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Effects of graded doses of alcohol on speed-accuracy tradeoff in choice reaction time

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The inconsistency of previous results concerning the effects of alcohol on reaction time (RT) may be related to possible tradeoffs between speed and accuracy. In the present experiment, complete speed-accuracy tradeoff functions were generated for each of five doses of alcohol (0-1.33 ml/kg) in a choice RT task. Such functions permit RT differences resulting from changes in performance efficiency to be distinguished from those due to changes in subjects' speed accuracy criteria. 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 intercept of the functions with the RT axis. Thus, alcohol reduced performance efficiency by decreasing the rate of growth of accuracy per unit time. A change in speed-accuracy criterion was combined with the decrease in efficiency at the highest alcohol dose.

The possibility of tradeoffs between speed and accuracy presents an important interpretative problem for choice reaction time (RT) experiments. The term speed-accuracy tradeoff refers to the observation that subjects can achieve increases in speed at the cost of decreases in accuracy, and vice versa, over a substantial range (e.g., Fitts, 1966; Lappin & Disch, 1972a, b; Pachella & Fisher, 1969, 1972; Swensson, 1972a). Thus, variations in subjects' bias or criterion for speed vs. accuracy (i.e., the particular compromise between speed and accuracy adopted in a given situation) can produce substantial changes in RT, even under constant experimental conditions. Unless subjects' speed-accuracy criteria can be in some way assessed or controlled experimentally, variations in criteria may produce changes in RT totally apart from the experimental variable of interest. For additional discussion of the problem of speed-accuracy tradeoffs in choice RT experiments, see Pachella (1974).

Fitts' Law

* In order to control for possible changes in speed-accuracy criterion, complete speed-accuracy functions may be compared across experimental conditions instead of mean RTs and error rates (Lappin & Disch, 1972a; Pachella, 1974; Pew, 1969; Swensson, 1972b). Speed-accuracy tradeoff functions have been generated empirically by inducing subjects to vary their speed-accuracy criteria systematically over a wide range, resulting in pairs of joint speed-accuracy values reflecting different criteria. The function relating speed and accuracy may then be used as a criterion-controlled dependent variable, much as the ROC function relating hit rate and false-alarm rate provides a criterion-controlled dependent variable in signal detection experiments. Thus, if a change in mean RT from one experimental condition to another results solely from changes in speed-accuracy criterion, then the speed-accuracy tradeoff functions derived separately for each condition should be indistinguishable. Otherwise, changes in mean RT should be accompanied by differences in the speed-accuracy tradeoff functions for the two conditions.

The present experiment employed speed-accuracy tradeoff functions to investigate the influence of graded doses of alcohol on choice RT. Two aspects of previous results suggested the potential utility of speed-accuracy concepts in alcohol experiments. First, although alcohol in moderate doeses is generally assumed to increase choice RT, a number of investigators have reported no significant effects of alcohol on choice RT, at least under some conditions (Carpenter, 1962; Huntley, 1972, 1974; Moskowitz, 1973; Pearson, 1968). These inconsistent results may be due to undetected variations in speed-accuracy criteria. For example, Tharp, Rundell, Lester, and Williams (1974) have recently reported an instance of increased error rate under alcohol without significant changes in RT. Second, speed-accuracy tradeoff techniques may clarify the relation between alcohol at different dose levels and choice RT. Deficits in choice RT have not been commonly observed at blood alcohol concentrations lower than 80 mg% (mg/100 ml of blood) (Carpenter, 1962; Shillito, King, & Cameron, 1974), and some investigators have suggested that low doses of alcohol may even facilitate performance in tasks such as choice RT (Carpenter, 1968; Wilkinson & Colquhon, 1968). Similarly, pharmacologists have suggested that alcohol in low doses often acts as a psychological stimulant despite its clear pharmacological role as a depressant at higher doses (Ritchie, 1970). These somewhat paradoxical dose-dependent effects of alcohol may

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potentially be clarified through a speed-accuracy tradeoff analysis. For example, the apparent facilitatory effects of alcohol in low doses might be due entirely to changes in criteria toward increased emphasis on speed at the expense of accuracy.

