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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 casks 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 mgZ). 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 of recall were substantial ($\overline{r} = .76$), 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 alcoholrelated decrease in the d' statistic and an increase in 8. 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 is 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 intexicated 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 ware 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 slophel. The isolation of the case effect on the intercept parameter probably reflects increased requirements

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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.

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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.

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EFFECTS OF ALCOHOL ON HUMAN INFORMATION PROCESSING

Sumary

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 mgZ). The paradigm assessed performance on free recall, multi-tricl 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 ($\overline{r} = .76$), 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 severally 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 8. 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 assassed 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 tisk 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 intoricated 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 cubject to respond according to a highly compatible left-right position rule. The pitchdiscrimination 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 effect were independent of those of alcohol. The isolation of the task effect on the inte cept 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 43 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 wase trends in the data suggesting that alcohol interfores with the beneficial effects of practice.

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

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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 mgZ) 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 * task variable. list length, suggested that the alcohol deficit seen in output '...a LIS 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 intexicated subjects were impaired in the use of objective organizational aids as indexed by a measure of clustering. In addition, the clustering measure correlated strongly ($\underline{r} = .87$, $\underline{p} < .001$) 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 vertal 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 frems 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 date 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:

 Alcohol (EAC = 100 mg%) impairs recall from two hypothetical memory stores: STS and UTS.

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 challow 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 Lagoratory on two successive days. These subjects received a placeto on Day 1 and a moderate dose of alcohol on Day 2. Half of the Group 1 subjects terformed 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) tame to the interatory on one occusion only, and performed Tasks 1b, 2, and 3. Thus,

approximately half of the subjects (Group 1) performed Task 13 while the remaind (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 la and 1b: Free Recall and/or Recognition

I.troduction

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 ().e., scarch-free retrieval; see, Anderson & Bower, 197 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 croognition tas' than on free recall.

Method

<u>Subjects</u>. 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 while randomly assigned to one of three group Group 1 subjects (N = 70) 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 = 12)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. Subjewere 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% ethapol per kg body weight mixed 1:4 with grange drink. The total beverage was divided into three drinks and consumed within 30 minutes. Placebo consisted of an identical voluce of grange drink (total 4.8 ml/kg) with 4-5 ml ethanol floated on the top of each of the three drinks. Initial Breathaly measures of BAC were taken 30 minutes following consumption of the final drink. Two subsequent BAC determinations were ande following Task 1 (about 25 minutes later) and Task 3 (about 60 minutes after the initial measurement).

Procedure. Task la consisted of free recall of ten 15-word lists, each list being followed by a recognition task. After rests 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

¹Groups 2 and 3 were planned to include 12 subjects each. The unequal style all 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 Extagraphic 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 teath 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 19 lists were used for Task la. Half of the Group I subjects received Lists 1-16 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 Dircussion

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 37 mg%. Means md standard deviations for the three BAC determinations are shown in Table 1. During Task 1 the subjects' mean BAC rose from 32 to 96 mg%.

Task la: 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.

"Stanificant at 2 < .05 or better, non-parametric tests.

Table 1

Blood Alcohol Concentration (N = 33)

	Time since	e consumption of	beverage (minutes)
	30	55	90
BAC (mgI)			
Mean	82	96	83
<u>SD</u>	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 la: 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 lewer false recognitions (false alarms), although this result vis 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 (\underline{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 B 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 & 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 (\underline{t} 22 = 1.67) \pm . As in the delayed recognition task the alcohol group had lower \underline{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 (\underline{t} 31 = 1.04) \star or placebo (\underline{t} 29 = .95) \star conditions. Thus, the data support rejection of the first hypothesis (viz., that alcohol interferes with the memory scanning aspect of retrieval).

Task la: 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 (\underline{t} 19 = 0.03, $\underline{2}$ < .001)⁺, and increased the number of errors of commission from 10.0 to 13.5 (\underline{t} 19 = 2.48, $\underline{2}$ < .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 (E 9, 171 = 13.3, E < .001) +, as was the drug by serial position interaction (F 9, 171 = 3.91, p < .001)t. Differences between the curves were significant at the .Ol 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 Jb, 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 ($\pm 22 = 4.01$, 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, \pm 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 sloohol subjects.

Task 2: Intra-List Recognition

Introduction

Tasks la and lb examined the effects of reduced retrieval load on alcoholimpaired 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 icem (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 intexication impaired coding processes, recall would be adversely affected.

