings, Wood and Lawrence (1976) which demonstrated that graded doses of alcohol cause systematic changes in speed-accuracy tradeoff functions (SATF) and (b) to examine the combined effects of alcohol and task difficulty on speed-accuracy tradeoff in CRT.

Data from typical CRT experiments where subjects are instructed for high accuracy can be difficult to interpret because such methods fail to separate the speed of perceptual processing from response bias. Moreover, Pachella (1974) showed that because the typical function relating accuracy to speed is negatively accelerated, very small changes in error rate at high levels of accuracy may be associated with large changes in CRT. This is the region of the SATF from which much of the data in "error-free" experiments are derived. The possibility of tradeoffs between speed and accuracy and the associated difficulties of interpretation led Lappin and Disch (1972a) and others to recommend that the SATF be employed as a dependent variable in CRT experiments.

If some estimate of accuracy, say the amount of information transmitted by the subject is represented on the ordinate and CRT on the abscissa, then the complete SATF can usually be divided into three regions: (a) a period of time on the abscissa during which accuracy (H_t) varies around zero (chance), (b) a second phase during which accuracy rises as a linear function of CRT, and (c) a final asymptotic phase. The upper bound of the first region represents the portion of CRT necessary for accuracy to exceed chance levels, while the slope of the second region is interpreted as rate of gain of accuracy over time. The intercept (at $H_t = 0$) and slope parameters of SATFs are often employed as summary statistics to represent the effects of various independent variables. On the assumption that a decision process determines the point in time at which perceptual processing is terminated and a response is selected, the SATF is used to obtain a decision-free estimate of the perceptual process, in the same sense that the ROC function in signal detection experiments is employed as a decision-free measure of detection. Identical SATFs across experimental conditions imply that any systematic differences either in CRT or accuracy were generated by changes in decision criteria. Tradeoff functions that differ across experimental conditions, either in intercept or slope, imply differences in processing efficiency (see Wood and Jennings, 1976, for a recent review and analysis).

Several task-related experimental variables have now been studied for their effects on the SATF. For example, Harm and Lappin (1973), investigating the combined effects of stimulus probability and S-R compatibility in visual CRT, found that S-R compatibility influenced the slope but not the intercept of the SATF, whereas stimulus probability had no effect on the function at either level of compatibility. Pachella and Fisher (1969) examined the effects of stimulus degradation and stimulus similarity on the SATF. Stimulus degradation increased the intercept but did not alter the slope, whereas stimulus similarity influenced the slope but not the intercept. Taken together, these results are perhaps consistent with a two-stage theoretical model in which the duration of a stimulus preprocessing and encoding phase is indexed by the intercept, whereas the slope indexes more central information-processing operations such as

"translation of perception into action" (Harm and Lappin, 1973, p. 418). However, such serial-stage notions are speculative because it is not clear whether the slope and intercept parameters represent independent aspects of performance. Thus, Lappin and Disch (1972b) reported that stimulus intensity, a variable that might be expected to influence early perceptual processes, affected both the slope and intercept of the SATF.

Although it is generally true that alcohol (BAC above 80 mg of alcohol per 100 ml of blood, mg%) causes slowing of average CRT (e.g., Tharp, Rundell, Lester and Williams, 1974), there are exceptions in the literature, particularly with two-choice tasks and under conditions of high S-R compatibility (e.g., Carpenter, 1962; Huntley, 1972; Moskowitz, 1973; Tharp et al., 1974). As Wood and Jennings suggested, an analysis of tradeoff between speed and accuracy might help clarify these discrepant findings. Employing a binaural, two-choice pitch-discrimination task, Jennings et al. (1976) found that alcohol in the dose range from 0 to 1.33 ml/kg body weight produced a systematic reduction in the slope parameter of the SATF. This dose-related monotonic decrease in the rate of growth of information over time, occurring in the absence of any significant effect of alcohol on average RT, showed convincingly that the SATF can be a very sensitive index of alcohol impairment, even at BACs lower than, sya, 80 mg%. Certain of their findings supported the conclusion the alcohol also altered their subjects' decision criteria, producing a bias for speed over accuracy.

The present experiment, a constructive replication of the Jennings et al. (1976) study, employed the SATF to investigate the effects of graded doses of alcohol on two tasks, referred to as the side-discrimination and pitch-discrimination tasks. Each required the subject to respond on one of two keys to one of two monaurally presented tones, the same two tones being used for each task. In the side-discrimination task, subjects were instructed to disregard the pitch of the signal and respond to side stimulated (i.e., left ear, left hand). In the pitch-discrimination task, subjects were to disregard side (ear stimulated) and respond to pitch according to a left-right rule. Longer average CRTs on the pitch-discrimination task should derive from at least two sources: (a) As a cue for left-right responding, side (ear) stimulated is more salient and more rapidly processed than tonal frequency. Thus, Simon, Small, Zigler, and Craft (1970) concluded that for subjects responding on a left-right rule, ear-stimulated was processed about 76 msec faster than pitch. Similarly, Lappin and Harm (1973), employing a left-right auditory coding task, found that information about spatial position was processed about 60 msec faster than information about two other stimulus variables, intensity and duration; (b) compared to the side-discrimination task, CRT in the pitch-discrimination task is increased further (by about 60 msec) on trials that involve a mismatch between the instructed pitch cue and side stimulated (Simon and Small, 1969; Simon, et al., 1970; Simon, Hinrichs and Craft, 1970; Callan, Klisz and Parsons, 1974; Bertera, Callan, Pishkin and Parsons, 1975). This latter interference effect fits under the general definition of S-R incompatibility proposed by Fitts and Seyar (1953) and was labeled lateral S-R incompatiblity by Simon, et al. (1970) and by Callan et al., (1974). With a 60 msec advantage based on cue salience and an overall 30 msec advantage based on lateral S-R compatibility (averaging high and low compatibility conditions), one would expect CRTs in the side discrimination task to average about 90 msec faster than CRTs for pitch discrimination. Experiments cited above on the cue properties of side stimulated and pitch and on S-R compatibility effects suggested that this effect of task might be distributed both to the intercept and the slope of the SATF. For example, Harm and Lappin's (1973) data suggest that the effect of lateral S-R compatibility should appear in the slope parameter. Since the results of Jennings et al. (1976) indicate that alcohol

influences the slope but not the intercept of the SATF, and because the effects of alcohol and some forms of S-R compatibility interact on average CRT (Huntley, 1972; Huntley, 1974; Tharp et al., 1974) we might anticipate a task-by-alcohol interaction effect with the slope parameter of the SATF as dependent variable.

Method

Subjects. Twelve healthy right-handed adult males (aged 22 to 26) from the medical and graduate school programs of the University of Oklahoma Health Sciences Center served as paid ($3.00/hr.) volunteers. All had normal hearing and normal color vision. All were light to moderate social drinkers, with no medical conditions that contraindicated alcohol consumption. None were taking prescribed medication and none reported abuse of other drugs. Each subject served as his own control and each received all alcohol dose and task conditions in a counterbalanced design. Subjects were instructed not to consume alcohol or other drugs during the week of the study and to fast for at least four hours prior to each experimental session.

Design. The experiment consisted of six sessions run on successive days, except for a 48-hr. interval following the highest alcohol dose. After two practice sessions, the subject performed both CRT tasks under a different alcohol dose on each of four days. The alcohol doses were counterbalanced in a 4 x 4 latin square design with 3 subjects per order. Further details of alcohol dosage and schedules are presented later. The testing began about 10:30 a.m. and concluded about noon.

CRT Tasks. Stimulus variables were identical for the two tasks, consisting on each trial of one of two tones (1,000 or 1,100 Hz) presented stereophonically through TDH, Model 49-102 headphones to the left or right ear at a sound pressure level of 90 db (re 0.0002 μ bar). For each task, a deadline procedure (described later) required the subject to make his choice responses prior to one of three designated deadlines. A loudspeaker situated in front of the subject broadcast continuous white noise at 70 db to mask ambient sounds.

The subject was seated comfortably at a table in a dimly lit room facing a display panel at a distance of about 80 cm. The panel contained three vertically arrayed lights (green, amber and blue). A response panel containing two telegraph keys was located on the table top. During testing the subject kept the index fingers of both hands resting lightly on the keys. Pressure to close the telegraph keys was 228 g and distance to closure was 0.5 mm.