In the present study, speed-accuracy tradeoff functions were computed for each of five alcohol doses. The functions were based on auditory choice RTs collected using a deadline procedure (e.g., Green & Luce, 1973). Tradeoff functions derived from this and related procedures appear to offer a number of methodological advantages over functions based on post hoc categorization of the RT data (Wickelgren, in press; Wood & Jennings, 1976). On a practical level, the deadline procedure assisted in clearly and consistently defining the task to the subjects, a factor which may be of considerable importance in alcohol experiments.

METHOD

Subjects

Five healthy adult males served as unpaid volunteers. All were light-to-moderate social drinkers with no medical conditions that contraindicated alcohol consumption. One subject was dropped and replaced due to equipment failure.

Each subject served under all of the five alcohol dose conditions. Following 2 or more practice days, each subject performed the choice RT task under a different alcohol dose on each of 5 days. The order of the doses was determined by a 5 by 5 Latin square.

The Choice RT Task

A choice RT paradigm was employed with two easily discriminable, response-terminated, pure-tone stimuli (1,000 and 1,100 Hz at 70 dB SL). A signaled deadline procedure required subjects to make their choice response prior to the onset of a visual deadline signal. The time interval between the tone stimulus and the deadline signal was constant within 100-trial blocks and was varied across blocks over the following intervals: 175, 225, 275, 325, and 375 msec. Subjects were awarded 2 points for each correct response prior to the deadline signal and were penalized 1 point for each response that was incorrect or beyond the deadline interval. Accuracy feedback was provided following each trial only if the response occurred prior to the deadline. The order of the deadline conditions for each session was determined by a 5 by 5 Latin square. A practice block with a 450-msec deadline preceded the five experimental blocks in each session.

Stimuli were presented binaurally over earphones to the subject, who was seated in a sound-attenuating chamber. White noise at approximately 25 dB SL was presented into the earphones throughout each session. Response keys were microswitches placed on the arm of the chair corresponding to the subject's dominant hand. A feedback display panel was positioned on the wall opposite the subject at a distance of less than 1 m. The display panel consisted of a blue deadline light, which was activated at the termination of the deadline interval, and green and red lights, which indicated correct and incorrect responses. Stimulus presentation and timing were achieved by a logic system composed of BRS and Coulbourn Instruments modules. The stimulus-response codes and RT on each trial were recorded with a Hewlett-Packard 5050B printer.

Alcohol

The alcohol doses consisted of a placebo, 0.33, 0.67, 1.00, and 1.33 ml of 95% ethyl alcohol/kg body weight. Subjects were instructed not to consume alcoholic beverages outside the experimental situation and not to take any other drugs throughout the week of the study. A fast of 4 h minimum prior to each experimental session was required. The scheduled dose for a given day was combined with enough orange drink to total 3.00 ml/kg body weight. This volume was divided into four equal portions and subjects were required to consume a portion every 6 min for a total drinking time of 24 min. The placebo dose contained 5 ml of alcohol floated on top of the first drink. An assistant administered the drinks and performed blood alcohol determinations with a Smith and Wesson Model 900 Breathalyzer. A double-blind procedure insured that neither subject nor experimenter knew the dose being administered. Breathalyzer determinations were made approximately every 10 min after allowing 20 min for elimination of residual alcohol in the mouth and throat mucosa (Spector, 1972). To insure that performance measures were obtained during absorption of alcohol into the blood (i.e., the ascending limb of the blood alcohol curve), the choice RT testing began at a predetermined blood alcohol level just below the expected peak reading for that dose.

Calculation of Speed-Accuracy Tradeoff Functions

Speed-accuracy tradeoff functions were computed for each subject under each alcohol dose condition. For each deadline condition, a mean RT was computed based on all 100 trials in that condition, regardless of accuracy and regardless of the relation between the obtained RT values and the nominal deadline. These mean RTs were paired with the corresponding accuracy values for each condition, and linear regressions of accuracy on RT were computed over the five deadline conditions in each alcohol dose. For this purpose, the linear regression equation may be written $A = m(RT - c)$, in which A represents accuracy, m represents the slope, and c represents the intercept of the function with the RT axis at chance accuracy.