Several of the possible encoding dimensions are known and their effect on retrievability has been deponstrated (Talving, 1970; Underwood, 1955). A number of investigators have hypothesized a hierarchy of encoding dimensions for worbal material, and have shown that these dimensions affect recall (con. Graik & Lockhart, 1970; Gardiner, 1974; Ryde & Jenkins, 1966; Posner & W. cren, 1970; 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 ($\underline{o} < .001$).

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 Techtsooni: (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 presens subject responds according to whether the word has appeared previously in the : Typically, the list is composed of pairs of repeated words, homonyms, high frequency associates, and synonyms (e.g., Anisfield & Knapp, 196.). 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, them the intoxicated subject should have increased false alarms to homonyms and associates. This is precisely what Cermak and Butters found with sober alcohol 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 TLR task on one occasion. Half of the Group subjects performed the task on Day 1 (placebo), and the remaining Group 1 subje 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 t 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 Extagraphic slide projector at a three-second rate. Follow 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 word were of relatively high frequency of occurrence according to the Thorndike-Lorg (1944) and Eucera-Francis (1967) norms, and none of the words had been presente 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 min later (after completion of Task 3), and had fallen to 33 mg% at that time. Thu 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 loss effective lavels, one we 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

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And a second s	A local second	A responsible contract, the second state of th	Statements and a first second s
Drug		Placebo	Alcohol
	Mean • <u>SD</u>	.56 .19	.30 .12
Trials		One	Two
	Mean SD	.34 .16	.52 .20
List Arrangement		Random	Blocked
	Mean SD	.38 .13	.48 .20
		Dr	ug
Trial 1		Placebo	Alcohol
알고, 관광학	Mean SD	.45	.23

Trial 2

SD	.16	.11
	Dre	12
	Placebo	Alcohol
Mean <u>SD</u>	.49 .08	.27 .08
Mean SD	.63 .17	.32 .09
	<u>SD</u> Mean SD Mean SD	SD .16 Dry Placebo Mean .49 SD .08 Mean .63 SD .17

Mean

19

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>U</u> test).

The <u>d</u>' statistic was nonsignificantly smaller in the alcohol group (<u>t</u> 19 = 1.46, <u>p</u> < .20)* and the ß statistic was marginally larger (<u>t</u> 19 = 1.78, <u>p</u> < .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.

Task 3 stimuli were two 54-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 (onehalf 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 mgZ. By the conclusion of Task 3, mean BAC had fallen to 83 mgZ.

<u>Correct recall</u>. 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 = 3.58, 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 recal. 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 Tria! 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.

Method



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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 (\underline{F} 1, 36 = 18.53, $\underline{p} < .001$)⁺. The main effect for list arrangement was nonsignificant ($\underline{F} = .03$)^{*}, but an interaction occurred between drug and list arrangement (\underline{F} 1, 36 = 2.10, $\underline{p} < .01$). 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 (\underline{F} 1, 36 = 4.57, $\underline{p} < .05$).

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

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 ($\underline{7}$ 1, 36 = 10.30, \underline{p} < .01)⁺, while the blocked arrangement led to increased organization (F 1, 36 = 7.81, g < .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 = 2.39, p < .10). Nevertheless, a posteriori tests revealed a significant effect of list arrangement for the placebo subjects only (p < .01, Tubev's HSD)+. Thus the data support the notion that both alcohol and the objecti -ganization of the list affect the degree to which items are organized in memory. The corrected ITS 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 (\underline{r} = .63, \underline{p} < .01) and higher for blocked (\underline{r} = .82, \underline{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 steppry present in the recall list, and \underline{Z} scores were derived (see Frankel & Cole, 1971) and subjected to a three-way analysis of variance. Main effects for drugt, trialst, and the list arrangement variablet 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. Wone of the interactions were significant, although the means for the drug by list arrangement interaction were in the direction of the appetted positiv 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 .80 Mean .61 .10 SD .19 List Arrangement Random Blocked Me an .72 .70 SD .14 .21 Drug List Arrangement Placebo Alcohol Random .68 Mean .75 SD .10 .17 Blocked Mean . 86 . 55 .07 .19 SD

Task	3.	Effe	ects	of	Alcoi	nol	and	List	Ar	ages	nent	on
See	quent	ial	Orga	n1:	atic	n of	Rea	call.	£	:es	are	
	Based	on	Inte	r-1	rial	Rep	eci	tions	a	*****	ed	
			fe	= (hanc	e 00	cur	rence				

Table 4

Drug		Placebo	Alcohol
	Mean SD	4.74 5.78	1.24 1.15
ist Arrangement		Randon	Blocked
	Mean <u>SD</u>	1.47 1.46	4.50 5.85
		Dr	<u>es</u>
list Arrangement		Pla:ebo	Alcohol
Random	Mean SD	2.26 1.63	0.89
Blocked	Me an SD	7.41 7.20	1.58



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 (2 < .10), the simple effect of list arrangement was significant only for the placebo group (HSD < .01).