Illumination of the green light signalled the beginning of a trial. The time between light onset and tone was 750 msec. The tone was terminated by the subject's key press. Feedback occurred after the subject's response as follows: If the response was both correct and within the deadline specified for that block of trials, none of the lights were illuminated. If the response was correct but RT was longer than the prescribed deadline, the blue light was illuminated. If the response was incorrect but faster than deadline, the amber light came on, and if the response was both slow and incorrect, both the amber and blue lights were illuminated. The intertrial interval, from response to onset of the green warning light, was 4 sec.

The designated deadline was constant within 100-trial blocks. Before each block the technician announced which of three deadlines was operating and stated the average accuracy expected for that deadline. The subject was to strive for

100% accuracy at the longest, at least 90% accuracy at the middle and at least 70% accuracy at the shortest deadline. To insure compliance, subjects received bonus pay for good performance, and were penalized for poor performance. Thus, with bonus pay set at 1/3¢ per point, they were awarded 2 points for each correct response occurring prior to the prescribed deadline and penalized 1 point for each response that was incorrect or beyond the deadline interval.

As anticipated, pilot data on 5 subjects showed that RTs were generally faster for the side-discrimination than for the pitch-discrimination task. Therefore, different deadlines were designed for each task in such a way that accuracy, defined as H_t, was equated across tasks for the shortest, middle and longest deadlines. In the side-discrimination task the three deadlines were 175, 200, and 300 msec, and for the pitch-discrimination task, the deadlines were 300, 375, and 425 msec. For each deadline and each session, there were 12 practice trials followed by 100 experimental trials. For each task, the deadlines were always presented in descending order, from longest to shortest (see Green & Luce, 1973; Shouten & Bekker, 1967; Jennings et al., 1976; and Wood & Jennings, 1976; for discussions of the merits of deadline and other procedures for generating SATFs).

Side Discrimination Task. The subject was instructed to press the right key with his right index finger for tones delivered to the right ear and to respond on the left-hand key with his left index finger for tones delivered to the left ear. He was told to disregard the pitch of the tone.

Pitch Discrimination Task. Instructions were to press the left or right key according to a pitch-by-hand rule (e.g., high pitch-left key, low pitch-right key). The task was counterbalanced, with half the subjects working under the high pitch-left hand rule, and half under the high pitch-right hand rule. Correct performance required the subject to disregard side of presentation. Half the subjects performed the side discrimination task first in each session and half performed pitch discrimination first.

Alcohol. The alcohol dose consisted of a placebo, .25, .50 and 1.0 g of 95% ethyl alcohol/kg body weight. The scheduled dose for a given day was combined in a 1:4 ratio with a commercial orange drink. The placebo consisted of 5 ml of ethanol floated on top of approximately 340 ml of the orange drink. This amount of ethanol is sufficient to produce the smell and taste of an alcoholic beverage. The low, medium and high doses of alcohol were expected to produce peak blood alcohol concentrations (BACs) of about 25, 50, and 100 mg%, respectively. In order to sustain peak BACs and thereby circumvent problems associated with differential deficit on the ascending and descending limbs of the BAC function (Jones, 1972), a maintenance dose of .062 g ethanol/kg body weight was administered approximately every 20 min (see Lentz & Rundell, 1976, for rationale and method). After consumption of the beverage, BACs were measured at 15, 35, 55 and 80 min with a Stephenson Breathalyzer, Model 900. Testing began at 15 min after consumption and lasted for a total of about 65 min. A rest period of 5 min was inserted between each block of 200 trials, and each task required 27 min. A second technician mixed the drinks and a double-blind procedure assured that neither the subject nor the experimental assistant knew which dose was being administered.

Calculation of Speed-Accuracy Tradeoff Functions. The methods of Jennings et al. (1976) were used for these calculations. Thus, for each subject in each deadline condition in each task, mean RT was computed for all 100 trials in that condition, regardless of accuracy or compliance with the prescribed deadline. These mean RTs were paired with corresponding H_t values for each condition and linear regressions of accuracy on RT were computed over the three deadline conditions in each alcohol condition. The appropriate linear regression equation

is $H_t = m(RT-c)$ in which m represents the slope and c the intercept of the function at chance accuracy, i.e., where $H_t = 0$ (see Wood & Jennings, 1976, for an analytic review of H_t and other proposed measures of accuracy. For our subjects, the proportion of variance in the speed-accuracy tradeoff data accounted for by the linear equations (r^2) ranged from 82 to 99%.

Results

Preliminary Analyses. Table 1 displays the means and standard deviations of BAC in mg% for each of the three alcohol doses at each of four time periods following consumption of the beverage. All BACs associated with the placebo dose were well below 10 mg%. As can be seen, the expected average BACs for these doses were achieved and maintained with reasonable accuracy throughtout testing.

Alcohol, CRT and Accuracy. We begin with a conventional analysis of CRT and accuracy data for the two tasks. The effects of deadline condition, task, task order, alcohol dose and accuracy (correct/incorrect) were analyzed in a five-way analysis of variance (ANOVA) with CRT as dependent variable. A similar analysis was performed on proportion correct {P(C)} where all correct responses were included regardless of conformity to the specified deadline. Means and standard deviations of CRT and the corresponding P(C) values for the two tasks and three deadlines are shown in Table 2.

Choice reaction time was significantly* influenced by deadline condition ($F_{2,20} = 81.5$), but not by alcohol dose ($F < 1$) or by order of task ($F < 0.1$). As expected, overall CRT was significantly (88 msec) longer for pitch discrimination than for side discrimination ($F_{1,10} = 197.0$). Correct responses were significantly (35 msec) slower than incorrect responses ($F_{1,10} = 27.5$). There were no significant two-way or higher order interaction effects. Proportion correct responses were significantly influenced by deadline condition ($F_{2,20} = 154.2$), but not by task ($F < 0.1$) or task order ($F_{1,10} = 1.5$). Alcohol significantly decreased the proportion of correct responses ($F_{3,30} = 10.7$) from .88 in the placebo condition to .84 for the highest dose.

These preliminary analyses show that the deadline procedures influenced both CRT and accuracy as expected, and that RTs were about 90 msec faster in the side than in the pitch task. Similar differences between these tasks have been found by others (e.g., Bertera et al., 1975). Mean accuracy scores were nearly identical for the two tasks.

Tharp et al. (1974), employing a 2-choice task had found only a small effect of alcohol on average CRT. Similarly, in this experiment alcohol produced only a non-significant trend toward slowed performance. Further, as in the Tharp et al. (1974) experiment, alcohol did produce significant impairment of overall accuracy. Whether this effect represents a tradeoff bias for speed over accuracy or impaired quality of performance or both should be clarified by analysis of SATFs.

As background for that analysis, mean RT and P(C) for each alcohol dose, averaged across all deadline conditions are presented in Figure 1. Note that for pitch discrimination the CRT difference for placebo and highest alcohol dose

*Unless otherwise specified, "significant" means .05 level or better.

Table 1

Average BAC (mg%) for each alcohol dose*

		Time Following Consumption			
Alcohol Dose		15 (mins)	35	55	80
High (1.0 g/kg)	$\bar{X}$	103	104	100	97
	SD	14.0	17.0	10.0	11.0
Med (.5 g/kg)	$\bar{X}$	53	51	50	51
	SD	20.0	14.0	11.0	10.0
Low (.25 g/kg)	$\bar{X}$	25	19	23	21
	SD	9.0	9.0	6.0	7.0

*Maintenance dose approximately every 20 minutes = .06 g/kg. First maintenance dose was skipped for high dose condition.

Table 2

Effects of Deadlines on CRT and Accuracy for Side Discrimination and Pitch Discrimination Tasks

Choice Reaction Time				
		Deadline*		
Task		Short	Medium	Long
Side Discrimination	$\bar{X}$	146	181	237
	SD			
Pitch Discrimination	$\bar{X}$	240	276	310
	SD			

Accuracy				
		Deadline*		
Task		Short	Medium	Long
Side Discrimination	$\bar{X}$	.75	.88	.97
	SD			
Pitch Discrimination	$\bar{X}$	.77	.88	.95
	SD			

*The deadlines for the Side Discrimination and Pitch Discrimination tasks were 175, 200, 300 msec. and 300, 375, 425 msec., for short, medium, and long, respectively.