A transformation of proportion correct [P(C)] was used as an accuracy measure. The relation between P(C) and RT is typically negatively accelerated [i.e., nonlinear—see Pachella, 1974, and the RT-P(C) means for the five deadline conditions presented below]. In other words, larger changes in RT are associated with an increase in P(C) from .90 to .95 than with an increase from .55 to .60. Therefore, the use of linear equations as simple summary statistics of the speed-accuracy tradeoff functions required transformation of the raw P(C) values for each deadline condition.

The information transmitted or contingent uncertainty between stimuli and responses [U(x:y), Garner, 1962] was employed to transform the P(C) values in the present experiment. This measure was selected on the basis of empirical considerations and recent comparisons of alternative accuracy transforms by Lappin and Disch (1972a) and Swensson (1972a). Taken together, these experiments compared a total of seven different transforms of P(C), including d′, U(x:y), and $-\ln\eta$. Neither experiment found consistent differences in the empirical goodness of fit of linear equations based on the different accuracy transforms. The proportion of variance in the speed-accuracy data accounted for by the linear equations (r^2) ranged from .72 to .96. Given the roughly equivalent goodness of fit of different transforms, U(x:y) was selected because it was the only one among those studied which is defined at $P(C) = 1.0$. This property was necessary in the present experiment because of the high levels of accuracy obtained in the placebo and low alcohol conditions.[1]

Garner

RESULTS

Preliminary Analyses

Before analyzing the speed-accuracy tradeoff functions, the effectiveness of the deadline conditions in manipulating speed and accuracy and the effectiveness of the alcohol doses in changing blood alcohol levels were assessed. The effects of deadline condition and drug dose were analyzed in a two-way analysis of variance on P(C). Correct responses were

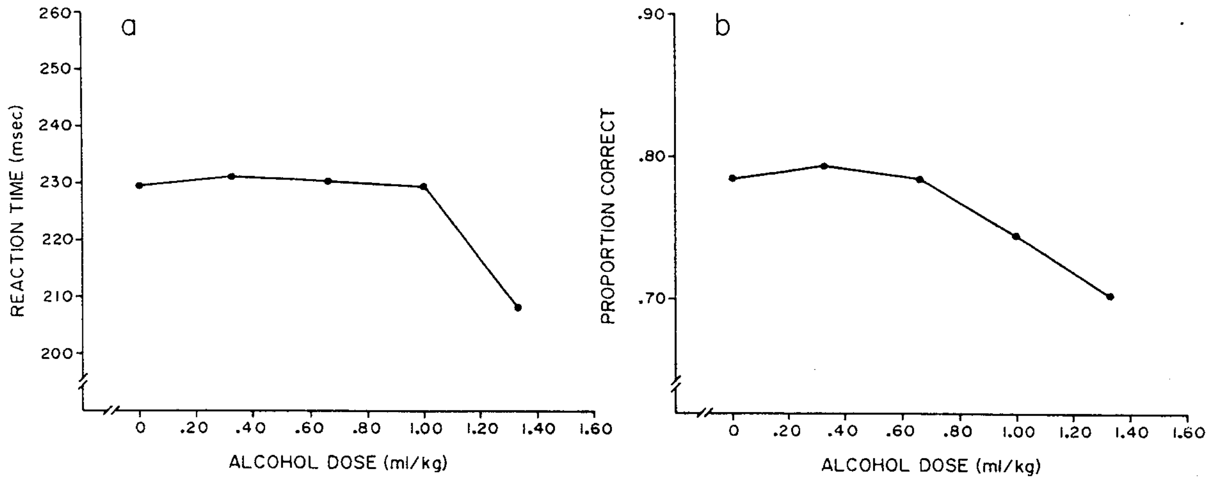

Figure 1. Mean choice RT (a) and proportion correct (b) as a function of alcohol dose.