Task 3. Effects of Alcubol, List Arrangement, and Trials on Subjective Organization of Recall. Scores are <u>Z</u> Scores Representing Clustering.

(See, Frankel & Cole, 1971).

	and the second se	a de la companya de l	the second second second second second
Drug		Placebo	Alcohol
	Mean SD	7.38 2.93	3.65 2.74
List Arrangement		Pandom	Blocked
	Me an SD	4.01 2.58	7.02 3.46
Trials		One	Two
	Mean SD	4:47 3.11	6.56 3.37
		Dr	ug
List Arrangement		Placebo	Alcohol
Randes	Mean SD	5.54 1.94	2.48 2.23
Blocked	Mean SD	9.22 2.60	4.82 2.76

27

Table 5

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 ($\underline{r} = .78$, $\underline{p} < .001$). As with the previous measures, the correlations were higher in the placebo group ($\underline{r} = .86$, $\underline{p} < .001$) than in the alcohol group ($\underline{r} = .68$, $\underline{p} < .001$) and higher for blocked presentation ($\underline{r} = .85$, $\underline{p} < .001$) than for random presentation ($\underline{r} = .64$, $\underline{p} < .01$). There was little difference in the correlations on Trials 1 and 2 for the placebo subjects ($\underline{r} = .87$ and $\underline{r} = .84$, respectively). In contrast, the intoxicated subjects showed a substantial increase ($\underline{p} < .03$) in the correlation between clustering and recall from Trial 1 ($\underline{r} = .42$, $\underline{p} < .10$) to Trial 2 ($\underline{r} = .84$). 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 8 statistic); but the data are not strong. An increase in 8 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, 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 ware 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 derive 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 (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 la and 1b) and was not confirmed. Instead, alcohol productd nearly identical decrements in free recall and recognition performance. The levels of processing hypothesis (namely, that alcohol interfares 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 insbility 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 simificantly with recall. These results support the data from Experiment 3 and strengthen the motion 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 ($\underline{r} = .07$). 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 ($\underline{r} = .41$, $\underline{p} < .01$; and $\underline{r} = .52$, $\underline{p} < .001$, respectively).

In summary, alcohol produced reliable $(p < .C^{1})$ decrements in four independent tests (. 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, Farker 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 tatrieval 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. Ferhaps some attention should be focused on the model itself. Two points are of particular interest: (1) How well did the model stard 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.

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

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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 .976) which demonstrated that graded doses of alcohol cause systematic changes in speedaccuracy 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 ifficult 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 negativel 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 Fisch (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,) 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. = 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 decisionfree 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 experimenta. 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 3-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, unereas 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 motions 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 30 mg of alcohol per 100 ml of blood, mgZ) 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; Hurtley, 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 EACs lower than, sya, 80 mgZ. 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 pitchdiscripination tasks. Each required the subject to respond on one of two keys to one of t to monautally 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 asec faster than information about two other stimulus variables, intensity and duration; (b) comparto 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, Pishkis 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 commutibility 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

<u>Subjects</u>. 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 practisessions, 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.

<u>CRT Tasks</u>. 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 b th correct and within the deadline specified for that block of trials, more 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 deaulines was operating and statud the average accuracy expected for that deailine. 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 1/3c per point, they were awarded 2 points for each correct response occurring prior to the prescribed deadline and penalizes 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 are 12 practice trials followed by 10% experimental trials. For each task, the chilines were always presented in descending order, from longest to shortest and Green & Lure, 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 al 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 mg7, 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.

<u>Calculation of Speed-Accuracy Tradeoff Functions</u>. 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 concliance with the prescribed deadline. These seam RTs were paired with corresponding H, values for each condition and linear segressions of accuracy on RT were computed over the three deadline conditions in each alcohol condition. The appropriate linear regression equation

is $H_{e} = m(RT-c)$ in which <u>m</u> represents the slope and <u>c</u> the intercept of the function at chance accuracy, i.e., where $H_{e} = 0$ (see Wood & Jennings, 1976, for an analytic review of H_{e} and other proposed measures of accuracy. For our subjects the proportion of variance in the speed-accuracy tradeof: data accounted for by the linear equations (r^{2}) ranged from 82 to 997.