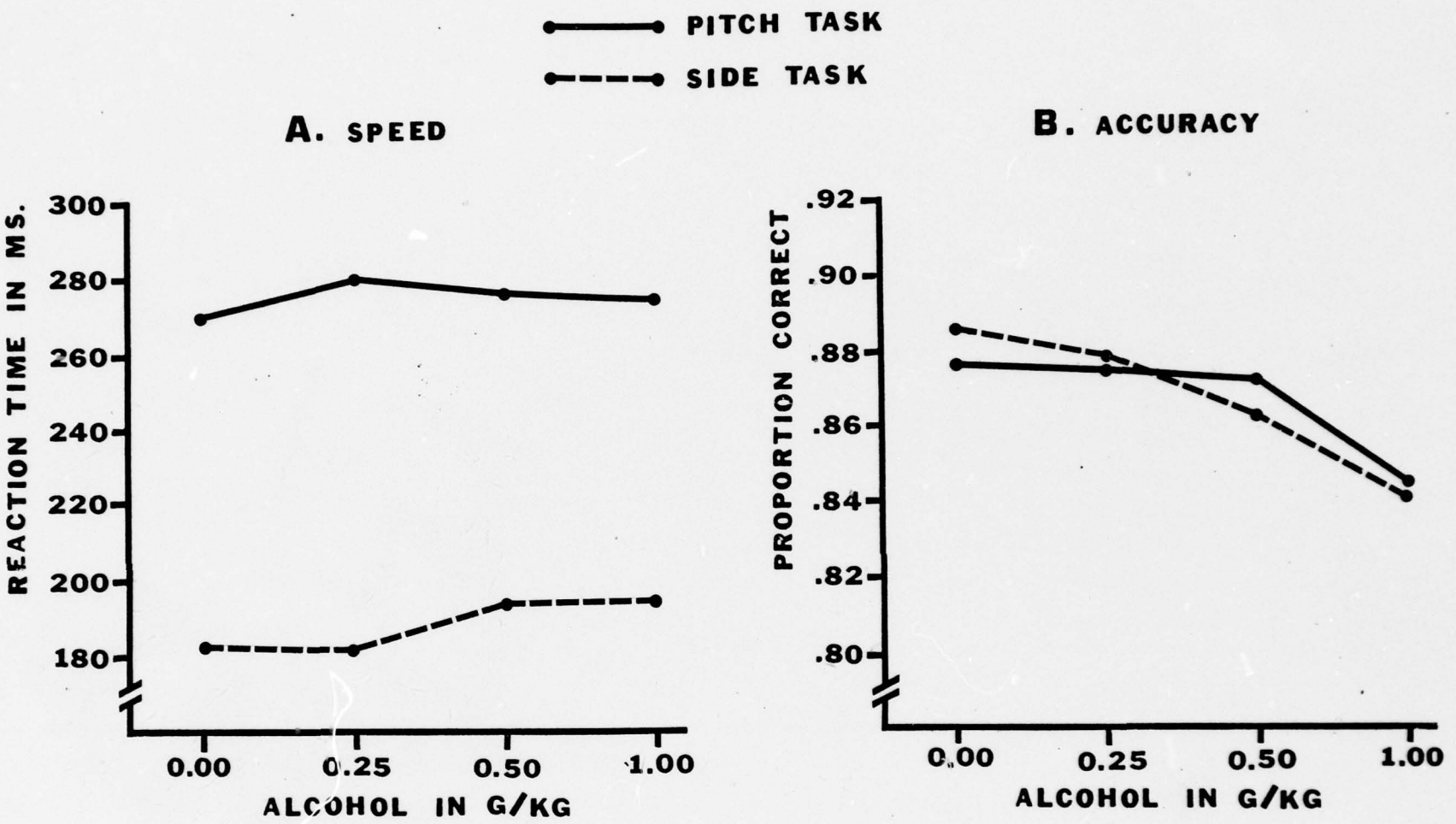


Figure 1. Effects of alcohol and task on speed and accuracy for side and pitch tasks.

averaged about 4 msec and for the side discrimination task, about 12 msec. Note also, that even though significant, the drop in accuracy across alcohol doses averaged only about 4 percentage points.

Alcohol and Speed Accuracy Tradeoff. Each subject's SATF was calculated (as described above) for each task and each alcohol dose. In general, the linear fit of the SATFs to the data was satisfactory. The average r^2 over all subjects' tasks and doses was .90 and did not differ significantly between doses or tasks.

Other Effects of Alcohol. It is important to know whether alcohol impaired the subjects' ability to comply with the deadline procedure. To examine this, we computed the Pearson rs between mean RTs for each deadline condition and the specified nominal deadlines. In the side-discrimination task, the coefficients were .97, .98, .93 and .93 for the placebo to 1.0 g/kg doses; and in the pitch-discrimination task the corresponding coefficients were .94, .98, .97, .92. All coefficients except the last one are significant beyond the .05 level (Z test), the latter being at .056. Based on the magnitude of these correlations, we conclude that alcohol had no systematic effect on compliance with the nominal deadlines.

The effects of task and alcohol dose on slope and intercept parameters of the subjects' SATFs were analyzed in separate ANOVAs. Means and standard deviation for slopes and intercepts are presented in Table 3. The effects of alcohol dose and task were independent for the slope and intercept measures. Alcohol significantly decreased the slope of the SATFs ($F_1,33 = 7.0$), but did not affect the intercept values at $H_t = 0$ ($F < .05$). For the slope data, individual comparisons among means indicated that in both tasks, the high dose differed significantly from the medium, low, and placebo doses. The medium dose differed significantly from placebo but not from the low dose, and the low dose did not differ from placebo.

In contrast to the effects of alcohol, the task variable did not significantly affect the slope parameter ($F_1,11 = 1.9$), but task had a strong (90 msec) and significant effect on the intercept ($F_1,11 = 191.2$). In addition, the task x alcohol interactions were nonsignificant for both slope ($F_3,33 = 1.1$) and intercept ($F < .05$). Earlier studies had suggested that because the side and pitch discrimination tasks differ in an interference effect classified as a form of S-R compatibility, we should expect a task effect also on the slope parameter of the SATF. This did not occur. Figure 2 illustrates the parallel SATFs for the two tasks and the effect of the high dose of alcohol on the slope parameter.

In summary, these results show that for the pitch discrimination and side discrimination tasks, alcohol produced a dose-related decrease in the rate of growth of information over time, whereas the task variable influenced the time necessary for accuracy to exceed chance levels. The effects of alcohol and task were clearly independent.

As pointed out earlier, there is no certainty that the intercept and slope of the SATF index independent psychological processes. Although the data in Table 3 do not suggest that changes in one parameter were compensated by changes in the other, it is useful, nevertheless, to combine the slope and intercept into a single measure representing the overall level of performance in each alcohol condition and task. As suggested by Wood and Jennings (1976) and Jennings et al. (1976) one way to do this is to derive "equal-RT contours" by inserting fixed values of RT into the linear tradeoff equation and solving for the corresponding values of accuracy.

