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The Effect of Acute Alcohol Intoxication on Memory Scan and Memory Span in Working Memory

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THE EFFECT OF ACUTE ALCOHOL INTOXICATION ON MEMORY SCAN AND MEMORY SPAN IN WORKING MEMORY

by

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This dissertation, submitted by Dawn M. Kugler in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota, has been read by the Faculty Advisory Committee under whom this work has been done and is hereby approved.

(Chairperson)

This dissertation meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

The efficiency of working memory processes has been studied by many researchers. Verbal ability and intoxication with ethanol are two hypothesized influences on the efficiency of working memory processes. This study looked at these factors across two measures, memory span tasks and memory scan tasks.

This study also examined the extent to which verbal ability modulates the effect of alcohol on working memory performance.

Seventy-eight male subjects participated in the present study. Subjects who reported drinking at least two drinks on two separate occasions per week were invited to participate. Subjects were administered the WAIS-R Vocabulary subtest and categorized as high verbal or low verbal by a median split of the scores.

Subjects were given four memory span tasks. These included digit span forward, digit span backward, word span, and sentence span. Digit span forward and backward were administered as they are in the WAIS-R. Word span was similar to digit span with the exception that there were three trials at each level. Sentence

span was that introduced by Daneman and Carpenter (1980). Subjects had to read a group of sentences aloud and remember the last word in each sentence.

Subjects received two memory scan tasks. The first required them to judge whether a probe word was one from a stimulus set. The second required them to judge whether a probe word was a member of the categories from the stimulus set. Subjects were tested over twelve sequences consisting of 32 trials per sequence, with three sequences each of set sizes of two, three, and four. One half of the judgments were positive and one half were negative.

Verbal ability was a significant factor in all span tasks. Alcohol was a significant factor only for digit span backward. Alcohol did not affect digit span forward, word span, or sentence span.

Task and set size were significant factors in the memory scan tasks. Verbal ability and alcohol intoxication were minimally related to the memory scan tasks.

Support was found for the elaboration explanation of alcohol intoxication. No support was found for overall cognitive slowing.

CHAPTER I

LITERATURE SURVEY

Many researchers have investigated the effect of acute alcohol intoxication on memory processes (Birnbaum, Johnson, Hartley & Taylor, 1980; Birnbaum, Parker, Hartley & Noble, 1978; Hashtroudi, Parker, DeLisi, & Wyatt, 1983; Hashtroudi, Parker, DeLisi, Wyatt & Mutter, 1984; Kalin, 1964; Maylor, Rabbitt & Kingstone, 1987; Miller, Adesso, Fleming, Gino & Lauerman, 1978; Parker, Birnbaum & Noble 1976; Petros, Kerbel, Beckwith, Sacks & Sarafolean, 1985; Ryback, 1971; and Williams & Rundell, 1984). The research has focused in two different areas. The first area is concerned with the memory processes of alcoholics as compared to nonalcoholics. The second area, which is of interest in the present study, is concerned with the effect of acute alcohol intoxication in non-alcoholic subjects.

Pharmacology of alcohol

Ethanol is a depressant drug that affects the central nervous system. It first depresses the brain structures that affect higher level integrative functions (Ritchie, 1980). The loss of integrative functions results in uncoordinated motor processes and jumbled thought processes (Ritchie, 1980). Many individuals who do not know the actual effect of alcohol on the central nervous system believe that ethanol is a stimulant (Ritchie, 1980). They often gain self-confidence, and become cheerful and vivacious. The self restraint when an individual is sober often becomes loosened as alcohol is consumed. Though an individual may believe that alcohol helps him or her to think better or to be stronger, the evidence does not support these claims. The exception is one in which an individual's anxiety level is so high that it impairs performance. A moderate dose of ethanol may then remove those inhibitions allowing an individual to perform more optimally (Ritchie, 1980).

Ethanol is highly soluble in water (Goldstein, 1983). Tissues with higher concentrations of water tend to have higher concentrations of alcohol. The rate of diffusion of alcohol in tissues depends on the amount of vascular tissue present. As brain tissue is highly vascular, it contains a high proportion of diffused alcohol (Goldstein, 1983).

Alcohol is eliminated largely through the process of oxidation via liver enzymes (Ritchie, 1980). The primary step in this process is the oxidation of ethanol into acetaldehyde by the action of the enzyme alcohol dehydrogenase. The liver is responsible for the metabolism of approximately 90% of all alcohol.

The body eliminates small amounts of ethanol through sweating, urination, and breathing (Ritchie, 1980). Once alcohol has been completely absorbed into the bloodstream, the rate of elimination is fairly constant at about 15 ml/hr, however, the rate of elimination is roughly proportional to body and liver weight (Ritchie, 1980). Females, smaller males and teenagers tend to metabolize ethanol more slowly (Goldstein, 1983). The amount of ethanol contained in 120 ml (4 oz) of hard liquor or 1.2 liters of beer can be oxidized in five to six hours in an average sized (150 lb male) human. Any ethanol which is consumed in excess of this rate of metabolism results in intoxication. The maximum amount of ethanol per day that can be metabolized by the average human is about 450 ml, thus the effects of ethanol are often long and pervasive (Ritchie, 1980).

Behavioral studies

One of the first questions for researchers in the alcohol and memory field was whether ethanol disrupts the storage of information, or whether it disrupts retrieval of information already in storage, or whether it interrupts both processes.

Kalin (1964) conducted a study to look at the effect of ethanol on both the storage of information and the retrieval of information. Half of the subjects were allowed to drink as they normally would in a social setting, drinking their normal amounts of alcohol. Half of the subjects drank soft drinks. Subjects were invited to participate in a study examining "the effects of a party atmosphere on people's imaginativeness" (Kalin, 1964). The study was conducted on two consecutive days. On the first day, subjects wrote four Thematic Apperception Test (TAT) stories at each of three different times such that 12 TAT cards were used altogether. Four stories were written before any drinking, four stories were written after 25 minutes after onset of drinking and four stories were written 50 minutes after onset of drinking. Each subject wrote 12 different stories all together. Subjects wrote stories at a party either with alcoholic beverages or at a party with no alcoholic beverages. On the following day, subjects were asked to recall the stories they had written the day prior.

Subjects were allowed to drink as much as they wanted in the alcohol group, but signed for each drink such that the amount of alcohol was monitored. The subjects did not know that they would have to recall their stories until they showed up for the second day's testing. Only half of the subjects in both the alcohol and the nonalcohol group participated in the second day's events. In the recall phase, subjects were given the 12 TAT pictures and were instructed to recognize the first four pictures that they were shown as well as recall the original stories they had written about those pictures. The second group of four pictures was then selected by the subjects and they recalled the stories they had written about them. The same procedure was used for the last four cards.

Picture recognition was not affected by alcohol consumption. Subjects did not fabricate any stories, that is, there were no stories recalled about pictures that didn't exist in the original stimulus set. Measures were obtained on amount of recall (similarity between reproduction and original), exactness of recall (percentage of words recalled on Day 2 that were of the same meaning as the words used on Day 1), and importation (words in the recall story that did not appear in the original).

Persons coding the stories were blind to alcohol condition of the subjects that they were rating. Interrater reliability for the coders ranged from .90 to .92.

The alcohol group had a significant decrease in the amount of material recalled with respect to amount of drinking time elapsed. More material was forgotten after drinking as compared to this group's amount of recall of stories written before drinking (Kalin, 1964).

Exactness of recall was not significantly different for any of the stories in the nonalcohol group. The alcohol group's exactness did not diminish until 50 minutes after drinking had begun.

There was no difference between the groups with regard to importation. The average number of pictures remembered per administration decreased for the alcohol group. The conclusion was made that during social drinking, the loss of memory associated with alcohol is very gradual and strongly dependent upon how much alcohol is consumed (Kalin, 1964).

Parker, Alkana, Birnbaum, Hartley & Noble (1974) also showed that intoxication with alcohol impairs memory. They looked at alcoholic and nonalcoholic subjects. Each subject participated in a sober, moderate dose (0.67 milliliters per kilogram) and a high dose (1.33 ml/kg) session that occurred one week apart.

To evaluate registration, or how well subjects could keep information in working memory, digit span tests were administered each session. Subjects were given digits forward and digits backward. A multitrial free-recall task was then administered to assess memory and learning capacities. Subjects were presented a list of 30 words at a rate of two seconds per word. The list consisted of six words from each of five conceptual categories which were randomly arranged. Immediately after hearing each list, the subjects were asked to recall as many of the words as possible. The experimenter recorded the subjects' recall verbatim. Subjects were not told that there were five conceptual categories. Immediately after recall, subjects were presented with the same list in a different order and then asked to recall the list. Therefore, the pattern of presentation followed by recall occurred a total of four times. A different list was used each session, and a particular category appeared on only one list.

The results indicated that intoxication with alcohol impaired digit span performance, but there was no difference between alcoholics and nonalcoholics on this task. On the free recall task, fewer words were recalled at higher doses of alcohol as compared to moderate doses as compared to sober conditions, and again, there was no difference between alcoholics and nonalcoholics. Alcohol reduced category clustering in both groups, but alcoholics had a significantly poorer amount of category clustering as compared to nonalcoholics.

Parker et al. (1974) concluded that alcohol intoxication results in significant impairments in the registration, recall, learning and organization of information. Memory deficits are a pervasive concomitant of alcohol intoxication, but the acute effects of alcohol do not differentiate alcoholics from nonalcoholics.

Tulving (1968) conceptualized memory as consisting of an encoding stage, or getting information into memory, and a retrieval stage, or calling information back from memory. This framework has guided much research in the past 20 years. The work of Parker et al. (1974) and Kalin (1964) did not specify whether alcohol disrupts encoding or retrieval of memory. However, subsequent research has attempted to isolate the processes in memory which are disrupted by acute alcohol intoxication.