included in the P(C) value, even if they occurred after the deadline. An additional factor, correct vs. error responses, was included in a three-way analysis on RT. The average of the Breathalyzer alcohol readings just before and just after the five RT blocks was analyzed in a separate one-way analysis of variance with alcohol dose as the independent variable. All analyses used a rejection region of $p < .05$. The degrees of freedom used in the repeated measures analyses were reduced because homogeneity of the variance-covariance matrices could not be assumed.[2] Post hoc comparisons between individual means were performed using the Tukey (b) technique (Winer, 1962).

The five alcohol doses produced highly consistent differences in breath alcohol levels, F(adjusted df 1,4) = 260.0. The mean breath alcohol reading for the placebo condition was 0 mg% (milligrams of alcohol per 100 ml of blood), 20 mg% for the .33-ml/kg dose, 60 mg% for the .66-ml/kg dose, 90 mg% for the 1.00-ml/kg dose, and 110 mg% for the 1.33-ml/kg dose.

Reaction time was significantly influenced by deadline condition and correct vs. error response, but not by alcohol dose, F(adjusted df 1,4) = 46.52, F(1,4) = 12.45, and F(adjusted df 2,6) = 4.17, respectively. Proportion correct values were significantly influenced by deadline condition, F(adjusted df 1,4) = 52.09, but not by alcohol dose, F(adjusted df 2,8) = 2.58. Mean RT and corresponding P(C) values for the 175-375-msec deadline conditions were 170 msec (.59), 192 (.67), 227 (.78), 257 (.87), and 278 (.89). All RTs were included in these means, both those before and those after the nominal deadline. Mean RTs for correct and error responses were 230 and 201 msec, respectively.

The preliminary analyses thus established two important methodological points: (a) the desired effect of the deadline procedure in manipulating RT and P(C); and (b) the desired effect of the alcohol doses on blood alcohol concentration.

Although not statistically significant, the effects of alcohol on the mean RT and P(C) for each dose provide a useful background for the assessment of performance using the speed-accuracy tradeoff functions. Mean RT and P(C) across all deadline conditions for each dose are presented in Figure 1. Note that the RT data suggest a facilitation of performance at the highest alcohol dose (i.e., a decrease in RT), while the P(C) results suggest a performance decrement [i.e., a decrease in P(C)]. The use of speed-accuracy tradeoff functions permits an unconfounded analysis of results such as these, which is impossible based on the mean speed and accuracy data alone.

Alcohol and Speed-Accuracy Tradeoff Functions

Illustrative speed-accuracy tradeoff functions for a single subject are presented in Figure 2. This figure compares tradeoff functions for this subject at the placebo and 1.33-ml/kg doses and also illustrates the goodness of linear fit to the data for each dose. The average r^2 over all subjects and doses was .84, and did not differ significantly between doses.[3]

The speed-accuracy tradeoff functions for different alcohol doses were compared statistically using the slope and intercept parameters of the best fitting linear equations for each subject at each dose. Mean slopes and RT intercepts are presented in Table 1 as a function of alcohol dose. One-way analyses of variance showed that the decrease in slope with increasing alcohol dose apparent in Table 1 was significant, F(adjusted df 2,10) = 5.31, while the intercept values did not differ significantly, F(adjusted df 2,10) = 3.18. The decreasing linear trend in slope with increasing alcohol dose was highly significant, F(1,4) = 19.58, accounting for 92% of