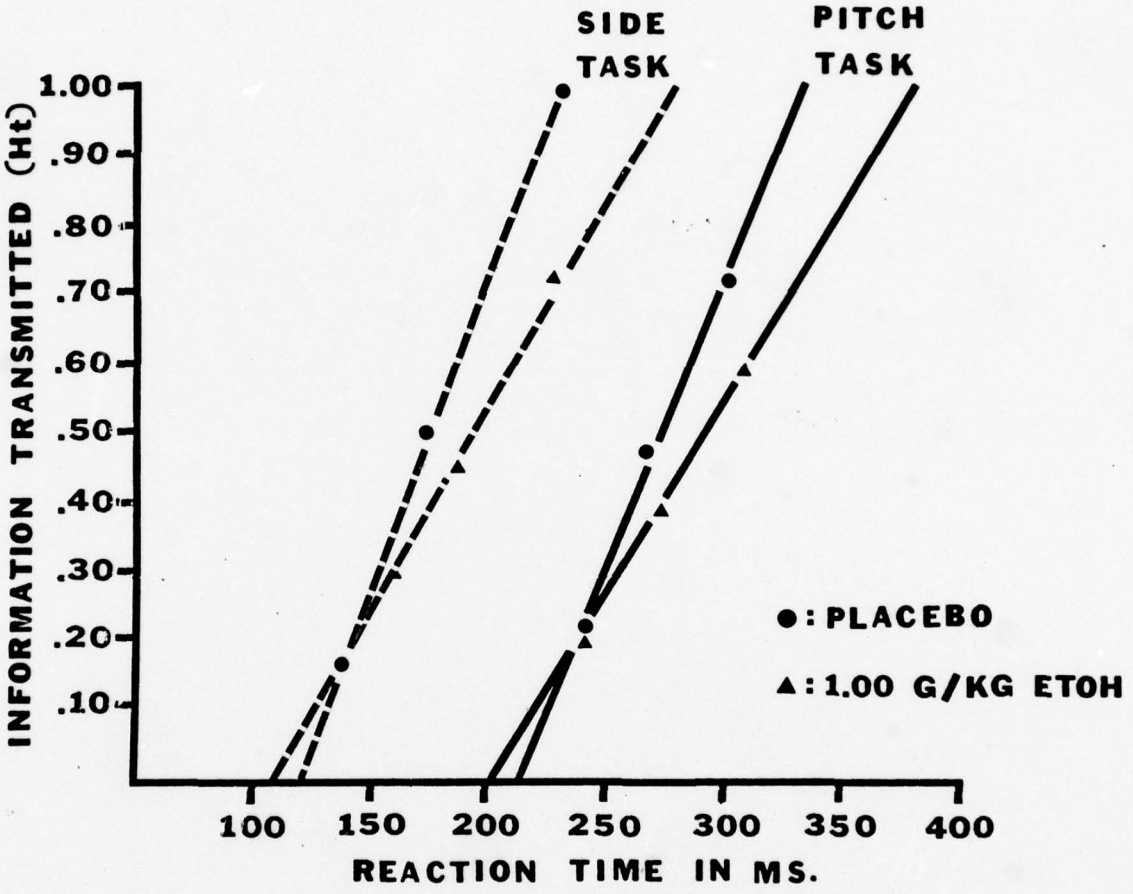


Figure 2. Effects of alcohol and the task on the speed-accuracy tradeoff function.

Table 3

Mean Slopes and Intercepts for Best-Fitting Linear Equations for Each Task in Each Alcohol Condition

		Alcohol Dose (g/kg)			
		0	.25	.50	1.0
Task					
Side Discrimination					
Slope (bits/msec)	$\bar{X}$	.00869	.00862	.00757	.00599
	SD	.00129	.00298	.00312	.00248
Intercept (msec)	$\bar{X}$	118.7	120.1	121.8	112.2
	SD	27.9	24.9	36.8	33.7
Pitch Discrimination					
Slope (bits/msec)	$\bar{X}$	.00820	.00679	.00676	.00567
	SD	.00324	.00196	.00301	.00323
Intercept (msec)	$\bar{X}$	213.4	207.6	205.0	201.5
	SD	38.1	41.1	50.7	51.0

Figure 3 shows mean information transmitted as a function of alcohol dose at three selected values of RT for each task (330, 290 and 250 msec for pitch discrimination and 230, 190 and 150 msec for side discrimination). As could be deduced from Figure 3, at the relatively fast RT levels of 150 msec for the side-discrimination task and 250 msec for the pitch-discrimination task accuracy was relatively low and was not influenced by alcohol. In contrast at the relatively slow RTs of 230 and 330 msec, alcohol caused a progressive decrease in accuracy. These conclusions were verified statistically by two-way ANOVAs performed on the data from each task separately. For each task, the expected CRT by dose interaction effect was significant ($F_6,66 = 4.9$ for side and $F_6,66 = 2.5$ for pitch), and for each task there were significant differences in accuracy as a function of choice RT ($F_2,22 = 143.8$ and 88.3). There was a significant main effect of dose for the side-discrimination task ($F_3,33 = 9.1$) but not for the pitch-discrimination task ($F_3,33 = 2.2$). The CRT by dose interaction effects were assessed further by analyses of the simple main effects of dose at each level of RT. As suggested by the data in Figure 3, for the pitch-discrimination task, the dose effect was significant at CRT = 330 msec ($F_3,33 = 3.9$) but not at either CRT = 290 msec ($F_3,33 = 2.6$) or RT = 250 msec ($F < 0.2$). For the side-discrimination task the dose effect was significant at CRT = 230 msec ($F_3,33 = 15.4$) and at 190 msec ($F_3,33 = 6.7$) but not at 150 msec ($F_3,33 = 1.9$). These results are in close agreement with those reported by Jennings et al. (1976) for their binaural task.

Discussion

These findings confirm those of Jennings et al. (1976), demonstrating the advantage gained by joint analysis of speed and accuracy as dependent variables. In a conventional analysis, the absence of a significant alcohol effect on mean CRT could lead to the erroneous conclusion that alcohol produced no discernable impairment either in side-discrimination or pitch-discrimination. As illustrated in Figure 1_b, however, overall accuracy on both tasks did show a small but significant decline with alcohol dose. Considering the trends in mean CRT and mean accuracy together, the data do imply that alcohol caused a deficit in processing efficiency, not simply a bias toward speed over accuracy.

In this study, as in that of Jennings et al. (1976), alcohol impairment of processing efficiency was clearly demonstrated by a systematic, dose-related decline in the slope of the SATF; a decrease in the rate of growth of accuracy over time. On the other hand, alcohol had no significant effect on the intercept of the SATF, and thus, no effect on the portion of CRT necessary for accuracy to exceed chance levels. A second method of comparing SATFs combined the intercept and slope parameters into "equal-RT contours" (Wood & Jennings, 1976). The equal contour data confirmed the conclusion of Jennings et al. (1976) that the effect of alcohol on processing efficiency is dependent upon the level of accuracy and CRT at which performance is measured. Alcohol had no effect on fast but relatively inaccurate responses, but as was implicit in the average slope and intercept data, produced substantial deficit in relatively slow but accurate performance. For example, at $H_t = 0.9$, CRT in the high dose condition was 40.1 msec slower than placebo in the side-discrimination and 40.7 msec slower in the pitch discrimination task.

It is clear from these results that the tradeoff function for speed vs. accuracy provided a more sensitive and informative index of the impairment of CRT by alcohol than either average speed or accuracy taken alone. Several