One investigation which looked into the effect of acute intoxication with ethanol on encoding processes was conducted by Parker et al. (1976). Subjects were given a placebo, a medium dose (0.5 ml/kg) or a high dose (1.0 ml/kg) of alcohol. The subjects were required to complete a paired associates task and a picture recognition task. In the paired associates task, the stimulus items were digits while the response items were the months of the year. In the paired associates task, subjects are initially presented with the stimulus item paired with the response item. On subsequent trials, subjects are presented with the stimulus item and asked to produce the response. It was hypothesized that using the months of the year as response items would minimize retrieval demands as the twelve months of the year are readily available information. Two different random pairings were used to form two paired-associate lists. Subjects practiced the pairings until one complete recitation of the pairs was achieved.

For the recognition task, there were 40 pairs of pictures. Subjects participated in two testing sessions. On Day 1, subjects were presented with 40 slides, each with a picture on them and told to pay attention to the details of each picture. Subjects were not told that their retention would be tested on Day 2, but were told they would be engaging in similar tasks. After presentation of the 40 slides, a two-alternative forced-choice recognition test, with half of the pictures presented as distractors, was administered on half of the pictures. Two weeks later, in the second testing session, the subjects were tested on the remaining half of the pictures. The recognition test was self-paced and omissions were not allowed. Response latencies were measured.

Parker et al. (1976) found that for the paired associate task, there was virtually no difference between the placebo and medium dose groups, while the high dose group showed impairment in learning the new associations.

On the recognition task, the high group took significantly longer to achieve five correct responses than did either the placebo or medium group. The high dose of alcohol had an immediate detrimental effect on learning new associations.

On day two of testing, subjects were reassigned to the three experimental conditions. Analysis of the results showed no evidence for state dependent learning. Alcohol did not produce decrements in memory for the original material for any group of subjects.

The authors concluded that the extent of alcohol induced memory loss may be directly related to the storage demands of the particular memory task. That is, the storage phase of memory was impeded by alcohol intoxication (Parker et al., 1976).

The results of Parker et al. (1976) strongly suggest that alcohol primarily disrupts the storage of information in memory since the tasks used were chosen to minimize retrieval demands. However, the tasks used by Parker et al. (1976) minimized but did not eliminate retrieval demands from consideration. Therefore, Birnbaum et al. (1978) examined the effects of ethanol on retrieval while completely eliminating possible effects of ethanol on encoding of information. In order to accomplish this goal, Birnbaum et al. (1978) had all subjects learn a free recall list and a paired associate list while they were sober. One week later, half of the subjects were administered a placebo while half were given 1.0 ml/kg of body weight of ethanol. Subjects were then asked to recall the lists of words learned the week before followed by a test of their memory for the paired associates.

The results indicated that intoxication with ethanol had no effect on retrieval of information learned one week earlier. The results suggested that alcohol does not influence the retrieval of information previously stored. The study did replicate the findings of Parker et al. (1976) which showed disruption of the encoding process. While intoxicated, one group was given new word lists to remember and they performed more poorly than a placebo group which was also given new word lists to remember.

Subsequent investigations of the effect of ethanol on memory have attempted to examine specific components of the encoding process that may be disrupted by ethanol. Specifically, ethanol may impair the subject's ability to process the semantic features of the information presented, thus increasing the likelihood of shallow processing. Previous work with sober subjects clearly indicates that memory for information is greater when subjects process the semantic attributes of the information (Craik & Tulving, 1975). Williams and Rundell (1984) investigated the possibility that intoxicated subjects do not process information at a semantic level. If intoxicated subjects spontaneously do not process information at a deep semantic level, they perhaps would be able to do so if given proper tasks that would induce them to process the information in a semantic fashion.

On the free recall experiment, subjects were shown lists of 16 words. Two practice and 10 experimental lists were assembled such that there were eight animal and eight plant names per list. Half of the words in each list contained the letter A, and half did not. During presentation of one half of the lists, subjects classified words into groups by whether the word contained the letter A (graphemic analysis). The other half of the lists were classified by plant or animal (semantic analysis). After presentation of each list, subjects were given 90 seconds for immediate written free recall. The length of time it took subjects to recall the words was recorded.

Results indicated that for the recall experiment, performance declined with dose and was better for items processed semantically than for those processed graphemically. Semantic classification was slower than graphemic classification as indicated by increased response latencies. There was no trend toward a dose by processing level interaction as measured by number of words recalled and response latencies.

For the recognition experiment, subjects were presented with 90 target words and immediately before each target word was presented they were given a prompt question that they had to answer concerning the upcoming target word. One third of the time subjects were required to say whether the word was in the lower or upper case (graphemic analysis), one third of the time they indicated whether a word indicated rhymed with a designated prompt word (phonemic analysis), and the other third of the time they indicated whether the word fit logically into a prompt sentence (semantic analysis). After the test trials were administered, subjects were given 90 distractor words interspersed with the original 90 experimental words. The distractor words were matched with list items for word frequency and word length. Subjects were then required to rate 1-6 how confident they were that each word was on the experimental list. A 1 indicated they were certain the word was not on the original list, and a 6 indicated they were certain that the word was on the original list. Ratings of 1-3 were scored as no responses and ratings of 4-6 were scored as yes responses.

In the recognition experiment, recognition declined with increased dose and increased with deeper processing levels. Positively encoded items were recognized significantly more often than negatively encoded items. Reaction times were faster for positive than negative items. Response times increased from graphemic to phonemic to semantic levels of processing. There was no trend toward a dose by levels of processing interaction for number of words recalled or response latencies.

From these results, the authors concluded that intoxicated subjects were able to engage in progressively deeper levels of processing to the same degree as sober subjects. For both groups, both recall and recognition performance were enhanced with deeper processing levels. The results of the study by Williams and Rundell (1984) provided no support for the view that verbal retention deficits associated with alcohol intoxication are related either to spontaneous failure to undergo deep processing levels or an inability to do so. A similar experiment conducted by Hartley, Birnbaum and Parker (1978) resulted in the same conclusions drawn.

The work of Williams and Rundell (1984) and Hartley et al. (1978) suggested that the intoxication with ethanol did not impair subject's ability to process information to a deep semantic level during encoding. However, recent work suggests that intoxication impairs a subject's ability to elaborate and integrate activated information in working memory (Birnbaum et al., 1980; Hashtroudi et al., 1983).

Birnbaum et al. (1980) used sentences in their study that were grammatically correct, but whose meaning was puzzling when presented alone. For example, "The notes went sour when the seams split." For half of the subjects, a word used in context was presented to make the meaning clear, for example, "bagpipes". The other half of the subjects received no context. Subjects were presented with 32 sentences, one at a time, and told that their memory for the sentences would be tested. All subjects were male. For each of 32 sentences, a prepared index card was handed to the subject, he read the material aloud at his own pace and then handed the card back to the experimenter. When the original 32 sentences were read, subjects were then handed a stack of 64 cards which they read a loud and were told to decide whether it was the same as or different from the experimental sentence. Half of the sentences were distractors. The test was self paced and total time for test trials was recorded.

Subjects received either a placebo or 1.0 ml/kg of body weight of ethanol. They were randomly assigned to either a context or a no-context condition.

Experiment 1 results indicated that sober subjects made significantly fewer recognition errors than intoxicated subjects in the no-context condition while no effects of ethanol on recognition memory were observed in the context condition. This finding was replicated in two subsequent experiments (Birnbaum et al., 1980).

Overall, Birnbaum et al. (1980) concluded that without a clarifying context, sober subjects showed better recognition for sentences than did intoxicated subjects. With no context, the interpretation of the sentences required a deliberate thoughtful effort on the part of the subject. When elaborators were provided, intoxicated subjects used them effectively. The intoxicated subjects may produce inefficient elaborators when no context is provided.

Hashtroudi et al. (1983) expanded on the study by Birnbaum et al. (1980). They addressed three different questions about elaborative operations under the influence of alcohol. The first question was whether intoxicated subjects can utilize subtle elaborators that facilitate normal memory. The second question was whether acute alcohol amnesia is attenuated when subjects are forced to engage in elaborative processing. The third question was whether intoxicated subjects generate deviant elaborators when allowed to develop them on their own.

In the experiment, subjects were given either a placebo or 1.0 ml/kg of ethanol. The subjects were presented with a set of sentences and were later tested for their recognition of a target word in the sentence. For example, in the sentence, "The old man bought the paint," the subjects were tested for the recognition of the word "old". Within each dose group, there were four memory conditions: no elaborators, precise elaborators, imprecise elaborators, and subject generated elaborators. In the no elaboration condition, subjects were presented with a set of base sentences to remember (i.e., The old man bought paint). In the precise elaboration condition, subjects were presented with a set of sentences that contained precise elaborators of the target word (i.e., The old man bought paint to color his cane). In the imprecise elaboration condition, the elaborator in the sentence did not specifically elaborate the meaning of the sentence (i.e., The old man bought the paint that was on the top shelf). In the subject elaborator condition, subjects were told to elaborate on the base sentence so that it would facilitate their recall of the base sentences.

One hundred and twenty-eight males participated in the study. All subjects listened to a set of sentences which were prerecorded on a cassette tape. After presentation of the set of sentences, subjects counted backwards by threes for 1 minute. They then heard the sentences with one word missing and had 7 seconds to recall each target word within the sentence.

The recognition results indicated that sober subjects recalled more than intoxicated subjects and recognition was greater for precise elaborators than no elaborators, but the size of this difference was larger for sober subjects. Thus, sober subjects benefitted greatly from precise elaborators while intoxicated subjects did not. There was a difference between the alcohol and placebo groups with precise elaborators.

In addressing the second question concerning self generated elaborators, subjects in the self generated condition recalled significantly more target words than did those in the no elaboration condition. Self generated elaborators were of more benefit to intoxicated subjects than were any elaborators that the experimenter provided. When subjects were instructed to follow the provided elaborators, they had a more difficult time than when they developed their own elaborators.