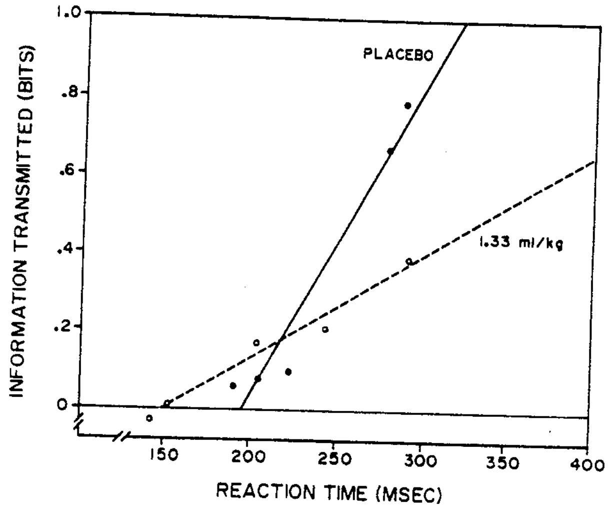

Figure 2. Speed-accuracy tradeoff functions for a single subject in the placebo (filled circles) and the 1.33-ml/kg (open circles) dose conditions. The solid and dotted lines are the least squares linear fits to the data for each condition. The RT intercept and slope measures for the placebo condition were 195 msec and .00798 bits/msec. Corresponding values for the 1.33-ml/kg dose were 150 msec and .00265 bits/msec. The horizontal line at U(x:y) = 0 represents chance performance.

the variance in the slope means. Individual comparisons among the slope means indicated that the 1.33-ml/kg dose differed significantly from the placebo and .33-ml/kg doses. Thus, the rate of increase in accuracy per unit time (i.e., the slope) decreased in a generally linear fashon with increasing dose.

A potential problem associated with using the slope and intercept parameters as summary statistics is that changes in one parameter may be compensated for by changes in the other parameter. For example, a decrease in slope indicating a decrease in performance may be offset by a concomitant decrease in the intercept indicating an increase in performance. The slope and intercept data presented in Table 1 illustrate several possible instances of compensating changes in the two parameters. For example, note that the progressive decrease in slope is interrupted at the 1.00-ml/kg dose, where there appears to be little additional decrement over that produced by the .66-ml/kg dose. However, even though the intercept did not differ significantly across doses, the numerical increase in the intercept at the 1.00-ml/kg dose tends to offset the relatively high value of the slope at this dose. These considerations suggest that neither the slope nor the intercept can provide an unambiguous performance index unless the other parameter is virtually constant. Clearly, both parameters should be analyzed in order to assess the possibility of compensating effects. Furthermore, an overall index of speed-accuracy performance which takes such effects into account would seem highly desirable.

Table 1
Mean Slopes and Intercepts of Best-Fitting Linear Equations for Each Alcohol Condition

	Alcohol Dose (mg/kg)				
	0	.33	.66	1.00	1.33
Slope (bits/msec)	.00645	.00571	.00492	.00490	.00338
Intercept (msec)	168	162	161	173	150

One way of incorporating both the slope and intercept parameters into a single measure of performance is presented in Figure 3, which shows mean information transmitted as a function of alcohol dose at three selected values of RT (200, 250, and 300 msec). These data represent "equal-RT contours" derived by solving the linear tradeoff equation for each subject and dose at each of the three indicated values of RT. Since this procedure is based on the complete tradeoff equations, it directly takes into account the changes in both the slope and intercept parameters. Reference to Figure 2 provides a graphical illustration of the procedure: at 250 msec, the U(x:y) value for the placebo dose would be .42, while the 1.33-ml/kg dose value would be .24. Thus, Figure 3 provides a slightly different perspective on the differences in the speed-accuracy tradeoff function parameters shown in Table 1. At the relatively fast RT level of 200 msec, accuracy was relatively low and was uninfluenced by alcohol. In contrast, at the relatively slow RT of 300 msec, alcohol produced a progressive decrease in accuracy. These conclusions were verified statistically by a