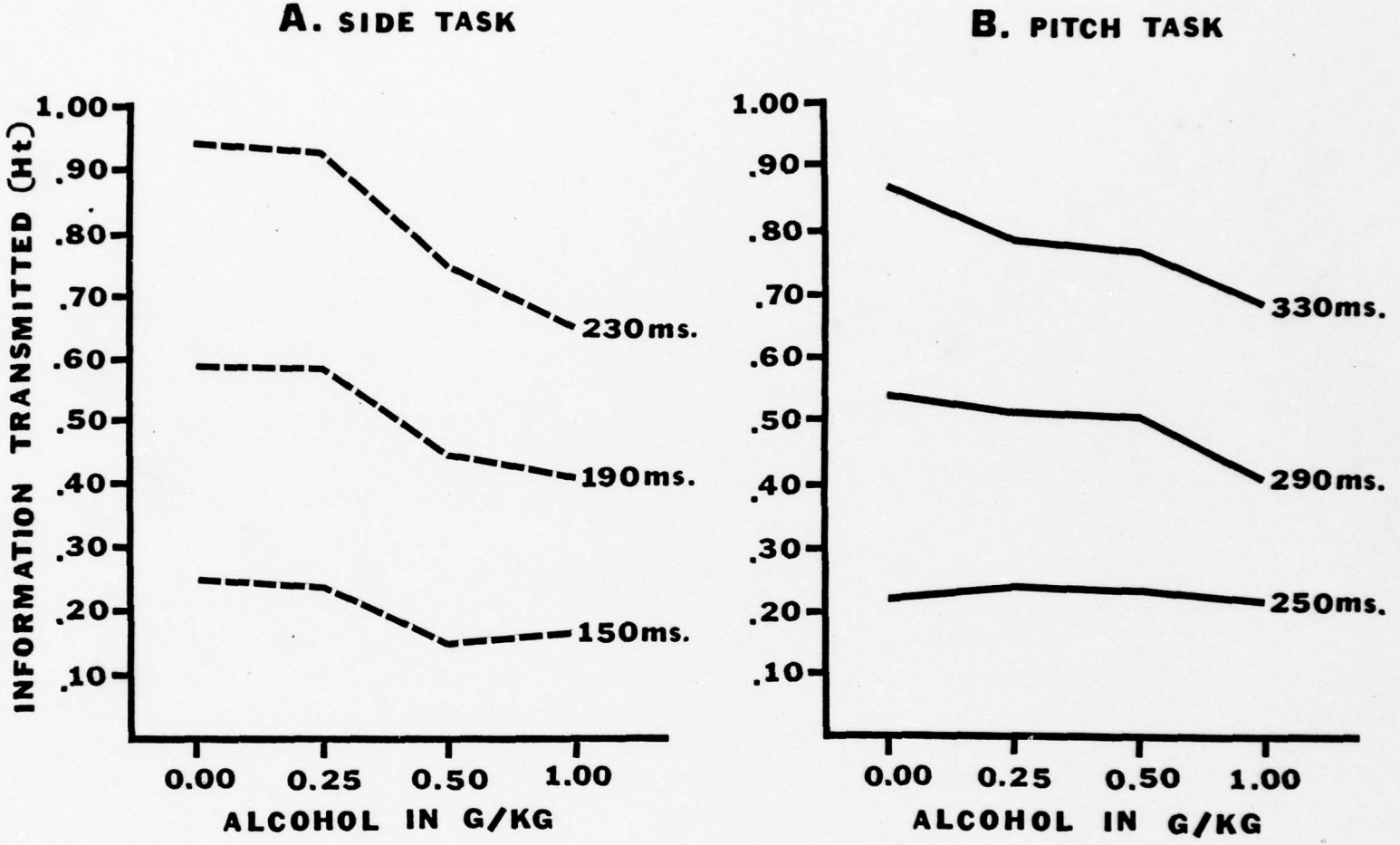


Figure 3. Amount of information transmitted as a function of alcohol dose at several reaction times for each task.

investigators, including ourselves, have found only small alcohol effects on mean RT in choice tasks even with BACs as high as 100 mg% (e.g., Carpenter, 1962; Huntley, 1972; Moskowitz, 1973; Tharp et al., 1974). Yet, as in the study by Jennings et al. (1976) the present results, employing SATF, demonstrated an increasing monotonic effect of alcohol over the entire dose range from placebo to 1.0 g/kg.

We had anticipated that the effect of task in this study might be distributed both to the intercept and slope of the SATF and that with the slope parameter as dependent variable, a two way interaction might emerge between the effects of alcohol and task. This did not occur. Instead, the effects of alcohol and task were independent. Alcohol affected the slope but not the intercept whereas the task variables influenced the intercept but not the slope. In the Harm and Lappin (1973) study, employing visual choice tasks, a conventional manipulation of S-R compatibility influenced the slope of the SATF. The isolation of our task effect on the intercept suggests that the substantial difference in average CRT between the two tasks was not due to S-R compatibility effects. Instead, this difference most probably reflects increased requirements for stimulus processing in the pitch discrimination task.

Tharp et al. (1974) and Huntley (1972, 1974) advanced the hypothesis that alcohol impairs output cognitive processes associated with response selection rather than input processes involved in stimulus processing. The present data do not permit definite conclusions concerning the functional locus of alcohol effects. As in the results of Jennings et al. (1976) one can eliminate from consideration any substantial effect of moderate doses of alcohol on simple motor speed. Any such effect should have caused a dose-related increase in average CRT. Moreover, since task differences were localized on the intercept of the SATF, the extra processing requirements hypothesized for pitch discrimination were not influenced by alcohol. From the perspective of several serial stage CRT models (e.g., Sternberg, 1969; Smith, 1968) the remaining cognitive step would be selection of the correct motor program. Thus, the data are not inconsistent with the notion that the slope parameter of the SATF contains information about response-selection processes and that the effects of alcohol are targeted on this stage. However, systematic evaluation of this hypothesis awaits further study.

References

Bertera, J.H., Callan, J.R., Parsons, O.A., and Pishkin, V. Lateral stimulus-response compatibility effects in the oculomotor system. Acta Psychologica, 39: 175-181, 1975.

Callan, J.R., Klisz, D., and Parsons, O.A. Strength of auditory stimulus-response compatibility as a function of task complexity. Journal of Experimental Psychology, 102: 1039-1045, 1974.

Carpenter, J.A. Effects of alcohol on some psychological processes. Quarterly Journal of Studies on Alcohol, 23: 274-314, 1962.

Fitts, P.M., and Seegar, C.M. Stimulus-response compatibility: Spatial characteristics of stimulus and response codes. Journal of Experimental Psychology, 46: 199-210, 1953.

Green, D.M., and Luce, R.D. Speed-accuracy tradeoff in auditory detection. In, S. Kornblum (Ed.), Attention and Performance IV. New York: Academic Press, 1973.

Harm, O.J., and Lappin, J.S. Probability compatibility, speed and accuracy. Journal of Experimental Psychology, 100: 416-418, 1973.

Huntley, M.S. Influences of alcohol and S-R uncertainty upon spatial localization time. Psychopharmacologia (Berlin), 27: 131-140, 1972.

Huntley, M.S. Effects of alcohol, uncertainty and novelty upon response selection. Psychopharmacologia (Berlin), 39: 259-266, 1974.

Jennings, J.R., Wood, C.C., and Lawrence, B.E. Effects of graded doses of alcohol on speed-accuracy tradeoff in choice reaction time. Perception & Psychophysics, 19(1), 85-91, 1976,

Jones, B.M., and Vega, A. Cognitive performance measured on the ascending and descending limb of the blood alcohol curve. Psychopharmacologia (Berlin), 23: 99-114, 1972.

Lappin, J.S., and Disch, K. The latency operating characteristic: I. Effects of stimulus probability on choice reaction time. Journal of Experimental Psychology, 92: 419-427, 1972(a).

Lappin, J.S., and Disch, K. The latency operating characteristic: II. Effects of visual stimulus intensity on choice reaction time. Journal of Experimental Psychology, 93: 267-372, 1972(b).

Lappin, J.S., and Harm, O.J. On the rate of acquisition of visual information about space, time and intensity. Perception and Psychophysics, 13: 439-445, 1973.

Lentz, S.K., and Rundell, O.H. Sustained control of blood alcohol levels. Alcohol Technical Reports, 5(2), 33-36, 1976.

Moskowitz, H. Laboratory studies of the effects of alcohol on some variables related to driving. Journal of Safety Research, 5: 185-199, 1973.

Pachella, R.G. The interpretation of reaction time in information processing research. In, B. Kantowitz (Ed.), Human Information Processing: Tutorials in performance and cognition. New York: Lawrence Erlbaum, 1974.

Pachella, R.G., and Fisher, D.F. Effect of stimulus degradation and similarity on the trade-off between speed and accuracy in absolute judgements. Journal of Experimental Psychology, 81: 7-9, 1969.

Shouten, J.R., and Bekker, J.A.M. Reaction time and accuracy. In, A.F. Sanders (Ed.), Attention & Performance. Amsterdam: North Holland, 1967.

Simon, J.R., and Craft, J.L. Effects of an irrelevant auditory stimulus on visual choice reaction time. Journal of Experimental Psychology, 86: 272-274, 1970.

Simon, J.R., Hinrichs, J.V., and Craft, J.L. Auditory S-R compatibility: Reaction time as a function of ear-hand correspondence and ear-response-location correspondence. Journal of Experimental Psychology, 86: 97-102, 1970.

Simon, J.R., and Small, A.M.J. Processing auditory information: Interference from an irrelevant cue. Journal of Applied Psychology, 53: 433-435, 1969.

