

SPEED-ACCURACY TRADEOFFS IN
SPATIAL ORIENTATION INFORMATION PROCESSING

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ABSTRACT

A study was conducted to further evaluate the Manikin Task, a test of spatial orientation information processing. The objectives of the study were to determine the speed vs. accuracy tradeoff characteristics of the task and to assess performance on the task under the influence of ethyl alcohol. Response times and accuracy were measured on five subjects over a five-week period. Analysis of the data indicated a definite decline in accuracy corresponding to a forced decrease in response time. The effect of alcohol was evidenced by a change in the slope of the speed-accuracy tradeoff function.

INTRODUCTION

An important element of many military and industrial tasks is the human ability to perform spatial orientation information processing. With respect to the task of piloting high-performance jet aircraft, spatial disorientation has consistently been cited as the cause of numerous accidents throughout the history of flight (Kirkham, 1978). It is vitally important, therefore, that the pilot and crew members maintain their ability to differentiate right vs. left and up vs. down based on available visual cues while under severe conditions of disorientation and exposure to various types of stressors.

A complex reaction time test known as the Manikin Task was developed by the Royal Air Force Institute of Aviation Medicine as a test of spatial orientation capability (Benson and Gedye, 1963). The task is a visual performance activity in which a sequence of human figures (manikins) in various orientations is presented on a CRT screen. The orientation categories consist of front-erect, front-inverted, back-erect and back-inverted.

For each presentation, the subject is required to identify in which hand (left or right) the manikin holds a particular shape (circle or square) identical to one presented below the figure. To achieve this, the subject must mentally rotate the figure and discriminate the right side from the left. The original task employed 35 mm slides in presenting the orientation series. Improved versions have been developed us-

ing computer generated CRT displays.

The Manikin Task has been shown to satisfy many of the criteria necessary to be considered a useful laboratory measure. In particular:

1. subjects can learn the task within 4 to 10 training sessions, each of 30 minutes duration;
2. the rate of acquisition of plateau performance is independent of the training schedule, occupational level and age of the subject;
3. the task has a high level of differential stability, i.e., individual performance remains essentially constant over time (Reader et al., 1981).

In addition, the task has been shown to be sensitive to mild hypoxia (Benel and Storm, 1981) but insensitive to changes in head temperature under hyperthermic conditions (Nunneley, Reader and Maldonado, 1982).

The objectives of the current study were:

1. to measure the speed vs. accuracy tradeoff characteristics of the task and
2. to assess performance on the task under the influence of ethyl alcohol.

SPEED-ACCURACY TRADEOFFS

With respect to many psychomotor tasks, it has been proposed that the inconsistency of previous results concerning the effects of alcohol on reaction time (RT) may be related to possible tradeoffs between speed and accuracy (Jennings et al, 1976). In the majori-

ty of information processing studies in which RT is used as the primary criterion, subjects are usually encouraged to respond "as rapidly and accurately as possible." The RT and error rate values thus represent an unpredictable compromise between the incompatible demands for maximum accuracy and minimum RT. This compromise is a function of several variables including the actual experimental conditions under investigation. It is therefore difficult to derive any valid conclusions in situations where the change in subject criteria is not identified and measured.

Several researchers have suggested that the solution to these problems is to utilize the complete tradeoff function as a measure of information processing performance in which changes in bias for speed and accuracy can be directly assessed. This approach allows one to distinguish a shift in the subject's speed-accuracy criteria from a possibly more significant change in processing efficiency independent of a shift in criteria. Processing efficiency differences can be easily identified by changes in either the slope or RT intercept of the tradeoff function.

This procedure has been employed in at least two studies evaluating the effects of alcohol on speed-accuracy tradeoffs. In an experiment by Jennings et al. (1976), five levels of alcohol were examined ranging from 0.00 to 1.33 ml/kg of body weight. Increasing doses of alcohol produced a progressive decrease in the slope parameter of linear equations fit to the speed-accuracy data, but did not significantly alter the intercepts of the functions with the RT axis. Thus, alcohol reduced the performance efficiency by decreasing the rate of growth of accuracy per unit time. Similar results were obtained in a study by Rundell and Williams (1979) who examined alcohol levels from 0.0 to 1.0/g/kg of body weight.

In both studies, deadline conditions were used to force subjects to respond within various time limits. The time limits were selected to provide accuracies ranging from chance levels to near perfection. These procedures have the effect of altering the workload demand such that the shorter time limits create extreme time-stressed conditions. A similar approach was employed in the current study to generate the data for computing speed-accuracy tradeoff functions for the Manikin Task. Data was collected for both baseline and alcohol conditions.