Results

<u>Preliminary Analyses</u>. Table 1 displays the means and standard deviations of BAC in mgZ 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 mgZ. As can be seen, the expected average BACs for these doses were achieved and maintained with reason-ble 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/incerrect) 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 (7 < 1) or by order of task (F < 0.1). As expected, overall CRT was significantly (38 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 CZT and accuracy as expected, and that RTs were about 90 meet 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 kI 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 hithest alcohol dose

"Unless otherwise specified, "significant" means .15 level or "etter.

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			Time Followi	ng Consumption	
Alcohol Dose		15 (mins)	35	55	80
High (1.0 g/kg)	x	107	104	100	97
	SD	14.0	17.0	10.0	11.0
Med (.5 g/kg)	ī	53	51	50	51
	SD	20.0	14.0	11.0	10.0
Low (.25 g/kg)	ī	25	19	23	. 21
	SD	9.0	9.0	6.0	7.0

Average BAC (mg%) for each alcohol dose*

*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	x	146	181	237
	SD			
Pitch Discrimination	x	240	276	. 310
	SD			
		Accuracy		
			Deadline*	
Task		Short	Medium	Long
Side Discrimination	x	.75	.83	.97
	SD			
	-		00	04
Pitch Discrimination	х	•11	.00	

*The deadlines for the Side Discrimination and Pitch Discrimination tasks were 175, 200, 300 msec. and 300, 375, 415 msec., for short, madium, and long, respectively.

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---- SIDE TASK

A. SPEED

D. ACCURACY





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.

<u>Alcohol and Speed Accuracy Tradeoff</u>. Each subject's SATF was calculated (as described above) for each task and each alcohol dose. In general, the lines fit of the SATFs to the data was satisfactory. The average r² 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, w 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 pitchdiscrimination 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 correlation 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 $H_t = 0$ ($\underline{F} < .05$). 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 Do	se (g/kg)	
	0	.25	.50	1.0
x	.00869	.00862	.00757	.00599
SD	.00129	.00298	.00312	.002 .0
x	118.7	120.1	121.8	112.2
SD	27.9	24.9	36.8	33.7
x	.00820	.00679	.00676	.00567
SD	.00324	.00196	.00301	.00323
x	213.4	207.6	205.0	201.5
SD	38.1	41.1	50.7	51.0
	TX SD TX SD TX SD TX SD TX SD	x .00869 SD .00129 x 118.7 SD 27.9 x .00820 SD .00324 x 213.4 SD 38.1	X .00869 .00862 SD .00129 .00298 X 118.7 120.1 SD 27.9 24.9 X .00820 .00679 SD .00324 .00196 X 213.4 207.6 SD 38.1 41.1	\overline{X} .00869.00862.00757 \overline{X} .00869.00862.00757 \overline{SD} .00129.00298.00312 \overline{X} 118.7120.1121.8 \overline{SD} 27.924.936.8 \overline{X} .00820.00679.00676 \overline{SD} .00324.00196.00301 \overline{X} 213.4207.6205.0 \overline{SD} 38.141.150.7

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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 sidediscrimination 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 inforaction 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 (F2,22 = 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 pitchdiscrimination 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 (F3,33 = 3.9) but not at either $CRT = 290 \text{ msec} (F_3, 33 = 2.6) \text{ or } RT = 250 \text{ msec} (F < 0.2).$ For the side-discriming tion task the dose effect was significant at CRT = $230 \mod (F_3, 33 = 15.4)$ and at 190 msec (F_3 , 33 = 6.7) but not at 150 msec (F_3 , 33 = 1.9). These results are in close agree ant 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 l_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-AT 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 slop and intercept data, produced substantial deficit in relatively slow but accurate performance. For example, at H = 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 crodeoff function for speed vs. accuracy provid d a more sensitive and informative index of the impairment of CRT by alcohol t an either average speed or accuracy taken alone. Several



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

investigators, including ourselves, have found only small alcohol effects on mean RT in choice tasks even with BACs as high as 100 mgZ (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 conventionar manipulation of S-R compatibility influenced the slope of the SATF. The isolatic 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 for ased requirements for stimulus processing in the pitch discrimination

Tharp et al. (1974) and Huntley (1972, 1' i) i inced the hypothesis that rather than input processes involved in stimulus processing. The present data do not permit definite conclusions concerning the functional locus of alcohol efforts. As , 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., Starnberg, 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 SATE contain 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.