In addressing the third question regarding the quality of self-generated elaborators for intoxicated subjects, judges rated the quality of the elaborators for all subjects. Intoxicated subjects were not significantly different from sober subjects in the quality of their own generated elaborators. Hashtroudi et al. (1983) suggested that since sober and intoxicated subjects did not differ in the quality of their self-generated elaborators, intoxicated subjects can activate semantic structures as well as sober subjects. However, since intoxicated subjects did not benefit from experimenter provided elaborators as well as sober subjects, Hashtroudi et al. (1983) suggested that intoxicated subjects are impaired in their ability to integrate information in working memory.

The results of Birnbaum et al. (1980) and Hashtroudi et al. (1983) suggest that the efficiency of working memory operations may be impaired by intoxication with ethanol. Since working memory is important for effective language comprehension, Petros et al. (1985) examined the influence of intoxication with ethanol on memory for prose passages. Subjects were presented with several short passages (200-220 words) at either a fast rate (200 wpm), a medium rate (160 wpm) or a slow rate

(120 wpm). Immediately after listening to each passage, subjects were required to recall orally as much of the passage as possible. Subjects were given either a placebo or 1.0 ml/kg of body weight of ethanol.

The results indicated that intoxication with ethanol impaired prose recall. Also, the size of the alcohol induced memory impairment was similar at all levels of importance at both the slow and medium rates of presentation. However, at the fast rate of presentation, significant recall differences were found for the more important idea units with no differences for least important idea units. The authors concluded that ethanol impaired prose recall, especially under conditions of severe working memory overload, as in the case of rapidly presented text material.

The research of Hashtroudi et al. (1983) and Petros et al. (1985) suggests that intoxication with ethanol impairs the efficiency of working memory. Working memory is a temporary memory store with a limited capacity. Working memory is the location where information is integrated and manipulated to make the information more retrievable at a later date (Daneman and Carpenter, 1980).

One purpose of the present study was to examine the role of intoxication with ethanol on the efficiency of working memory operations. There are two ways in which working memory operations were examined in the present study. The first way utilized a paradigm introduced by Sternberg (1969). When information is processed in working memory, some capacity must be allocated to encoding information into working memory, and some capacity must be allocated to searching for information in working memory. Sternberg's (1969) paradigm examines the rate of scanning information in working memory. In this task, subjects were asked to memorize memory sets that were 2, 3, or 4 units, as digits or words. Subjects were then presented a single probe and asked to decide as quickly as possible whether the probe was a member of the memory set. Sternberg (1969) found that response times increased as a function of the memory set size. One hypothesis of the present work was that if alcohol impairs the efficiency of working memory operations, then increases in memory set size should have a larger impact on intoxicated than sober subjects. Additionally, the rate of searching working memory increases dramatically when the probe stimulus must be coded at a semantic level (Juolla & Atkinson, 1971; Juolla & McDermott, 1976) as compared to making a physical comparison (Sternberg, 1969). For example, Juolla et al. (1971; 1976) presented subjects with a memory scanning task in which subjects decided whether a probe word physically matched one of the words in a memory set or whether the probe word was an example of one of the categories named in the memory set. Juolla et al., 1971; 1976) found much longer memory scanning times when the subject made category judgements as compared to physical judgements. Therefore, the increase in response time to make category judgements relative to physical judgements in a memory scanning task should be greater for intoxicated than sober subjects.

A second purpose of this study was to examine the role of alcohol on memory span performance using several memory span tasks. These include digit span both forward and backward (Parker et al., 1974), word span and sentence span tasks. In the digit span task, subjects are given three digits at a rate of one digit per second and told to repeat them back after the digits are presented. Subjects are given two sets of three digits and as long as they do not fail both sets, they are then given two sets of four digits. This process continues up to nine digits. Once a subject fails two trials of a given length of digits, the administration is stopped. Digit span backward is identical to digit span forward with the exception that subjects repeat the digits in the reverse order from which they were presented. Word span is similar to digit span except that subjects are initially given three sets of two words presented one set at a time. Subjects must correctly repeat two sets of the two words in order to graduate to three sets of three words. This process continues up to seven words per set. The words in the word span task are designed to be phonetically and semantically different from one another to help reduce confusion and avoid contamination of the results.

The sentence span task was introduced by Daneman and Carpenter (1980) to provide a more sensitive assessment of memory span operations. In this task, subjects are presented with a set of sentences and their goal is to read the sentences out loud and remember the last word in each sentence. The experimenter presents the next sentence in a set immediately after the subject finishes reading each sentence. The subject's task is to recall the last word in the sentences in the same order they were presented. The dependent measure (i.e., the subjects' reading span) is the largest set of sentences in which the subject can correctly recall the last words on two out of three trials.

Daneman and Carpenter (1980) found that reading span, (i.e., the number of last words recalled) correlated with reading comprehension measures including verbal SAT scores, while digit span and word span measures did not correlate with reading comprehension scores. Another hypothesis was that if alcohol reduces the efficiency of working memory operations, then intoxicated subjects should perform more poorly on memory span measures than sober ones, and the size of the difference would be larger for the reading span measure.

In the literature reviewed above, one explanation of the alcohol induced memory impairments has been the cognitive slowing hypothesis. The assumption of this hypothesis is that ethanol slows the rate with which the subject can execute elementary cognitive operations in working memory. The slower cognitive operations impair the efficiency with which information is elaborated and integrated within working memory, and thus resulting in information that is inadequately encoded.

Verbal ability has also been identified as a variable related to the speed of executing elementary cognitive operations in working memory. For example, Hunt, Davidson and Lansman (1981) examined the influence of verbal ability of college aged subjects, on the speed of accessing semantic information from long term memory. Verbal ability was determined by the Nelson-Denny Reading Test.

Subjects were presented with word pairs either simultaneously or in succession. Subjects had three tasks to perform. The first one was stimulus matching, in which they decided whether the two words had the same name. Subjects responded "same" if two words were physically identical (CAT, CAT) or if they were the same word but printed in different cases (DOG, dog). Words were either presented simultaneously or with a 1500 msec delay before the second word appeared.

The second task was a semantic verification task. In this task, subjects were presented with a category name and a word that was either an example of that category or another category, for example, Animal-Dog or Animal-Chair. Subjects had to respond whether or not the word was a member of the category specified. In the simultaneous condition, the category name and item appeared at the same time. In the sequential condition, the category name appeared on the screen and remained there for 500 msec. After the category name went off the screen, there was a 1500 msec delay before the first item appeared to be judged.

The third task was a semantic matching task. Subjects had to decide whether two items were members of the same semantic category (i.e. Dog, Cat or Dog, Chair). Again, there were simultaneous and sequential conditions.

Hunt et al. (1981) found a relationship between reading ability and response time when asked to judge whether two words had the same name, whether two items were members of the same category and also when asked whether a word was a member of a category. Skilled readers responded more quickly than less skilled readers on all tasks examined.

Hunt (1978) suggested that verbal ability is related to the speed with which cognitive operations occur in working memory. If intoxication with ethanol slows the rate of working memory operations, (Petros et al., 1985) and thus impairs the efficiency of working memory, then the effects of ethanol should be larger for low verbal than high verbal subjects. Therefore, the present study examined whether the verbal ability of the subject modulated the influence of ethanol on working memory performance.

CHAPTER II

METHODOLOGY

Method

Subjects

The subjects in this study were 78 males over the age of 21. Subjects received class extra credit for their participation. Potential subjects were screened prior to their participation to determine levels of general health as well as drinking history. Only subjects reported in good health and able to tolerate a moderate dose of alcohol were invited to participate. Participation was limited to moderate drinkers who reported on the Khavari Alcohol Test that they drank at least twice a week and drank at least two drinks for each instance of drinking (Khavari and Farber, 1978). The Michigan Alcoholism Screening Test (MAST) (Selzer, 1971) was also administered to help identify those that were problem drinkers who were then excluded from the study. In addition, the Children of Alcoholics Screening Test (CAST) (Pilat and Jones, 1984/85) was also used to identify those persons with a family history of alcoholism who were also excluded from the study. Subjects were instructed to avoid drugs (including alcohol) for 24 hours prior to participation in the study. Subjects were asked to eat a full meal three hours prior to participation in the study. All subjects reported that they had eaten as instructed prior to arriving for the study.

Materials

The stimuli to measure memory span for numbers were the digits 0-9 (see Appendix A). The word span materials consisted of three sets of words with a different number of words in each set (see Appendix B). For example, there were three sets of two words, three sets of three words and three sets of four words up to three sets of seven words. The words in each set were concrete nouns with no phonetic similarity. The sentence span test consisted of three sets of sentences with differing numbers of sentences in each set (see Appendix C). For example, there were three sets of two sentences, three sets of three, four, five, and six sentences. The sentences ranged from being 15 to 20 words long with the last word always being a noun.

The stimuli to measure memory scan for words and categories were 10 single word category labels and 12 exemplars chosen from each category (Battig and Montague, 1969). Words were chosen such that they fit clearly into one semantic category. The 10 categories were mammals, trees, metals, insects, clothing, vehicles, birds, tools, body parts, and colors.

Procedure

Upon arrival for the experimental session, subjects were weighed and were then given a blood alcohol test. Subjects are required to take a deep breath and slowly blow into a mouthpiece attached to the Alco-Sensor III (Intoximeters, Inc.) for three seconds. This apparatus measures the percentage of alcohol in the blood stream. Next, subjects were verbally given the Vocabulary Subtest of the Weschler Adult Intelligence Scale - Revised. On the basis of the raw score on the vocabulary subtest, subjects were assigned to either the intoxicated or the sober condition in order to ensure that both groups were equivalent in terms of their verbal ability.