EXPERIMENTAL METHODOLOGY

Subjects

Five male subjects, ages 18 to 49, participated in the study. All subjects were right-handed with normal (20/20 corrected) vision and were light to moderate social drinkers. Each subject performed the task under both baseline and alcohol conditions. The experimental protocol was approved by the Human Use Committee and the voluntary informed consent of the subjects was obtained in accordance with AFR 169-3.

Task

Each subject was instructed to observe a 25 cm CRT display (Digital Equipment Model VRL7LC) located 1 meter in front of him (approximately 15° visual angle). For each stimulus presentation, the subject was to mentally reorient the manikin and decide in which hand the manikin held a shape identical to the shape displayed at the bottom of the screen. A response was registered by pressing either the right or left button on a subject panel, always using the same finger of the right hand. Reaction time was measured from the initial presentation of the stimulus until the subject's response and recorded along with the accuracy of the response.

Procedure

The investigation consisted of initial training sessions, testing sessions to derive the speed-accuracy tradeoff function under baseline conditions and testing sessions employing alcohol.

Training. In the initial training sessions, each manikin remained on the screen for 2 seconds with a 1-second pause between presentations. A series of 96 manikins was presented in a random sequence followed by 2 minutes of rest. Four sequences were grouped to form a single testing session lasting approximately 25 minutes. All subjects participated in a minimum of 7 training sessions.

Baseline. Following training, the amount of time that the manikin remained on the screen was reduced to levels ranging from 400 to 1000 msec. The pause between presentations was increased accordingly to maintain a 2-second interval between the start of successive presentations. All other variables remained the same as during the training sessions. Subjects were instructed to respond "at or before the

instant the manikin leaves the screen." This provided the deadline conditions essential for measuring subject performance over a wide range of speed and error rates.

Alcohol. In addition to the baseline condition, a single alcohol dose consisting of 0.5 to 0.75 grams of pure alcohol per kilogram of body weight was administered to each subject. The actual dose depended on the body composition of the individual subject and was the calculated dose required to raise the subject's blood alcohol concentration (BAC) to a level of 0.08%. Subjects were instructed not to consume alcoholic beverages on the evening before the testing trial. Testing sessions were conducted in the morning prior to the consumption of any food or drink other than water.

The equivalent volume of 86 proof bourbon was combined with water in the ratio of two parts water to one part alcohol. Subjects were allowed 15 minutes to consume the beverage. Following consumption, blood alcohol levels were indirectly measured using an Intoxilyzer, Model 4011 alcohol-in-breath tester manufactured by CMI Incorporated.

Testing was initiated approximately 30 minutes after consumption of the alcohol. To sustain peak BAC levels, a maintenance dose of 0.05 g/kg of body weight was administered every 20 minutes. Following the experimental task, the subject was monitored until his BAC was at or below 0.005% and was then released.

Trial Sequence. Each subject entered the laboratory in the early morning and performed three baseline testing sessions, one each under the 1000, 700 and 400 msec deadline conditions. The subject was then weighed and the appropriate alcohol dose was calculated. Alcohol was administered and sufficient time elapsed for the subject to attain the desired BAC level. The subject then performed three additional testing sessions, again at 1000, 700 and 400 msec.

RESULTS

Training

With respect to training, it was evident that all subjects attained stabilized performance within the first seven sessions with some subjects requiring only four to five sessions. It was also evident that without the deadlines, high accuracy rates (95 to 99 percent correct) were attained even dur-

ing the initial stages of training. A previously discovered dependency of reaction times on specific manikin orientations was also confirmed in the present study.

Deadlines

The deadline procedures used to generate the tradeoff functions successfully produced a shift in accuracy and reaction time. Mean values for these variables are given in Table 1 for both the baseline and alcohol conditions. For the 1000 and 700 msec deadlines, subjects were able to consistently beat the deadline. This could not be accomplished for the 400 msec deadline where the subjects responded a full tenth of a second late on the average.

Significant declines in accuracy accompanied the reduced reaction times forced by the shorter deadlines for both the baseline and alcohol conditions. Statistical analysis indicated that all three deadlines produced significantly different ($p < 0.05$) levels of accuracy as measured by the percentage of correct responses. Figure 1 shows the mean accuracy levels for each deadline. Under baseline conditions, the percentage correct dropped from 98% at 1000 msec to 93% at 700 msec followed by a sharp decline to 68% at 400 msec.

Alcohol

With respect to the alcohol evaluation, the administration procedures were successful in generating the desired BAC levels. In addition, a speed-accuracy tradeoff shift appeared to occur. Examination of the reaction times indicated minimal difference between the baseline and alcohol conditions. The analysis of variance also showed no significant difference in reaction times.