Simon, J.R., Small, A.M., Ziglar- R.A., and Craft, J.L. Response interference in an information processing task: Sensory versus perceptual factors. Journal of Experimental Psychology, 85: 311-314, 1970.

Smith, E.E. Choice reaction time: An analysis of the major theoretical positions. Psychological Bulletin, 69: 73-110, 1968.

Sternberg, S. The discovery of processing stages: Extensions of Donder's Method. In, W.G. Koster (Ed.), Attention and Performance, Acta Psychologica, 30: 276-315, 1969.

Tharp, V.K., Rundell, O.H., Lester, B.K., and Williams, H.L. Alcohol and information processing. Psychopharmacologia (Berlin), 40: 33-52, 1974.

Wood, C.C., and Jennings, J.R. Speed-accuracy tradeoff functions in choice reaction time: Experimental designs and computational procedures. Perception and Psychophysics, 19: 92-101, 1976.

ALCOHOL, PRACTICE AND INFORMATION PROCESSING

Several recent theories of choice reaction time (RT) are logically related to the additive model proposed by Donders in 1868 (see Koster, 1969, and Smith, 1968). Donders postulated that the time required for a choice reaction is the sum of three temporal components: (a) simple RT, (b) the time required for stimulus categorization and (c) the time required for response selection. Despite difficulties encountered in attempts to validate this model, Donders' basic conception of choice RT as the sum of durations of a series of reactions or stages remains popular (Sternberg, 1967; Posner and Mitchell, 1967; Smith, 1968). In 1966 and 1969, Sternberg proposed a simple method of testing for additive choice RT components, the central assumption of which is that simultaneous manipulation of variables affecting the same stage of processing should produce hyperadditive effects on RT. Conversely, simultaneous manipulation of variables affecting different processing stages should produce additive effects. One limitation of Sternberg's method, however, is that it does not lead directly to estimates of the duration of each hypothesized stage. Procedures derived from Teichner and Krebs' review (1974) do permit such estimates.

Teichner and Krebs' quantitative analysis of the literature on visual choice RT was focussed principally on two traditional choice tasks: the so-called Light Key and Digit Key tasks. They gave considerable attention to one important question: Why, for all levels of practice, is performance on the Light-Key task consistently faster than performance on the Digit-Key task? They concluded that this difference is due to the fact that the latter task requires the subject to perform a translation operation for correct responding whereas the former task does not. The stimuli for the Light-Key task usually consist of a spatial arrangement of two or more lights for which there is a corresponding spatial arrangement of two or more keys. In a sense, each response key represents a simple extension of each stimulus. On the other hand, the numerical (or letter) stimuli for the Digit-Key task are usually presented one-by-one on a central display, but as in the Light-Key task the response keys are arranged by a spatial code. A critical difference between the two tasks is that in the Digit-Key task, the subject must follow a stimulus-to-response translation rule, translating from a numeric to a position code. Thus, in the Digit-Key task, as usually programmed, the subject has at least five operations to perform. He must (1) see the digit, (2) name it, (3) translate the numeric name to its corresponding response key position, (4) select the correct motor program, and (5) execute the response. In the Light-Key task, step 3 is not required because the only possible names that can be given to the lights as stimuli are those for the response position rule. Thus, stimulus-response compatibility is greater for the Light-Key task.

Employing the additive model and assuming that time for response selection (c) is identical for the two tasks, one can compute an estimate of translation time (T_{S-R}) by subtracting average reaction-time for the Light-Key task (choice RT_{LK}) from that for the Digit-Key task (choice RT_{DK}). Similarly, on the assumption that for simple RT, there is no requirement for response selection the duration of theoretical component "c" can be estimated by subtracting simple RT from choice RT_{LK}.

Thus,

$$\text{choice } RT_{DK} = \underline{a} + \underline{T}_{S-R} + \underline{c}$$

$$\text{choice } RT_{LK} = \underline{a} + \underline{c}$$

$$\text{and, simple RT} = \underline{a}$$

where $\underline{c}$ = response selection time and $\underline{T}_{S-R}$ = translation time.

The assumption that component $\underline{c}$ is identical for the Digit-Key and Light-Key tasks seems reasonable, particularly if the Light-Key task is modified by arranging digital stimuli according to a spatial code. Thus, with four stimulus-response alternatives, digits are presented one-at-a-time in four different windows, each associated with a different key. The relationship between spatial codes for stimuli and responses is one-to-one. Correct responding on this modified Light-Key task does not demand numerical coding. However, Teichner-Krebs (1974) showed that even with simple RT, the subject may encode information about both the probability and content of the stimulus. This implies that for estimates of stage duration, the simple RT task should also be modified to match the two choice RT tasks for stimulus content and number of alternatives. These task modifications were made and will be described in the method section.

We (Tharp et al., 1974) and Huntley (1974) had found that the effects of alcohol were hyperadditive with those of stimulus-response compatibility and had concluded that alcohol influenced output cognitive processes associated with response selection. However, the analysis by Teichner and Krebs suggests that stimulus-response compatibility treatments exert load on the translation stage rather than (or in addition to) response selection processes. The data so far reported by us are consistent with the notion that alcohol slows either translation operations or response selection operations or both. One aim of the present experiment was to employ three tasks, choice RT_{DK}, choice RT_{LK} and simple RT to investigate the degree to which these hypothetical cognitive processes are vulnerable to moderate levels of alcohol intoxication.

Practice Effects

A second aim of this study was to examine the degree to which extended practice modifies the effects of alcohol on overall RT performance and on the estimates of stage durations derived from the three RT tasks. There are several reasons to suppose that alcohol effects may change with practice. First, it is well-known that visual RT is a decreasing function of practice, but that the rates of decrease differ for the three tasks choice RT_{DK}, choice RT_{LK} and simple RT. Second, it is well-established that practice reduces the effect of S-R compatibility on choice RT. Thus, the function relating choice RT_{DK} to number of practice trials is steeper than the function for choice RT_{LK} (Teichner and Krebs, 1974). A priori, one assumes that the effects of alcohol on choice RT tasks will also decline as a function of practice on task, but we found no research addressed specifically to this question.

The experiment reported here, employing the three tasks, Digit-Key, Light-Key and simple RT, at two levels of practice, addressed the following questions:

1. Which stages in the serial stage model are vulnerable to moderate alcohol intoxication, and do the effects of alcohol decline with practice? A priori, one might assume that the more "automatic" a task becomes, the less the effect of intoxication.

2. Do alcoholized subjects adapt to intoxication such that with repeated doses of alcohol, the drug effect is reduced or overcome?

3. Does alcohol alter the effects of practice such that practice while in an intoxicated state fails to carry over to subsequent sober performance?

Method

Subjects. The subjects for this study were ten paid volunteers from the graduate and undergraduate medical programs of the University of Oklahoma Health Sciences Center. Ranging in age from 21-35, they were all in good health, all had normal vision, all were moderate social drinkers, none were receiving medication and none reported use or abuse of drugs other than alcohol. The subjects were instructed to abstain from alcohol for 24-hours prior to each test session and to fast for at least four hours prior to testing. The subjects were divided into two groups of six and four for short and long practice, respectively. Testing began about 11:00 a.m. and was concluded about 12:30 p.m.

Design. Group 1 (short practice) performed 100 practice trials on each task prior to receiving alcohol in two sessions, each followed by a rest day. They performed 250 trials per task during each alcohol session and for two days subsequent to the final rest day. Group 2 (long practice) performed 250 trials per task per session for eight sessions (2,000 trials) prior to receiving alcohol. Testing was on consecutive days except for days 1 and 2, each of which was followed by a rest day to maintain a schedule equivalent to that of Group 1. Each of two alcohol sessions was followed by a rest day, and testing was continued for two days subsequent to the final rest day.

On alcohol sessions, all subjects were given 1.0 g/kg of 95% ethanol mixed with a commercial, non-carbonated orange drink in a 1:4 ratio. They consumed their drinks in a period of 30 minutes. While drinking, each subject was offered antacid tablets (Maalox #2) to reduce stomach acidity. Blood alcohol concentration (BAC) was measured at 15 min. intervals throughout each alcohol session with a Stephenson Model 900 Breathalyzer.