Subjects in the intoxicated condition received 1.0 ml/kg of body weight of absolute alcohol in the form of 80 proof vodka. Subjects in the intoxicated condition received drinks in the form of 1 part vodka and 2 parts masking solution composed of a double concentration of lemonade flavored with peppermint extract. Subjects in the sober condition received water in the place of vodka, and the rims of the glasses were swabbed with 1.0 ml of vodka to give sober subjects the smell of alcohol on their glasses. All subjects were given two equal size drinks and told to consume them slowly and at an even pace so that drinks would last 20 minutes per drink. The two consecutive 20 minute drinking periods were followed by a 15 minute absorption period to allow the blood alcohol level to begin to rise such that subjects were tested on the ascending portion of the absorption curve.

Following the absorption period, subjects were individually tested by an experimenter who did not know whether the individual subject received alcohol or a placebo. In the memory scanning task subjects completed two blocks of 96 trials, with one block for the name scanning and the second block for scanning for category information. Within each block of 96 trials, 32 trials had a memory set size of two, 32 trials had a memory set size of three, while 32 trials had a memory set size of four. The memory sets were presented using a varied set procedure such that the specific stimuli in the memory sets changed from trial to trial. Within each memory set size, 16 trials required positive decisions and 16 trials required negative decisions. The order of presenting the name or category trials was randomized across subjects. Prior to consuming their drinks, subjects were given 30 experimental trials with digits of set size 2, 3 and 4 to become familiar with the memory scanning task.

Immediately after the experimental trials, a block of response time control trials was given to estimate the influence of ethanol on simple motor response times. In these trials, the subjects were presented with a memory set of two words, again using a varied set procedure. The words remained on the screen for three seconds, after which a row of five **X**'s appeared on the screen. Subjects were required to make their decision after the **X**'s appeared on the screen. The assumption was that these response latencies would only reflect the time necessary to make the motor response since the memory set was on the screen for three seconds, a time assumed to be sufficient for scanning working memory.

The memory span portion of the testing consisted of examining digit span, word span, and sentence span performance. In the digit span test, subjects were presented with a sequence of digits and asked to repeat the digits in the same order in which they were presented. The subjects began with a string of three digits and received two strings of each set size. The set size of the digit strings was increased until the subject missed both strings of a particular set size. The digit span score was the total number of individual trials that subjects could correctly recall. Subjects were then again given strings of digits but required to repeat them in reverse order. The same criterion as for digit span forward was followed for digit span backward.

The word span test was conducted in the same way as the digit span forward except that there were three trials of each set size and the subjects were required to recall correctly two of three trials at each level to advance to the next level. Subject's word span score was the total number of individual trials that the subject could correctly recall.

Finally, the sentence span test was presented to subjects with three sets of sentences with increasing numbers of sentences in each set. The subjects were asked to read each sentence out loud at their own rate from a computer screen, with exposure of subsequent sentences occurring immediately after the last word of the previous sentence was read. As the subject read the last word in a sentence, the experimenter would immediately press the space bar which brought the next sentence to the screen. Subjects were requested to recall the last word in each set of sentences. Subjects had to have all of the words correct per trial and two of three trials correct to advance to the next larger set size of sentences. The sentence span score was the total of the number of trials in which the subject could correctly recall the final word in each sentence.

Design

The design consisted of two between subjects factors and three within subjects factors. The between subjects factors were Dose (Alcohol or Placebo) and Verbal Ability (High verbal or Low verbal). Subjects were categorized as high verbal if they were at or above the median for WAIS-R Vocabulary scores, and as low verbal if they were below the median. The overall median for vocabulary scores was calculated. In this study, high verbal subjects had vocabulary scores of 56 or more on the WAIS-R Vocabulary subtest. Low verbal subjects scored below 56. On the scan tasks, the within subjects factors were memory set size (either two, three or four), task (either name or category) and decision (either positive or negative).

CHAPTER III

RESULTS

Results

The results for the present study were examined in two separate types of analyses. The first type of analyses consisted of a series of dose x verbal ability comparisons on various measures of individual differences and the memory span tasks. The second set of analyses examined the response times and error rates for the name scan and category scan tasks.

Individual differences and span tasks

A 2 (Dose) x 2 (Verbal ability) analysis of variance was conducted on age, WAIS-R vocabulary score, weight, blood alcohol level (BAL) prior to drinking (BAL1), blood alcohol level after 15 minutes after the last drink (BAL2), blood alcohol level midway through tasks (BAL3), blood alcohol level after completion of tasks (BAL4), digit span forward, digit span backward, digit span total (forward and backward combined), word span and sentence span (see Table 1). All significant results were observed with $p < .05$.

TABLE 1

INDIVIDUAL DIFFERENCE DATA

	Vocabulary				
	High		Low		
Factor	Intox	Sober	Intox	Sober	Effect
Age	26.684 (4.137)	28.650 (4.913)	24.842 (4.925)	23.350 (4.017)	V*
Vocab	62.053 (3.965)	62.200 (4.479)	48.421 (6.067)	49.100 (4.866)	V*
Weight (lbs)	175.684 (23.248)	169.800 (20.516)	176.789 (28.477)	179.200 (32.670)	
BAL1	0.001 (.001)	0.001 (.001)	0.001 (.001)	0.001 (.001)	
BAL2	0.071 (.018)	0.000 (.001)	0.064 (.023)	0.001 (.001)	D*
BAL3	0.078 (.015)	0.000 (.001)	0.081 (.016)	0.001 (.001)	D*
BAL4	0.073 (.011)	0.000 (.001)	0.074 (.017)	0.001 (.001)	D*
Digit Span Forward	9.316 (2.262)	9.700 (2.557)	7.316 (1.887)	8.150 (1.981)	V*
Digit Span Backward	8.421 (2.341)	9.900 (2.049)	6.684 (1.916)	8.800 (2.913)	D,V*
Digit Span Total	17.737 (3.871)	19.600 (4.173)	14.000 (3.464)	16.950 (4.322)	D,V*
Word Span	11.579 (2.714)	12.700 (3.541)	10.053 (2.656)	10.450 (2.523)	V*
Sentence Span	5.316 (2.518)	6.650 (4.344)	3.579 (1.895)	3.850 (1.182)	V*

Note. Standard deviations are in parentheses. V* and D* indicate main effects of verbal ability and dose. BAL1, BAL2, BAL3, & BAL4 indicate % alcohol in bloodstream.

Main effects of verbal ability were found for age, $\underline{F}(1,74) = 12.181$, $\underline{p} = .001$, WAIS-R vocabulary score, $\underline{F}(1,74) = 144.998$, $\underline{p} < .001$, digit span forward, $\underline{F}(1,74) = 12.800$, $\underline{p} = .001$, digit span backward, $\underline{F}(1,74) = 7.151$, $\underline{p} = .010$, digit span total, $\underline{F}(1,74) = 11.482$, $\underline{p} = .002$, word span, $\underline{F}(1,74) = 8.309$, $\underline{p} = .006$, and sentence span, $\underline{F}(1,74) = 13.161$, $\underline{p} = .001$. High verbal subjects were significantly older (M = 27.7 years) than low verbal subjects (M = 24.1 years) and scored significantly higher on the WAIS-R (M = 62.1) than did low verbal subjects (M = 48.8). High verbal subjects remembered significantly more digits forward (M = 9.5) than did low verbal subjects (M = 7.7), more digits backwards (M = 9.2) as compared to low verbal subjects (M = 7.7), and remembered more digits total (M = 18.7) than did low verbal subjects (M = 15.5). High verbal subjects also performed better than low verbal subjects on the word span (12.1 vs 10.3) and sentence span (6.0 vs 3.7).

Main effects of dose were observed for BAL2, $\underline{F}(1,74) = 426.559$, $\underline{p} < .001$, BAL3, $\underline{F}(1,74) = 1063.662$, $\underline{p} < .001$, BAL4, $\underline{F}(1,74) = 1074.182$, $\underline{p} < .001$, digit span backward, $\underline{F}(1,74) = 11.482$, $\underline{p} = .002$ and digit span total, $\underline{F}(1,74) = 7.130$, $\underline{p} = .010$. These effects indicated that subjects who received alcohol had higher mean blood alcohol levels than subjects who had the placebo at 15 minutes after finishing their final drink (BAL2: .068 vs .001), at the midway point of task completion (BAL3: .080 vs .001), and at the point of task completion (BAL4: .074 vs .001). No interactions of dose and vocabulary were observed on any blood alcohol measure. Alcohol produced a significant main effect on digit span backwards with sober subjects recalling more numbers (M = 9.4) than intoxicated ones (M = 7.6). There was no interaction between dose and vocabulary level for digit span backward. Since digit span total is simply digit span forward and digit span backward added together, it is not surprising that a significant main effect of dose was found for digit span total. Sober subjects recalled more numbers overall (M = 18.3) than did intoxicated ones (M = 15.9).

Memory scan tasks/ response latencies

The median response time for each subject was calculated for every cell of the design, however, response times associated with an error were excluded. The means of these latencies along with the standard deviations are presented in Appendix D as a function of dose, verbal ability, memory set size, and decision type. A 2 (dose) x 2 (vocabulary level) x 2 (task) x 3 (set size) x 2 (decision type) mixed analysis of variance was conducted separately on the response times and error rates for this data. All significant results were observed with $p < .05$. The analysis of variance source table for response times is in Appendix E and the source table for error rates is in Appendix F. All subsequent comparisons utilized Newman-Keuls procedures with alpha set at .05. Logarithmic transformations were completed on the response times and the same significant effects were observed as those found in the analysis on the raw data. Therefore, the results of the analysis on the raw data will be reported. The correlation between the means and the error rates, $r(48) = .33$, $p < .001$, suggests that there was not a speed/accuracy trade-off.