However, there were statistically significant differences in accuracy levels. The mean percent correct varied from 89% for the 1000 msec deadline to 77% at 700 msec to 54% at 400 msec. These are significantly different from the accuracies under the baseline condition. This can also be seen in Figure 1.

A plot of percent correct vs. reaction time is presented in Figure 2. Each point represents a single testing period. A simple least-squares linear regression reveals a distinct difference in slope between the baseline and alcohol conditions.

Table 1. Mean Accuracy and Reaction Times for Various Deadlines Under Baseline and Alcohol Conditions

Deadline (msec)	Baseline		Alcohol	
	Accuracy (% correct)	Reaction Time (msec)	Accuracy (% correct)	Reaction Time (msec)
1000	98%	652	89%	693
700	93%	605	77%	598
400	68%	508	54%	517

CONCLUSIONS

The results of the study may be summarized as follows:

1. It is possible to generate speed-accuracy tradeoff functions for the Manikin Task, thus verifying that the task is sensitive to workload demands.
2. The slope of the tradeoff function is influenced by the presence of alcohol.

Further analysis of the data is currently being performed. An evaluation is being made of alternative accuracy measures involving various transformations of the proportion correct. Additional work is also being performed to verify that the task is a valid measure of the spatial orientation process.

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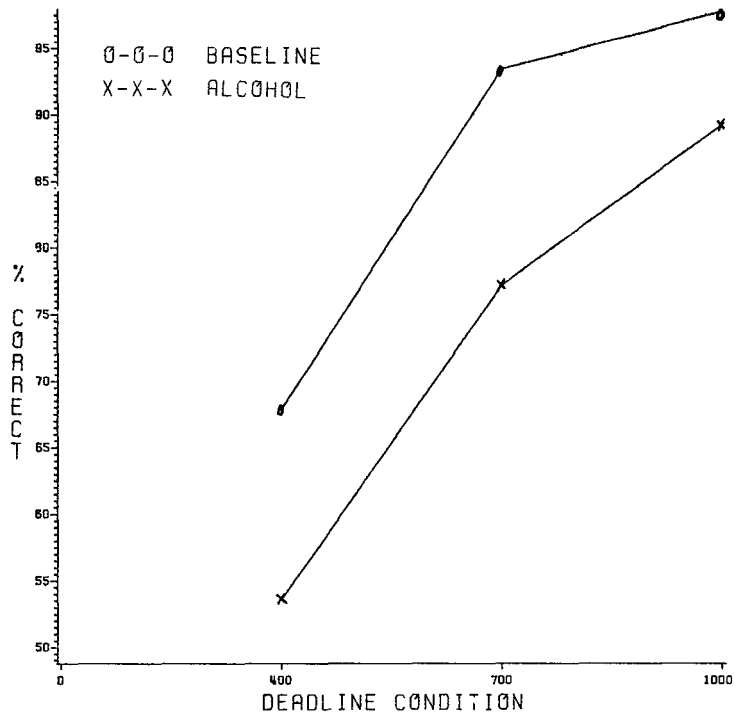


Figure 1. Mean Accuracy Level as a Function of Deadline Condition

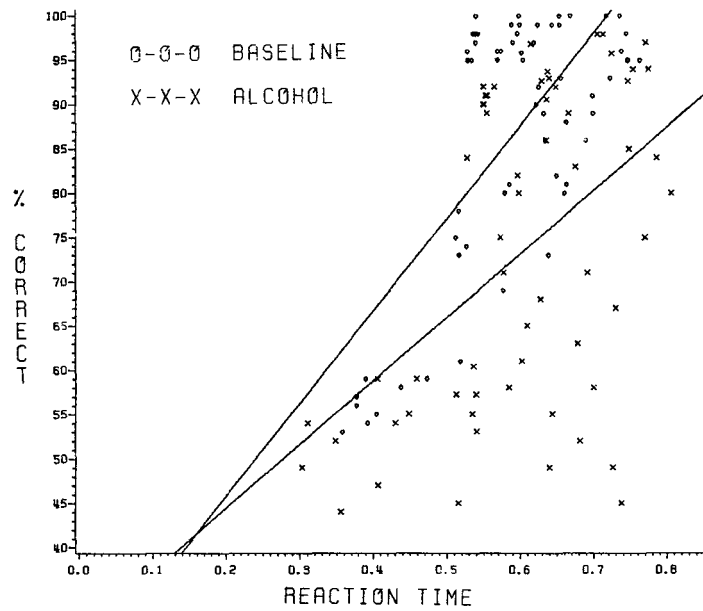


Figure 2. Accuracy vs. Speed Tradeoff for Alcohol and Baseline Conditions