Apparatus. Subjects were seated at a table approximately 80 cm in front of a vertical display panel containing five IEE rear-plane projectors. Four projectors were arrayed in a 180° semicircle with radius of 20.5 cm. The fifth, central, projector was located at the center of the semicircle.

Before each trial a green square appeared in the central display panel for 300 msec. A digit, drawn from the ensemble 1-4, then appeared for 10 msec. in one of the five displays 0.8, 1.0, or 1.3 sec. after termination of the green warning signal. White digits 1.5 cm high were presented on a black background. A response panel was located on the table in front of the subject and was configured exactly like the display panel. Thus, the response panel contained five telegraph keys arrayed in a semicircle with one key at the center. Distance between keys was 4 cm.

The subject was required to keep the central key depressed with the index finger of his right hand until the stimulus was presented. Failure to do so aborted the trial. Responses to the stimuli were made by moving the right index finger from the central key to one of the four response keys. Reaction time (from stimulus onset to response) and accuracy were measured and printed on paper by a BRS logic system and an associated Systron-Donner counter-printer system. The inter-trial interval from response to warning signal was 3 sec.

Tasks.

1. Choice RT_{DK}. Using four alternatives drawn from the ensemble 1 through 4, digits were presented one-by-one on the central display. The subject's task was to respond as quickly and accurately as possible according to a simple numerical-to-spatial code. The digit "1" signaled a response on the left-most key; a "2" required a response on the key located second from the left, etc. The same numerical to spatial code was used for all subjects and all trials.

2. Choice RT_{LK}. For this task, stimuli were presented only in the four peripheral displays forming the semicircle. When a digit was presented in one of these displays, the subject was required to respond by pressing the key corresponding in spatial location to the display illuminated. Thus, the responses were made according to a highly compatible one-to-one spatial code: the left-most display corresponding to the left-most response key, etc. The digit presented in a given display was always the same from trial to trial and thus was totally confounded with the spatial code, and irrelevant to correct performance. In other words, the left-most display always contained a "1", the next display a "2", etc. The subject was instructed to ignore the value of the digit displayed and to respond merely to the location illuminated.

3. Simple RT. This task (with simple RT defined as reaction time plus movement time) was performed with each of the four peripheral stimuli and with the response made on each of the four corresponding keys. Thus, during each session there were four blocks of simple RT trials, each block containing 62 trials. During the first block of trials the stimulus was the digit "1" presented in the left-most display, and the subject responded by pressing the left-most key. The next display, containing the digit "2" and the next response key were used in the second block of trials, etc. Consequently, estimates of simple RT contain RTs to numeric stimuli at each of the four peripheral locations and with responses on each of the four keys.

Results and Discussion

Mean blood alcohol concentration (BAC) for the short practice group was 93 mg% and 90 mg% for days 1 and 2, respectively. For the long practice group mean BAC on the two alcohol sessions was 102 mg% and 94 mg% (days 9 and 10, respectively).

Effects of Alcohol on Component Processes of CRT

Short practice. Table 1 shows means and standard deviations for the short practice group on each task in the alcohol sessions and the two baseline sessions preceding and succeeding those trials. Reaction times for each task declined from Day 1 (practice condition) to Day 4, but the improvement was statistically significant only for the simple RT task ($t_5 = 3.80$, $p < .01$). After 100 practice trials alcohol caused significant slowing in choice RT_{DK} (about 83 msec; $t_5 = 3.06$, $p < .05$) but only marginal slowing in choice RT_{LK} (about 37 msec, $p < .10$); and had no effect on simple RT. On day 2, the pattern of alcohol effects was about the same. Alcohol slowed performance on the Digit-Key task by a significant 77 msec ($t_5 = 3.18$, $p < .01$), again produced marginal slowing on the Light-Key task (43 msec; $t_5 = 1.90$, $p < .20$) and had no demonstrable effect on simple RT. Between alcohol sessions, decrement scores on the choice tasks were no significantly different for either task. Thus one day's practice under alcohol

TABLE 1

Short Practice Group (N=6)

Task		Session					
		1-Practice	1-Alcohol	2-Practice	2-Alcohol	3-Practice	4-Practice
RT	$\bar{X}$	339	322	319	312	304	261
	s	59	80	136	98	107	70
CRT_{LK}	$\bar{X}$	419	456	416	458	384	391
	s	121	113	108	110	86	132
CRT_{DK}	$\bar{X}$	492	575	486	562	499	482
	s	76	85	111	107	110	104

did not reduce impairment on the second alcohol session. Overall proportionate alcohol impairment was greatest for choice RT_{DK} (16.2%) and less for choice RT_{LK} (9.4%).

Table 2 exhibits means and standard deviations on alcohol and baseline sessions for the derived measures of stage durations, the translation stage, T_{S-R}, and the response selection stage, c. As mentioned above, the a stage, defined as simple RT, was not affected by alcohol. Alcohol slowed T_{S-R} about 45 msec on Day 1 ($t_5 = 2.43$, $p < .05$) but only about 34 msec on Day 2 ($t_5 = 1.41$, $p < .2$). Alcohol also slowed c about 54 msec on Day 1 ($t_5 = 3.65$, $p < .01$) and about 49 msec on Day 2 ($t_5 = 1.34$, $p < .20$). Thus, both hypothetical stages, stimulus-response translation and response selection were significantly impaired by alcohol on day 1, but the day 2 effects were somewhat smaller and were nonsignificant. The overall proportional slowing of the two stages across both alcohol sessions was nearly equal (c = 59% and T_{S-R} = 56%).

In summary, after a minimum of sober practice, alcohol slowed the Group 1 subjects' performance on both choice RT tasks while leaving simple RT unaffected. The subsequent stage analysis suggests that two hypothetical stages of information processing (T_{S-R} and c) were equally slowed by alcohol. Recall that the simple RT task, used to estimate the a stage, includes movement time (i.e., the time required to move the index finger from the central key approximately 4 cm to one of the four peripheral response keys). The negative finding with regard to simple RT at this level of practice suggests that neither the central processes involved in simple RT nor the motoric response were affected by alcohol.

Long practice. Tables 3 and 4 display similar data for the long practice group. As expected there was a substantial practice effect from Day 1 to Day 12 amounting to 50 msec for simple RT ($t_3 = 2.62$, $p < .05$), 67 msec for choice RT_{LK} ($t_3 = 2.26$, $p < .10$), and 83 msec for choice RT_{DK} ($t_3 = 2.58$, $p < .05$). After 2000 practice trials on each task, alcohol (Day 9) slowed simple RT by about 31 msec ($t_3 = 10.2$, $p < .005$), choice RT_{LK} by about 37 msec ($t_3 = 14.2$, $p < .001$) and choice RT_{DK} by about 65 msec ($t_3 = 3.52$, $p < .025$). The second administration of alcohol (Day 10) also significantly slowed performance on all tasks ($p < .01$ or better). As found for the short practice group, one day's practice under alcohol (Day 9) did not significantly improve task performance when alcohol was administered on a second occasion (Day 10). In fact, overall performance on the two choice RT tasks was slightly (not significantly) worse on the second alcohol day than on the first. Overall, the alcohol-related decrement was 14% for simple RT, 16% for the Light-Key task and 18% for the Digit-Key task.

As mentioned above, the a stage (plus movement time) as indexed by simple RT, was significantly slowed by alcohol. Table 4 shows the estimated stage durations of T_{S-R} and c. The estimated durations of both of these stages were longer for the two alcohol sessions than for the adjacent baseline sessions. However, acceptable levels of statistical significance were achieved only for the second alcohol session ($p < .001$ and $p < .05$ for T_{S-R} and c respectively). Overall, alcohol slowed T_{S-R} by about 36% and c by about 23% ($ps < .05$).

Thus, for both groups alcohol slowed performance on the two choice RT tasks and slowed the estimated time required to perform the T_{S-R} and c operations. In the long practice group significant slowing of simple RT was also found.