For the response times, significant main effects of dose, $F(1,74) = 6.514$, $p = .013$, task, $F(1,74) = 681.126$, $p < .001$, set size, $F(2,148) = 141.390$, $p < .001$, and decision, $F(1,74) = 167.287$, $p < .001$ were observed. Intoxicated subjects responded more slowly (M = 976.3 msec) than sober subjects (M = 879.3 msec). Name decisions were made faster (M = 617.7 msec) than category decisions (M = 1237.8 msec). A subsequent analysis of the set size effect revealed that decisions in which there were two words in the stimulus set were made faster (M = 809.1 msec) than stimulus sets with three words (M = 938.4 msec) and both of which were made faster than stimulus sets with four words (M =

1035.8 msec). Positive decisions were made significantly faster (M = 853.5 msec) than were negative decisions (M = 1002.0 msec).

Significant interactions of vocabulary level x decision type, $F(1,74) = 8.956$, $p = .004$, task x set size, $F(2,148) = 66.481$, $p < .001$, task x decision type, $F(1,74) = 89.883$, $p < .001$, set size x decision type, $F(2,148) = 33.072$, $p < .001$, dose x set size x decision type, $F(2,148) = 4.309$, $p = .016$, and task x set size x decision type, $F(2,148) = 17.379$, $p < .001$ were observed. Subsequent analysis of the vocabulary x decision type interaction revealed that high vocabulary level subjects had faster response times than low vocabulary level subjects for negative decisions, but that there was no difference between the two groups for positive decisions. Positive decisions were made more quickly than negative decisions for both vocabulary level groups (see Table 2).

The analysis of the task x set size interaction revealed that name responses were faster than category responses at all stimulus set sizes but the size of the task difference was smaller for set size of two (43%) when compared to set size three (53%) and four (53%). For name responses, there was no difference between set sizes of two and three, while response latencies were shorter than responses to set sizes of four. For

TABLE 2

RESPONSE LATENCIES AS A FUNCTION OF VOCABULARY AND DECISION TYPE

	Ability		
Decision	High Vocabulary	Low Vocabulary	% Difference
Yes	858	849	1
No	972	1032	6

Note. Means are in msec.

category responses, set size two response times were significantly faster than set size three response times which, in turn, were faster than response times to set size four (see Table 3).

TABLE 3

RESPONSE LATENCIES AS A FUNCTION OF TASK AND SET SIZE

	Task		
Set Size	Name	Category	% Difference
2	587	1031	43
3	604	1272	53
4	662	1410	53

Note. Means are in msec.

Subsequent analysis of the task x decision type interaction revealed that name responses were made faster than category responses at both decision types. There was no significant difference between yes and no for name responses. In contrast, no decisions took significantly more time than yes decisions for category responses (see Table 4).

TABLE 4

RESPONSE LATENCIES AS A FUNCTION OF TASK AND DECISION TYPE

	Task		
Decision Type	Name	Category	% Difference
Yes	601	1106	46
No	634	1370	54

Note. Means are in msec.

Further examination of the set size x decision type interaction revealed for both positive and negative decision types, response latencies increased with each increase in set size. The effect of set size was greater for no decision types than it was for yes decision types (see Table 5).

Subsequent analysis of the dose x set size x decision type interaction revealed that intoxicated subjects responded slower than sober subjects at all set size and decision type levels. All positive decision types were made faster than negative decision types at all levels. In examining simple effects, the dose x set size interaction was significant for no decision types $\underline{F}(2,148) = 2.992$, $\underline{p} = .05$, but not for yes decision types $\underline{F}(2,148) = 0.389$, $\underline{p} > .500$ (see Table 6). An examination of the dose x set size interaction for no responses indicated that the size of the dose effect was larger for larger set sizes.

TABLE 5

RESPONSE LATENCIES AS A FUNCTION OF SET SIZE AND DECISION TYPE

	Decision Type		
Set Size	Yes	No	% Difference
2	771	848	9
3	874	1003	13
4	916	1115	18

Note. Means are in msec.

The final interaction observed for response times was task x set size x decision type. Subsequent analysis of this interaction revealed that name responses were made faster than category responses at all decision types and set sizes. Positive decision types were made faster than negative decision types at all levels of set size and task. Subsequent examination suggests that the effect of set size was greater for category response times as compared to name response times (see Table 7).

TABLE 6

RESPONSE LATENCIES AS A FUNCTION OF DOSE, SET SIZE AND DECISION TYPE

		Set Size		
Decision	Dose	2	3	4
Yes				
	Intoxicated	815	909	949
	Sober	726	838	884
	% Difference	11	8	7
No				
	Intoxicated	883	1063	1239
	Sober	812	944	1072
	% Difference	8	11	13

Note. Means are in msec.

TABLE 7

RESPONSE LATENCIES AS A FUNCTION OF TASK, SET SIZE AND DECISION TYPE

		Task		
Set Size	Decision	Name	Category	% Difference
2				
	Yes	580	962	40
	No	595	1100	46
3				
	Yes	591	1156	49
	No	617	1389	56
4				
	Yes	633	1199	47
	No	690	1621	57

Note. Means are in msec.

Memory scan tasks/ error rates

Analysis of the error rates for the memory scan tasks showed main effects of dose, $F(1,74) = 6.904$, $p = .011$, vocabulary level, $F(1,74) = 10.764$, $p < .001$, task, $F(1,74) = 223.917$, $p < .001$, set size, $F(2,148) = 26.903$, $p < .001$, and decision, $F(1,74) = 8.380$, $p = .006$. Intoxicated subjects made significantly more errors (M = .086) than sober subjects (M = .060). High vocabulary level subjects made significantly fewer errors (M = .057) than did low vocabulary level subjects (M = .089). Significantly fewer errors were made for name responses (M = .038) than for category responses (M = .109). Subsequent analysis of the set size main effect revealed that the error rate at set size two (M = .060) was not significantly different from the error rate at set size three (M = .063) but both set size two and set size three were associated with significantly fewer errors than set size four (M = .097). Significantly more errors were observed for yes decisions (M = .079) than for no decisions (M = .067).

Significant interactions of vocabulary level x task, $\underline{F}(1,74) = 13.910$, $\underline{p} < .001$, dose x decision type $\underline{F}(1,74) = 16.966$, $\underline{p} < .001$, task x set size, $\underline{F}(2,148) = 13.936$, $\underline{p} < .001$, dose x task x decision type, $\underline{F}(1,74) = 5.770$, $\underline{p} = .019$, and dose x task x set size x decision type, $\underline{F}(2,148) = 4.020$, $\underline{p} = .020$ were also found in the analysis of the error rates.

Subsequent analysis of the vocabulary level x task interaction revealed that low verbal subjects made significantly more errors than did high verbal subjects for both name and category tasks, but the size of the vocabulary difference was greater for category responses than it was for name responses (see Table 8).

The subsequent analysis on the dose x decision interaction showed that intoxicated subjects made significantly more errors than sober subjects for both

TABLE 8

ERROR RATES AS A FUNCTION OF VOCABULARY LEVEL AND TASK

	Vocabulary Level		
Task	High	Low	% Difference
Name	.031	.046	33
Category	.084	.133	37

Note. Means are for proportion of errors.

yes and no decision types, but the size of the difference was much larger for no decisions. There was no significant difference between yes and no decision types for intoxicated subjects. However, there was a significant difference between yes and no decision types for sober subjects. Sober subjects made significantly fewer errors at negative decision types as compared to positive decision types (see Table 9).

TABLE 9

ERROR RATES AS A FUNCTION OF DOSE AND DECISION TYPE

	Dose		
Decision	Intoxicated	Sober	% Difference
Yes	.084	.074	12
No	.089	.046	48

Note. Means are for proportion of errors.

Subsequent analysis of the task x set size interaction revealed that more errors were made for category responses than for name responses across all levels of set size. For name responses, there was no effect of the set size, but for category responses, there was a significant difference at set size four as compared to set size three and two which were not significantly different from each other (see Table 10).

TABLE 10

ERROR RATES AS A FUNCTION OF TASK AND SET SIZE

	Task		
Set Size	Name	Category	% Difference
2	.038	.083	54
3	.030	.096	69
4	.047	.147	68

Note. Means are for proportion of errors.

Upon further examination of the dose x task x decision type interaction, it was found that intoxicated subjects made more errors than sober subjects at all levels except for the category, positive decision type where the error rates were identical. More errors were made for category responses than name responses across decision type and dose. More errors were made for positive decision types than were made for negative decision types across task and dose (see Table 11).

TABLE 11

ERROR RATES AS A FUNCTION OF DOSE, TASK AND DECISION TYPE

		Dose		
Task	Decision	Intoxicated	Sober	% Difference
Name				
	Yes	.054	.036	33
	No	.044	.018	59
Category				
	Yes	.113	.113	0
	No	.133	.075	44

Note. Means are for proportion of errors.

For the final interaction, dose x task x set size x decision type, the effect that was examined was the dose effect. At yes, name, set size three intoxicated subjects made significantly more errors than sober subjects. This was also true at yes, category, set size three. Intoxicated subjects made significantly more errors at no, name, set sizes two and four, and at no, category, set sizes two, three and four (see Table 12).

TABLE 12

ERROR RATES AS A FUNCTION OF DOSE, TASK, SET SIZE AND DECISION TYPE

			Dose		
Task	Set Size	Decision	Intoxicated	Sober	% Difference
Name					
	2				
		Yes	.046	.041	11
		No	.048	.017	65
Name					
	3				
		Yes	.054	.020	63
		No	.023	.020	13
Name					
	4				
		Yes	.063	.047	25
		No	.061	.016	74

Note. Means are for proportion of errors.

TABLE 12 (cont)

ERROR RATES AS A FUNCTION OF DOSE, TASK, SET SIZE AND DECISION TYPE

Task	Set Size	Decision	Dose: Intoxicated	Sober	% Difference
Category					
	2				
		Yes	.105	.086	18
		No	.096	.044	54
Category					
	3				
		Yes	.087	.121	28
		No	.115	.061	47
Category					
	4				
		Yes	.147	.132	10
		No	.189	.119	37

Note. Means are for proportion of errors.