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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, 1963). 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 assurption 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 keyr 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-Kay 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 (\underline{T}_{S-R}) by subtracting average reaction-time for the Light-Key task (choice R 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_{LP} .

Thus,

choice $RT_{DK} = \underline{a} + \underline{T}_{S-R} + \underline{c}$ moice $RT_{LK} = \underline{a} + \underline{c}$ and, simple $RT = \underline{a}$

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

The assumption that component <u>c</u> 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 respondin 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 zethod section.

We (Tharp it al., 1974) and Huntley (1974) had found that the effects of alcohol were hyperadditive with those of stinulus-response compatibility and had concluded that alcohol influenced output cognitive processes associated wich 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_{DV}, choice RT_{LK} and simple RT to investigate the degree to which these hypothetical cognitive process 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 $simp^{1}$: RT. Second, it is well-established that practice reduces the effect of S-R compatibility on choice RT. Thus, the function relating choice RT_{LK} (Teichner ar. 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 resear addressed specifically to this question.

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

 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" i task becomes, the less the effect of intoxication. 2. Do alcoholized subjects adapt to intoxication such that with repeated Soses 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

<u>Subjects</u>. 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-bours 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 32) to reduce stomach acidity. Blood alcohol concentration (BAC) was measured at 15 min. intervals throughout each alcohol session with a Stephenson Model 900 Breathalyzer.

<u>Apparatus</u>. Subjects were seated at a table approximately 80 cm in front of a vertical display panel containing five ISE tear-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.

Refore 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 wore presented on a black background. A response panel was located on the table in front of the subject and was configur 4 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 stimulu were made by moving the richt inies finger from the central key to one of the four r tomse keys. Realing time (from stimulus onset to response) and accuracy were measured and printed on paper by a BRS logic system and an associated System-Ammaer counter-printer system. The inter-trial interval from response to varming signal was 1.44.

Tasks.

1. Choice RT_{DK}. Using four alternatives drawn from the ensemble 1 through 4, digits were presented one-by-one on the contral 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 americ 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 mgZ and 90 mgZ for days 1 and 2, respectively. For the long practice group mean BAC on the two alcohol sessions was 102 mgZ and 94 mgZ (days 9 and 10, respectively).

Effects of Alcohol on Component Processes of CRT

<u>Short practice</u>. Table 1 shows means and standard deviations for the short practice group on each task in the alcohol pessions and the two baseline sessions preceding and succeeding these trials. Reaction times for each task declined from Day 1 (printice condition) to Day 4, but the improvement was statistically significant only for the simple RT task (\underline{e}_{p} = 3.80, $\underline{p} < .01$). After 100 practice trials all sholl reused simificant slowing in choice KT_{DK} (about 83 meet; $\underline{e}_{p} =$ 1.06, $\underline{p} < .05$) but only marrial slowing in choice KT_{DK} (about 87 meet; $\underline{p} < .10$); a d had no effect on simple RT. On day 2, the pattern of alcohol effects was about the same. Alcohol slowed performance in the Digit-Key task by simificant 77 meet ($\underline{e} = 3.15, \underline{p} < .01$), are the dimensional slowing on the Light-day task (41 meet $\underline{e} = 1.90, \underline{p} = .12$, and had no depondentiable effect on single KL, between slowing for either task. Thus one day's truttice under alcohol

TABLE]

Short Practice Group (N=6)

Session

			1-Practice	1-Alcohol	2-Practice	2-Alcohol	3-Practice	4-Practice
	Task							
	RT	x	339	322	319	312	304	261
		9	59	80	136	98	107	70
	CRTLK	x	419	456	416	458	384	391
125 138		5	121	113	108	110	86	132
	CRTDK	x	. 492	575	486	562	499	482
		s	76	85	111	107	110	104

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did not reduce impairment on the second alcohol session. Overall proportionate alcohol impairment was greatest for choice RT_{DK} (16.22) and less for choice RT (9.42).