TABLE 2

Hypothetical Stage Duration

Short Practice Group (N=6)

Stage		Session					
		1-Practice 100 Trials	1-Alcohol 250 Trials	2-Practice 100 Trials	2-Alcohol 250 Trials	3-Practice 250 Trials	4-Practice 250 Trials
Stimulus Response Translation							
(T_{S-R})	$\bar{X}$	73	118	70	104	115	91
	s	53	71	30	50	41	35
Response Selection							
(c)	$\bar{X}$	80	135	96	146	80	131
	s	84	76	41	76	37	88

TABLE 3

Long Practice Group (N=4)

Task		Session: Practice 1	2	3	4	5	6	7	8	Alcohol 9	10	Practice 11	12
RT	$\bar{X}$	261	242	234	223	206	213	209	207	240	237	210	211
	s	36	90	36	35	12	28	37	26	28	29	22	26
CRT_{LK}	$\bar{X}$	346	319	311	299	289	282	282	280	318	337	282	278
	2	54	47	42	45	34	20	21	25	29	19	25	32
CRT_{DK}	$\bar{X}$	460	420	420	404	391	397	392	374	445	454	386	377
	s	64	25	37	19	18	20	13	19	32	12	20	15

TABLE 4

Hypothetical Stage Durations

Long Practice Group (N=4)

Stage		Session											
		Practice								Alcohol		Practice	
		1	2	3	4	5	6	7	8	9	10	11	12
Stimulus Response Translation													
(T_{S-R})	$\bar{X}$	114	101	109	105	102	114	111	94	127	118	104	99
	s	35	28	26	27	36	8	8	20	31	16	12	26
Response Selection													
(c)	$\bar{X}$	84	76	77	75	83	70	72	73	79	100	72	67
	s	27	21	17	18	25	18	18	13	17	17	11	16

One major question was whether one practice session with alcohol would improve performance on a second alcohol session. This clearly did not happen. On the contrary, although the alcohol sessions were separated by 48 hrs., performance was usually worse on the second session. This trend held for both short practice and long practice groups.

Comparison of short and long practice groups.

One of the major questions addressed by the present study was whether extended practice on a task decreases the vulnerability of the task to disruption by moderate alcohol intoxication. Using the alcohol-related increase in response time as the dependent measure, we found no statistically reliable difference between short and long practice for any of the three tasks. For simple RT, the long practice group showed a 32 msec greater alcohol effect ($t_8 = 1.45$, $p < .2$). For the two choice RT tasks, alcohol tended to produce slightly less slowing in the long practice group (about 3 msec for CRT_{LK}, $t < 1$; and about 19 msec for CRT_{DK}, $t < 1$). Similar trends were found for the two derived stage estimates, T_{S-R} and c. Again, when alcohol effects for the short practice and long practice groups were compared, we found trends toward less slowing of the long practice subjects (by 33 msec for T_{S-R}, $p < .2$; and by 70 msec for c, $p < .1$). The proportional alcohol-related slowing of T_{S-R} and c also tended to be smaller in the long practice group, but the differences between groups were not significant. Thus, though there was some evidence that prolonged practice may reduce the effects of alcohol on these processing stages, the data are equivocal given the significance levels achieved and the power of the tests.

Another question addressed by this study was whether alcohol interfered with practice effects such that later sober performance failed to benefit from practice under alcohol. To make this comparison, we found the improvement in mean RT over approximately the first 1000 trials (i.e., from Session 1 to Session 4 or 5) for subjects in Group 1 and Group 2. Recall that the short practice group (Group 1) performed 500 of the first 1000 trials of each task while intoxicated. Group 2 (long practice) subjects were sober throughout this period. Over the first 1000 trials, the short practice group actually showed slightly more improvement in simple RT (by 9 msec; $t < 1$) than did the long practice group. For the two choice RT tasks there was a tendency (nonsignificant) for alcohol to interfere with practice effects. Thus, Group 2 showed a 43 msec greater improvement on the Light-Key task ($t_8 = 1.3$, $p < .2$) and 73 msec greater improvement on the Digit-Key task ($t_8 = 1.4$, $p < .2$) than did Group 1. These data suggest that alcohol intoxication may not interfere with early practice effects on relatively uncomplicated performance tasks as represented by simple RT. Alcohol intoxication may, however, interfere with learning more complex tasks, as represented by the two choice RT tasks. The t tests were clearly nonsignificant. However, our previous experience with similar tasks indicates that group differences in the range of 40-70 msec will produce highly significant statistical results when group size is in the range of 12-15 subjects.

Summary

For subjects receiving either short (100 trials) or long (2,000 trials) practice, blood alcohol concentrations of about 90-100 mg% caused systematic slowing of performance on both the Light-Key and Digit-Key choice RT tasks. However, the effects of alcohol on simple RT (plus movement time) may depend on the amount of practice on task. Performance by the long-practice group was significantly slowed by alcohol, whereas performance by the short-practice group was not.

Estimates of the durations of three hypothetical information processing stages were derived from the three tasks. The results of analysis of alcohol effects on these derived measures permit us to infer that alcohol causes slowing of both stimulus-response translation operations and response selection operations. That is to say, in choice RT tasks alcohol intoxication produces slowing of central cognitive processes such as those involved in translating from a numerical code on the stimulus side to a spatial code on the response side as well as of output processes such as those involved in selecting the correct motor program. Whether at this dose level, alcohol also impairs such basic processes as sensory-motor transmission times is not clear for two reasons. First, our measure of simple RT was confounded by movement time and second, as reported above, the effects of alcohol were not consistent across practice groups.

These results confirm those of Tharp et al. (1974) showing that output cognitive processes associated with response selection are vulnerable to alcohol intoxication. The findings extend those of Tharp et al. by showing further that more central processes in the serial-stage model, those associated with translating from a stimulus code to a response code, are also vulnerable to alcohol.

Although there were trends in the data suggesting that extended practice on choice reaction time tasks might reduce somewhat their vulnerability to alcohol intoxication, none of these trends were statistically significant. Overall, the evidence indicates that practice up to at least 2,000 trials, spaced over 8 days fails to protect reaction time performance against alcohol-induced deficit.

Does alcohol reduce the beneficial effects of practice? Our results indicate that alcohol intoxication probably does not interfere with early practice effects on simple reaction time. However, trends in the data, though non-significant with these sample sizes, do suggest that moderate intoxication may interfere with learning more complex tasks, as represented by choice reaction time.

References

Huntley, M.S. Effects of alcohol, uncertainty, and novelty upon response selection. Psychopharmacologia, 39: 259-266, 1974.

Koster, W.G. (Ed.), Attention & Performance II. Acta Psychologica: 30, 412-431, 1969.

Posner, M.I., and Mitchell, R.F. Chronometric analysis of classification. Psychological Review, 74: 392-409, 1967.

Smith, E.E. Choice reaction time: an analysis of the major theoretical positions. Psychological Bulletin, 69: 77-110, 1968.

Sternberg, S. High speed scanning in human memory. Science, 153: 652-654, 1966.

Sternberg, S. Two operations in character recognition: some evidence from reaction time measurements. Perception & Psychophysics, 2: 45-53, 1967.

Sternberg, S. The discovery of processing stages: extensions of Donder's method. Attention & Performance II. Acta Psychologica: 30, 276-315, 1969.

Teichner, W.H., and Krebs, M.J. Laws of visual choice reaction time. Psychological Review, 81: 75-98, 1974.

Tharp, V.K., Rundell, O.H., Lester, B.K., and Williams, H.L. Alcohol and information processing. Psychopharmacologia, 40: 33-52, 1974.

Publications

Rundell, O.H. Alcohol and mechanisms of human memory. Unpublished doctoral dissertation, University of Oklahoma, 1976.

Jones, B.M., Parsons, O.A., and Rundell, O.H. Psychophysiological correlates of alcoholism. In, R. Tarter & A. Sugerman (Eds.), Alcoholism: Interdisciplinary approaches to an enduring problem. Reading, Mass.: Addison-Wesley, 1976, 435-477.

Lentz, S.K. and Rundell, O.H. Sustained control of blood alcohol levels. Alcohol Technical Reports, 1976, 5, 33-36.

Rundell, O.H., and Williams, H.L. Effects of alcohol on organizational aspects of human memory. In, F.A. Seixas (Ed.), Currents in Alcoholism, Vol. II. New York: Grune & Stratton, 1977, pp. 175-186.

Rundell, O.H., and Williams, H.L. Alcohol and organizational processes in free recall. Submitted for publication.