Reaction time controls

The median reaction time for each subject was calculated across 24 trials. A 2(Dose) x 2(Verbal ability) analysis of variance was conducted separately for this group of data. No effects involving verbal ability were observed on this data. However, a significant main effect of dose, $F(1,74) = 6.019$, $p = .017$, was observed. Intoxicated subjects' reaction times (M = 324 msec) were significantly slower than sober subjects (M = 273 msec). In light of this finding, the scan task analyses were recomputed. The reaction times on the control task were subtracted from the median response times in the experimental trials for each subject. When this analysis was completed, the only effect that changed was that the main effect of dose from the previously described results was no longer significant. No additional significant effects were found.

Slope and intercept analyses

The data were further examined by computing the slope of the line relating set size to response time separately for name and category tasks. Thus, analyses were completed on slope for response latency, slope for error rate, intercept for response latency and intercept for error rate. Since the main effect of dose was no longer present after the mean reaction time control was subtracted out, slopes and intercept data were also computed with the response time control data subtracted from the experimental data. Additionally, since positive and negative decisions gave very differing results in the analysis of variance, slopes and intercepts were computed separately for data associated with positive and negative decisions. The slope is a measure of the rate of change in response time as a function of changes in the memory set size, and thus is used as an index of the rate of memory scanning (Sternberg, 1969). Therefore, smaller slope values indicate a faster rate of memory scanning. The intercept of the line relating set size to response time was also computed. This measure is used to estimate the time it takes to encode the memory probe and make a positive or negative decision.

A 2 (Dose) x 2 (Verbal ability) X 2 (Task) mixed analysis of variance was conducted on the slope and intercept data. Analysis of the slope for the response latency with the reaction time controls included showed a main effect of task, $F(1,74) = 94.040$, $p < .001$, with the slope for name responses (M = 37.1) being significantly lower than the slope for category responses (M = 189.6). Although slopes were larger for intoxicated subjects than sober subjects, no effect of dose was observed (see Table 13).

Analysis of the slope of the error rates revealed that there was a main effect of task, $F(1,74) = 22.82$, $p < .001$, with the slope for name responses (M = .004) being significantly lower than the slope for category responses (M = .032) (see Table 14).

TABLE 13

SLOPE OF RESPONSE LATENCIES AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	45.2	199.6
Sober	29.1	179.4

Note. Means are in msec as a function of set size.

TABLE 14

SLOPE OF ERROR RATES AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	.007	.034
Sober	.001	.030

Note. Means are for proportion of errors as a function of set size.

A main effect of task was observed for the intercept for the response latencies, $F(1,74) = 150.74$, $p < .001$. The intercept for name responses (M = 543.5) was significantly lower than the intercept for category responses (M = 858.8). Although intercepts were larger for intoxicated subjects than sober subjects, no effect of dose was observed in this analysis (see Table 15).

There were no significant effects for the intercept for the error rates (see Table 16).

TABLE 15

INTERCEPT OF RESPONSE LATENCIES AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	555.0	907.8
Sober	531.9	809.7

Note. Means are in msec.

TABLE 16

INTERCEPT OF ERROR RATES AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	.034	.056
Sober	.024	.033

Note. Means are for proportion of errors.

A similar set of analyses was conducted on the slopes and intercepts after each subject's reaction time control data were subtracted from the experimental data. The effects observed in these analyses were the same as were observed in the previous analyses.

Analyses of data by decision type.

The computation of slope and intercept data separately for yes and no decisions was done after the response time control data were subtracted from the experimental data. This was the most conservative measure as there was a dose effect in mean reaction time in the previous analyses.

Analyses of data associated with positive responses.

An analysis of the positive responses revealed a significant main effect of task, $F(1,74) = 48.167$, $p < .001$, for the slope of the response latencies. Name responses had a lower slope (M = 74.0) than category responses (M = 165.9) (see Table 17).

TABLE 17

SLOPE OF RESPONSE LATENCIES FOR POSITIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	79.6	153.9
Sober	68.4	177.9

Note. Means are in msec as a function of set size.

The slope of the error rates to positive decisions showed no significant effects. The effect for task was marginal, $F(1,74) = 3.955$, $p = .051$, suggesting that category decisions were associated with more errors than name decisions (see Table 18).

TABLE 18

SLOPE OF ERROR RATES FOR POSITIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	.008	.021
Sober	.003	.023

Note. Means are for proportion of errors as a function of set size.

Analysis of the intercept data for the response latencies showed main effects of dose, $F(1,74) = 6.826$, $p = .011$, and task, $F(1,74) = 123.386$, $p < .001$. The intercept for intoxicated subjects (M = 409.7) was significantly higher than the intercept for sober subjects (M = 316.1). Name responses were associated with a lower intercept (M = 202.7) than category responses (M = 523.1) (see Table 19).

Task was the only significant main effect found for the intercept of the error rates, $F(1,74) = 4.205$, $p = .044$. The intercept for the name responses was significantly lower than the intercept for the category responses (.034 vs .070) (see Table 20).

TABLE 19

INTERCEPT OF RESPONSE LATENCIES FOR POSITIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	223.0	596.2
Sober	182.3	449.9

Note. Means are in msec.

TABLE 20

INTERCEPT OF ERROR RATES FOR POSITIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	.038	.072
Sober	.030	.067

Note. Means are for proportion of errors.

Analyses of data associated with negative responses. For negative responses, the slopes on the response latencies showed main effects of dose, $F(1,74) = 4.601$, $p = .036$, and task, $F(1,74) = 72.587$, $p < .001$. The slope for intoxicated subjects ($M = 227.5$) was significantly higher than the slope for sober subjects ($M = 174.4$). The slope for name responses ($M = 94.5$)

was significantly lower than the slope for category responses (M = 307.9) (see Table 21).

TABLE 21

SLOPE OF RESPONSE LATENCIES FOR NEGATIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	212.2	242.9
Sober	183.9	164.8

Note. Means are in msec as a function of set size.

The same pattern of results was found for the analysis of the slope for the error rates of the negative responses. Significant main effects were found for dose, $F(1,74) = 9.021$, $p = .004$, and task, $F(1,74) = 32.660$, $p < .001$. The slope for intoxicated subjects (M = .049) was significantly larger than the slope for sober ones (M = .029). The slope of the error rates for name responses (M = .021) was significantly smaller than the slope for error rates for category responses (M = .057) (see Table 22).

Analysis of the intercepts for the negative responses revealed that for response latency, task was the only significant effect, $F(1,74) = 88.686$, $p < .001$. There was a significantly higher intercept for category responses (M = 504.5) as compared to name responses (M = 194.3) (see Table 23).

TABLE 22

SLOPE OF ERROR RATES FOR NEGATIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	.031	.067
Sober	.012	.047

Note. Means are for proportion of errors as a function of set size.

TABLE 23

INTERCEPT OF RESPONSE LATENCIES FOR NEGATIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	192.6	524.9
Sober	196.1	484.1

Note. Means are in msec.

Analysis of the intercept for the error rates of the negative responses showed main effects of dose, $F(1,74) = 12.389$, $p = .001$, vocabulary, $F(1,74) = 5.661$, $p = .020$, and task, $F(1,74) = 22.014$, $p < .001$.

The intercept for intoxicated subjects was significantly higher than the intercept for sober ones (.088 vs .049). High vocabulary level subjects had a significantly lower intercept as compared to low vocabulary level subjects (.056 vs .082). The intercept for the name responses was significantly lower than the category responses (.048 vs .089) (see Table 24).

TABLE 24

INTERCEPT OF ERROR RATES FOR NEGATIVE DECISIONS AS A FUNCTION OF DOSE AND TASK

	Task	
Dose	Name	Category
Intoxicated	.066	.110
Sober	.031	.068

Note. Means are for proportion of errors.

CHAPTER IV

DISCUSSION

Discussion

The main purpose of this study was to examine the role of intoxication with ethanol on the efficiency of working memory operations. This study examined the effect of ethanol on memory span tasks and also memory scan tasks. This study also examined the extent to which the verbal ability of a subject modulated the influence of ethanol on working memory performance.

The effect of ethanol observed in the present study was mixed, yet provides some evidence suggesting that intoxication with ethanol impairs working memory performance under several conditions.

The present study found that intoxication with ethanol impaired performance on digit span backwards, yet had no influence on any of the other measures of memory span. Parker et al. (1974) found that ethanol impaired performance on both digit span forward and digit span backward. The present study found that verbal ability was a factor in digit span forward, digit span backward, word span, and sentence span.

However, intoxication with ethanol only influenced performance on digit span backward in which intoxicated subjects performed more poorly than sober ones.

The fact that high verbal ability was associated with higher memory span scores on each of the span tasks indicates that the span tasks were sensitive measures of memory span (Daneman and Carpenter, 1980). One reason for the absence of ethanol effects on word or sentence span may be the meaningfulness of the words and sentences that provided contextual cues that enhanced performance. Perhaps these contextual cues superseded any alcohol effect for the word and sentence span tasks. To examine this hypothesis further, one could administer the word and sentence span tasks and require the words be given in reverse order as in the digit span task. Unfortunately, the present study did not have such a measure.

The alcohol effect observed only in the digit span backward task implies that ethanol impairs memory span performance when manipulation of information is concurrently occurring in working memory, and that the task is not a simple serial repetition of the input stimuli. This hypothesis is consistent with recent claims that intoxication with ethanol impairs the efficiency, integration and elaboration of information in working memory (Hashtroudi et al., 1983). The absence of any dose x verbal ability interactions provides no support for the cognitive slowing explanation of ethanol's impact on memory performance. Since verbal ability is associated with the speed of mental operations, it was anticipated that larger ethanol effects would be found for low verbal subjects. Possibly more extreme manipulations of verbal ability would provide a more sensitive assessment of this hypothesis.