Table 2 exhibits means and standard deviations on alcohol and baseline set for the derived measures of stage durations, the translation stage, \underline{T}_{S-R} , and the response selection stage, <u>c</u>. As mentioned above, the <u>a</u> stage, defined as simple RT, was not affected by alcohol. Alcohol slowed \underline{T}_{S-R} about 45 msec on Day 1 ($\underline{t}_5 = 2.43$, $\underline{p} < .05$) but only about 34 msec on Day 2 ($\underline{t}_5 = 1.41$, $\underline{p} < .2$) Alcohol also slowed <u>c</u> about 54 msec on Day 1 ($\underline{t}_5 = 3.65$, $\underline{p} < .01$) and about 49 msec on Day 2 ($\underline{t}_5 = 1.34$, $\underline{p} < .20$). Thus, both hypothetical stages, stimula response translation and response selection were significantly impaired by alcohol on day 1, but the day 2 effects were somewhat smaller and were nonsign: ficant. The overall proportional slowing of the two stages across both alcohol sessions was nearly equal ($\underline{c} = 597$ and $\underline{T}_{S-R} = 567$).

In summary, after a minimum of sober practice, alcohol slowed the Group 1 subjects' performance on both choice RT tasks while leaving simple RT unaffects. The subsequent stage analysis suggests that two hypothetical stages of informat processing $(\underline{T}_{S-R} \text{ and } \underline{c})$ were equally slowed by alcohol. Recall that the simple task, used to estimate the <u>a</u> stage, includes movement time (i.e., the time require to move the index finger from the central key approximately 4 cm to one of the peripheral response keys). The negative finding with regard to simple RT at the level of practice suggests that neither the central processes involved in simplinor 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 1 amounting to 50 msec for simple RT ($\underline{t}_3 = 2.62$, $\underline{p} < .05$), 67 msec for choice RT₁ ($\underline{t}_3 = 2.26$, $\underline{p} < .10$), and 83 msec for choice RT_{DK} ($\underline{t}_3 = 2.58$, $\underline{p} < .05$). After 2000 practice trials on each task, alcohol (Day 9) slowed simple RT by about 31 ($\underline{t}_3 = 10.2$, $\underline{p} < .005$), choice RT_{LK} by about 37 msec ($\underline{t}_3 = 14.2$, $\underline{p} < .001$) and choice RT_{DK} by about 65 msec ($\underline{t}_3 = 3.52$, $\underline{p} < .025$). The second administration of alcohol (Day 10) also significantly slowed performance on all tasks ($\underline{p} < .01$ 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 14Z for simple RT, 16Z for the Light-Key task and 13% for the Digit-Key task.

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

Thus, for both groups alcohol slowed performance on the two choice RT task and slowed the estimated time require' to perform the \underline{T}_{S-R} and \underline{c} operations. I the long practice group significant slowing of simple RT was also found.

TABLE 2

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Hypothetical Stage Duration

Short Practice Group (N=6)

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
Stage							
Stimulus Transla	Response						
(\underline{T}_{S-R})	x	73	118	70	104	115	91
	8	53	71	30	50	41	35
Response	Selection						
(<u>c</u>)	x	80	135	96	146	80	131
	s	84	76	41	76	37	88

TABLE 3

Long Practice Group (N=4)

Session

					Practice						Ald	cohol	Practice		
			1	2	3	4	5	6	7_	8	9	10	11	12	
	Task														
	RT	x	261	242	234	223	206	213	209	207	240	237	210	211	
		8	36	90	36	35	12	28	37	26	28	29	22	26	
	CRTLK	x	346	319	311	299	289	282	282	280	318	337	282	278	
66		2	54	47	42	45	34	20	21	25	29	19	25	32	
	CRT	x	460	420	420	404	391	397	392	374	445	454	386	377	
		5	64	25	37	19	18	20	13	19	32	12	20	15	

TABLE 4

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Hypothetical Stage Durations

Long Practice Group (N=4)

			Practice								Alcohol		tice
		1	2	3	4	5	6	7	8	9	10	11	12
Stage													
Stimulus R Translat	esponse ion												•
(<u>T</u> S-R)	x	114	101	109	105	102	114	111	94	127	' 118	104	99
	ß	35	28	25	27	36	8	8	20	31	16	12	26
Response S	election	n											
(<u>c</u>)	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
													1

Session

and the second sec

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 ($t_3 = 1.45$, p < .2). For the two choice RT tasks, alcohol tended to produce eligntly 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 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 significa 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 usec; 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 ($\underline{t}_g = 1.3$, $\underline{p} < .2$) and 73 msec greater isprovement on the Digit-Key task ($\underline{t}_g = 1.4, \underline{p} < .2$) 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 at 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 statistica 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 2T tanks. 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 operation That is to say, in choice RT tasks alcohol intoxication produces slowing of central cognitive processes such as those involved in translating from a numeric 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 sensor; 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 alcolintoxication, 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 defici

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

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