The memory scan task as introduced by Sternberg (1969) requires subjects to encode information in working memory and also allocate some working memory capacity to searching for information in working memory. Sternberg (1969) found that response latencies increased as a function of set size. The results from the present study replicate these findings.

Sternberg (1969) hypothesized that response latencies reflect the time to encode the information, the time to make the decision and the time to make the motor response. In examining the analysis of variance results, one could conclude that alcohol only affected the motor response. There was no main effect of alcohol and only one interaction involving alcohol.

In examining the slope and intercept analyses, for the overall analysis, there was no effect of ethanol. As the analysis of variance results were very different for positive versus negative decision types, the slope and intercept data were also examined in this fashion.

In examining the slope data, alcohol had an effect for negative, but not positive decisions. Perhaps the added difficulty in making a negative decision is what caused this alcohol effect. Unfortunately, the absence of an interaction of dose and task qualifies the strength of this interpretation. Regardless, the data suggest an ethanol induced impairment in the speed of scanning working memory.

It is possible that larger set sizes, perhaps up to set size of six, would more accurately reflect the effect of the additional cognitive processing demand on the efficiency of working memory processing for both dose and verbal ability.

In examining the intercept data, alcohol had an effect for both positive and negative decisions. Sternberg (1969) hypothesized that the intercept is a reflection of the time necessary to encode information and make a decision about the information. Haut, Beckwith, Petros and Russell (1989) found that alcohol slows the speed with which subjects can encode information to retrieve it from long term memory. The current study is consistent with those findings.

In addition to the above mentioned possible alterations to the methodology of the present study, future researchers may want to use more extreme verbal ability groups to obtain a more sensitive manipulation of verbal ability. It may be beneficial to obtain and correlate consumption measures to see if average consumption is a factor in the effect of alcohol on working memory tasks. Finally, one may wish to use a different reaction time control measure as it is possible the one used in this study was not a pure measure of motor response time. Subjects were required to change their method of responding to the stimuli after 12 blocks of trials. Experimenter observations noted that subjects reported difficulty in having to wait to respond to the stimuli as compared to the previous twelve blocks of trials in which they responded as quickly as possible. It seems plausible that the reaction time control measure was a measure of motor response time plus some additional time reflective of the conscious effort to wait to respond.

APPENDICES

APPENDIX A

DIGIT SPAN STIMULUS MATERIALS

DIGIT SPAN STIMULUS MATERIALS

Digits Forward

# of digits	Trial 1	Trial 2
3	5-8-2	6-9-4
4	6-4-3-9	7-2-8-6
5	4-2-7-3-1	7-5-8-3-6
6	6-1-9-4-7-3	3-9-2-4-8-7
7	5-9-1-7-4-2-8	4-1-7-9-3-8-6
8	5-8-1-9-2-6-4-7	3-8-2-9-5-1-7-4
9	2-7-5-8-6-2-5-8-4	7-1-3-9-4-2-5-6-8

Digits Backward

# of digits	Trial 1	Trial 2
practice	9-1-7	
2	2-4	5-8
3	6-2-9	4-1-5
4	3-2-7-9	4-9-6-8
5	1-5-2-8-6	6-1-8-4-3
6	5-3-9-4-1-8	7-2-4-8-5-6
7	8-1-2-9-3-6-5	4-7-3-9-1-2-8
8	9-4-3-7-6-2-5-8	7-2-8-1-9-6-5-3

APPENDIX B

WORD SPAN STIMULUS MATERIALS

WORD SPAN STIMULUS MATERIALS

Word Span # of words	Trial 1	Trial 2	Trial 3
2	mouth-bridge	farm-space	jazz-team
3	heart-club job	staff-rain book	plane-act child
4	hair-sun ground-mile	vote-wire smoke-milk	voice-post art-list
5	nail-stage film-store gun	king-law race-friend car	plant-road blood-play ball
6	hall-sea floor-wall face-cloth	air-board song-pool key-dance	church-week light-spring science-game
7	girl-door cent-son bed-eye gold	oil-land class-dog fire-price queen	food-stock hill-range month-clay field

APPENDIX C

SENTENCE SPAN STIMULUS MATERIALS

SENTENCE SPAN STIMULUS MATERIALS

BLOCK A

Number of sentences = 2

Set 1

The dog who had a white patch over his left eye ran until he could run no more.
His mother is a tall lady with red hair who shops at all the expensive stores in town.

Set 2

Right after you left town the rain turned into snow and the wind blew from the north.
Little Johnny was late for school and the teacher sent him to see the principal.

Set 3

The old lady slipped on the ice and spilled her groceries on the pavement.
Throughout her performance the entertainer made the audience laugh and cry.

Number of sentences = 3

Set 1

Filled with these dreary forebodings I fearfully opened the heavy wooden door.
I'm not certain what went wrong, but I think it was my cruel and bad temper.
I imagine that you have a shrewd suspicion about the object of my earlier visit.

Set 2

I turned my memories over at random like pictures in a photograph album.
Sometimes I get so tired of trying to convince him that I love him and shall forever.
The woman hesitated for a moment to taste the onions because her husband hated the smell.

Set 3

It was your belief in the significance of my suffering that kept me going.
When in trouble, children naturally hope for a miraculous intervention by a superhuman.
With shocked amazement and appalled fascination, Marion looked at the pictures.

Number of sentences = 4

Set 1

It is possible of course that life did not arise on the earth at all.
The poor lady was thoroughly persuaded that she was not long to survive this vision.
After all, he had not gone far and some of his walking had been circular.
The announcement of it would resound throughout the world and penetrate to the remotest land.

Set 2

To do so in directions that are adaptive for mankind would be a realistic objective.
Slicing it out carefully with his knife, he folded it without creasing the face.
He laughed sarcastically and looked as if he could have poisoned me for my errors.
He tolerated another intrusion and thought himself a paragon of patience for doing so.

Set 3

The reader may suppose that I had other motives besides the desire to escape the law.
On the desk where she wrote her letters was a clutter of objects coated in dust.
He stuffed his denim jacket into his pants and fastened the stiff new snaps securely.
He had an odd elongated skull which sat on his shoulders like a pear on a dish.

<u>Number of sentences = 5</u>

Set 1

I wish that there existed someone to whom I could say that I felt very sorry.

Here, as elsewhere, empirical patterns are important and abundantly documented.

As the intervals of silence grew, progressively longer delays became maddening.

Two or three substantial pieces of wood smouldered on the hearth for the night was cold.

I imagined that he had been thinking things over while his secretary was with us.

Set 2

There was still more than an hour before breakfast and the house was silent and asleep.

He leaned on the parapet of the bridge and the two policemen watched him from a distance.

These splendid melancholy eyes were turned on me from the mirror with a haughty stare.

He sometimes considered suicide, but the thought was too oppressive to stay in his mind.

And now that a man had died, some unimaginably different state of affairs must come to be.

Set 3

When I got to the tobacco field, I saw that it had not suffered much.

The products of digital electronics will play an important role in your future.

One problem with this explanation is that there appears to be no defense against cheating.

Sometimes the scapegoat is an outsider who has been taken into the community.

I should not be able to make anyone understand how exciting it all was.

Number of sentences = 6

Set 1

The incorrigible child was punished brutally for his lack of respect for elders.
The brilliant trial attorney dazzled the jury with his astute knowledge of the case.
I found the keynote speaker incredibly boring, inarticulate, and not well read.
The devastating effects of the flood were not fully realized until months later.
In a moment of complete spontaneity, she developed a thesis for her paper.
At the conclusion of the musician's performance, the enthusiastic crowd applauded.

Set 2

The mother nagged incessantly about her lack of concern for the welfare of the children.
Circumstantial evidence indicated that there was a conspiracy to eliminate him.
Without any hesitation, he plunged into the difficult mathematics assignment blindly.
To determine the effects of the medication, the doctor hospitalized his patient.
The lumberman worked long hours in order to obtain the necessary amount of wood.
They attended the theater habitually, except for circumstances beyond their control.

Set 3

The old lady talked to her new neighbor on her weekly walks from church.
After passing all of the exams, the class celebrated for an entire week without resting.
The entire town arrived to see the appearance of the controversial political candidate.
The weather was very unpredictable that summer, so no one made plans too far in advance.
According to the results from the survey, Robert Redford is the most liked Hollywood star.
Jane's relative had decided that her gentleman friend was not one of high status.

BLOCK B

Number of sentences = 2

Set 1

In a flash of fatigue and fantasy he saw a fat Indian sitting beside a campfire.
The lieutenant sat beside the man with the walkie-talkie and stared at the muddy ground.

Set 2

I will not shock my readers with a description of the cold-blooded butchery that followed.
The courses are designed as much for professional engineers as for amateur enthusiasts.

Set 3

The taxi turned up Michigan Avenue where they had a clear view of the lake.
The words of human love have been used by the saints to describe their version of God.

Number of sentences = 3

Set 1

There are days when the city where I live wakes in the morning with a strange look.
We boys wanted to warn them, but we backed down when it came to the pinch.
He stood there at the edge of the crowd while we were singing and he looked bitter.

Set 2

What would come after this day would be inconceivably different, it would be real life.
John became annoyed with Karen's bad habit of biting her nails and chewing gum.
Due to his gross inadequacies, his position as director was terminated abruptly.

Set 3

As the painters began to put their equipment away, rain drops fell from the cloudy sky.
I sat in my favorite chair to watch television only to find that the chair was broken.
It was a dark gloomy night when I began to suspect that something was wrong.

Number of sentences = 4

Set 1

His imagination had so distracted him that his name was called twice before he answered.

The basic characteristic of the heroes in the preceding stories is their sensitivity.

He listened carefully because he had the weird impression that he knew the voices.

He had patronized her when she was a schoolgirl and teased her when she was a student.

Set 2

The rain and the howling wind kept beating against the rattling window panes.

He covered his heart with both hands to keep anyone from hearing the noise it made.

The stories all deal with a middle-aged protagonist who attempts to withdraw from society.

Without tension there could be no balance either in nature or mechanical design.

Set 3

When the boy awoke in the morning, he did not know what happened last night.

She was a plain young girl and her classmates always said that she was an ugly duckling.

I was frightened when the furnace turned on and blew hot air in my face.

The inability of Jack to work independently resulted in him losing his job.

Number of sentences = 5

Set 1

A small oil lamp burned on the floor and two men crouched against the wall watching me.

The sound of the approaching train woke him and he started to his feet.

The boisterous laughter of the children was disturbing to the aged in the building.

In comparison to his earlier works, the musician had developed a unique, enthralling style.

The entire construction crew decided to lengthen their work day in order to have lunch.

Set 2

The smokers were asked to refrain from their habit until the end of he production.

All students that passed the test were exempt from any further seminars that semester.

Despite the unusually cold weather, the campers continued their canoe trip.

The young business executive was determined to develop his housing projects within the year.

In order to postpone the business trip, he cancelled his engagements for the week.

Set 3

The angry defendant denied that he stole the necklace from the jeweler.

My spirit was lifted when I saw that my boss and his beautiful wife finally arrived.

The picture of my father hangs on the wall above my fireplace.

The detective searched frantically for a clue to solve the murder mystery.

When I came around the corner, I lost control of the car and hit the curb.

<u>Number of sentences = 6</u>

Set 1

Before the boy could get to the station his horse lifted his fore foot.

The Araucano Indians never built great pyramids and never ruled a great empire.

Half the planes were on deck when we went into the wall of rain.

Last winter before a crowd of sightseers, a sixteen-year old boy subdued alligators.

The solder should not be melted by the direct heat of the blow torch.

Are you surprised to know there are fourteen thousand species of birds in the world.

Set 2

When the world's largest telescope was turned on this spot, two galaxies were discovered colliding.

He wrote nearly one thousand poems about these small insects who were his friends.

From my window I looked westward over the lake toward a high mountain range.

The heat is more dangerous to man than the rattlesnake, tiger, or lion.

They put the body in a coffin that had a face painted on it to look like the person inside.

Don't be surprised if you see a group of servicemen throwing a frisbee into the air.

Set 3

When I saw him coming toward me, I knew my destiny would be to tell the truth.

The two well dressed businessmen left the restaurant in a hurry.

Where the road turns north on the hill straight ahead is where I live.

On her way out the door, the young girl slipped and fell and ruined her new shoes.

The player kicked the soccer ball so hard that it stuck in the net of the goal.

The writer worked so late last night that he fell asleep on his desk.

APPENDIX D

MEDIAN RESPONSE TIMES FOR SCAN TASKS

TABLE 25

MEMORY SCAN TASKS: MEAN RESPONSE TIMES AND STANDARD DEVIATIONS

		Task					
		Name					
		Decision					
		Yes			No		
		Set Size					
Verbal ability	Dose	2	3	4	2	3	4
High	Intox	585 (91.5)	609 (115.9)	667 (117.5)	577 (94.9)	615 (74.4)	657 (79.9)
High	Sober	558 (127.8)	584 (109.9)	602 (100.1)	579 (101.9)	598 (102.0)	654 (116.5)
Low	Intox	629 (156.4)	625 (128.5)	666 (162.6)	647 (122.8)	661 (103.6)	808 (499.6)
Low	Sober	547 (82.6)	547 (99.3)	598 (118.3)	579 (83.0)	595 (91.5)	639 (86.3)

Note. Means and standard deviations (in parentheses) are in msec.

TABLE 25 (cont)

MEMORY SCAN TASKS: MEAN RESPONSE TIMES AND STANDARD DEVIATIONS

		Task					
		Category					
		Decision					
		Yes			No		
		Set Size					
Verbal ability	Dose	2	3	4	2	3	4
High	Intox	1025 (221.6)	1136 (279.3)	1230 (268.6)	1098 (280.3)	1338 (470.0)	1668 (625.5)
High	Sober	911 (161.4)	1176 (261.7)	1283 (349.6)	1030 (178.6)	1293 (250.5)	1511 (317.0)
Low	Intox	1021 (304.9)	1266 (326.5)	1232 (282.7)	1212 (291.1)	1586 (350.3)	1823 (478.4)
Low	Sober	890 (144.3)	1045 (165.5)	1122 (241.7)	1061 (186.4)	1290 (270.7)	1482 (374.3)

Note. Means and standard deviations (in parentheses) are in msec.

APPENDIX E

ANALYSIS OF VARIANCE SOURCE TABLE FOR MEDIAN RESPONSE TIMES: SCAN TASKS

TABLE 26

MEDIAN RESPONSE TIMES: SCAN TASKS
ANALYSIS OF VARIANCE RESULTS

Source	DF	Mean Square	F-Test	Significance
Dose	1	2198286.000	6.514	.013
Vocabulary	1	148567.188	0.440	>.500
Dose x Vocabulary	1	616747.938	1.827	.181
Error	74	337484.063		
Task	1	89925200.000	681.126	<.001
Dose x Task	1	404506.125	3.064	.085
Vocabulary x Task	1	3472.078	0.026	>.500
Dose x Vocabulary x Task	1	78163.688	0.592	.445
Error	74	132024.375		
Set Size	2	4031270.000	141.390	<.001
Dose x Set Size	2	25967.371	0.911	.405
Vocabulary X Set Size	2	1022.450	0.036	>.500
Dose x Vocabulary x Set Size	2	36569.531	1.283	.281
Error	74	28511.727		
Decision	1	5159410.000	167.287	<.001
Dose x Decision	1	114555.875	3.714	.058

TABLE 26 (cont)

Source	DF	Mean Square	F-Test	Significance
Vocabulary x Decision	1	276223.938	8.956	.004
Dose x Vocabulary X Decision	1	30781.203	0.998	.322
Error	74	30841.578		
Task x Set Size	2	1945409.000	66.481	<.001
Dose x Task x Set Size	2	3020.068	0.103	>.500
Vocabulary x Task x Set Size	2	21661.277	0.740	.479
Dose x Vocabulary x Task x Set Size	2	47794.594	1.633	.199
Error	74	29262.824		
Task x Decision	1	3144076.000	89.883	<.001
Dose x Task x Decision	1	134726.875	3.852	.054
Vocabulary x Task x Decision	1	46126.844	1.319	.255
Dose x Vocabulary x Task x Decision	1	2352.947	0.067	>.500
Error	74	34979.824		

TABLE 26 (cont)

Source	DF	Mean Square	F-Test	Significance
Set Size x Decision	2	532196.000	33.072	<.001
Dose x Set Size x Decision	2	69335.813	4.309	.016
Vocabulary x Set Size x Decision	2	6699.059	0.416	>.500
Dose x Vocabulary x Set Size x Decision	2	31270.105	1.943	.147
Error	74	16092.215		
Task x Set Size x Decision	2	294309.125	17.379	<.001
Dose x Task x Set Size x Decision	2	31389.609	1.854	.161
Vocabulary x Task x Set Size x Decision	2	1441.909	0.085	>.500
Dose x Vocabulary x Task x Set Size x Decision	2	5373.969	0.317	>.500
Error	74	16934.422		

APPENDIX F

SCAN TASKS: ANALYSIS OF VARIANCE SOURCE TABLE FOR ERROR RATES

TABLE 27

ERROR RATES: SCAN TASKS
ANALYSIS OF VARIANCE RESULTS

Source	DF	Mean Square	F-Test	Significance
Dose	1	0.157	6.904	.011
Vocabulary	1	0.245	10.764	.002
Dose x Vocabulary	1	0.001	0.028	>.500
Error	74	0.023		
Task	1	1.160	223.971	<.001
Dose x Task	1	0.003	0.592	.445
Vocabulary x Task	1	0.072	13.910	<.001
Dose x Vocabulary x Task	1	0.016	3.018	.087
Error	74	0.005		
Set Size	2	0.128	26.903	<.001
Dose x Set Size	2	0.010	2.020	.137
Vocabulary X Set Size	2	0.002	0.495	>.500
Dose x Vocabulary x Set Size	2	0.001	0.111	>.500
Error	74	0.005		
Decision	1	0.032	8.338	.006
Dose x Decision	1	0.064	16.966	<.001

TABLE 27 (cont)

Source	DF	Mean Square	F-Test	Significance
Vocabulary x Decision	1	0.004	1.076	.303
Dose x Vocabulary X Decision	1	0.009	2.419	.125
Error	74	0.004		
Task x Set Size	2	0.060	13.936	<.001
Dose x Task x Set Size	2	0.003	0.803	.450
Vocabulary x Task x Set Size	2	0.000	0.040	>.500
Dose x Vocabulary x Task x Set Size	2	0.002	0.413	>.500
Error	74	0.004		
Task x Decision	1	0.002	0.269	>.500
Dose x Task x Decision	1	0.037	5.770	.019
Vocabulary x Task x Decision	1	0.006	0.936	.337
Dose x Vocabulary x Task x Decision	1	0.000	0.006	>.500
Error	74	0.006		

TABLE 27 (cont)

Source	DF	Mean Square	F-Test	Significance
Set Size x Decision	2	0.007	1.698	.187
Dose x Set Size x Decision	2	0.001	0.307	>.500
Vocabulary x Set Size x Decision	2	0.002	0.367	>.500
Dose x Vocabulary x Set Size x Decision	2	0.002	0.357	>.500
Error	74	0.004		
Task x Set Size x Decision	2	0.011	2.570	.080
Dose x Task x Set Size x Decision	2	0.017	4.020	.020
Vocabulary x Task x Set Size x Decision	2	0.005	1.217	.299
Dose x Vocabulary x Task x Set Size x Decision	2	0.007	1.622	.202
Error	74	0.004		

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