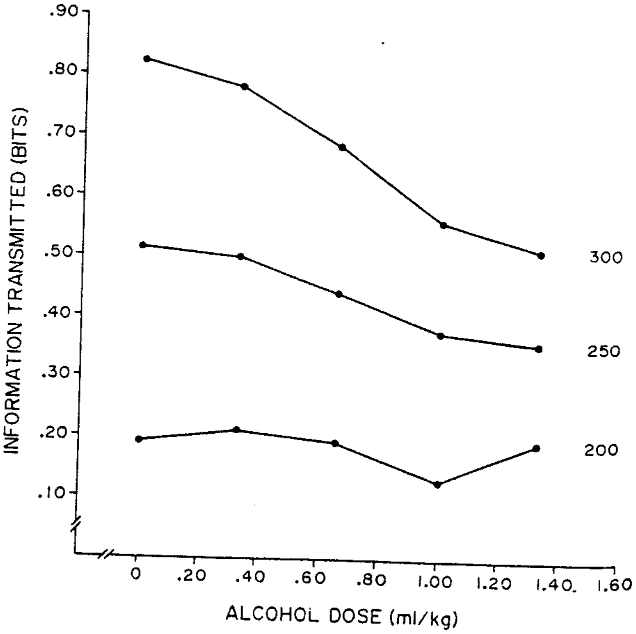

Figure 3. Mean accuracy [U(x:y)] as a function of alcohol dose for three values of RT (200, 250, and 300 msec). These data were derived by inserting the three values of RT into each subject's tradeoff equation and solving for corresponding values of U(x:y).

two-way analysis of variance on the data in Figure 3, which indicated the expected significant RT by Dose interaction, F(adjusted df 2,7) = 6.18, a significant main effect of RT, F(adjusted df 1,4)= 73.35, but no significant main effect of dose, F(4,16) = 2.99. The RT by Dose interaction was assessed further by analyses of the simple effects of dose at each of the three values of RT to verify directly the impression given by Figure 3. The dose effect was significant at RT = 300 msec, F(adjusted df 1,4) = 7.81, but not significant at either RT = 200 or RT = 250 msec, F(4,16) < 1.00 and F(4,16) = 2.42, respectively.

Other Effects of Alcohol

To assess the influence of alcohol on subjects' ability to comply with the deadline procedure, obtained mean RTs for each deadline condition were regressed on the nominal value of the deadline, i.e., 175, 225, 275, 325, or 375 msec. Alcohol did not significantly affect the degree of compliance with the nominal deadlines, F(adjusted df 2,7) = 3.39. The beta weights reflecting compliance with the deadlines were uniformly high; the equivalent correlation coefficients were .97, .98, .96, .93, and .95, for the placebo to 1.33-ml/kg doses. Thus, alcohol failed to produce significant shifts away from near perfect compliance with the nominal deadline values.

Another potential effect of alcohol might be to increase RT variability relative to the placebo dose. The standard deviations of the RT distributions were compared in a three-way analysis of variance with deadline, alcohol dose, and correct vs. error responses as factors. Neither deadline nor alcohol dose produced significant effects upon RT standard deviations, F(adjusted df 1,5) = 5.05 and F(adjusted df 2,9) = 3.84, respectively.

DISCUSSION

The effects of graded doses of alcohol on choice RT performance obtained in the present experiment illustrate the importance of considering both speed and accuracy as dependent variables in choice RT experiments. If mean RT were considered without respect to accuracy, the results shown in Figure 1a would suggest that alcohol produced no discernible decrement in performance. However, when the accuracy data in Figure 1b are considered as well, it is clear that subjects may have maintained roughly constant RT performance by sacrificing accuracy at the higher alcohol doses; that is, by changing their speed-accuracy criteria.

Based on a single pair of mean RT and accuracy values for each dose, it is impossible to determine whether the joint changes in speed and accuracy shown in Figure 1 represent: (a) changes due solely to random error, (b) changes in speed-accuracy criteria, or (c) changes in RT performance independent of changes in criteria. The first alternative is indicated if neither RT, accuracy, nor speed-accuracy tradeoff functions differ significantly across conditions. The latter two alternatives may be distinguished by the pattern of significant differences in RT, accuracy, and the tradeoff functions. Specifically, a change in criterion or tradeoff bias is demonstrated when an obtained difference in RT or accuracy results solely from a shift in performance along a single speed-accuracy tradeoff function. In contrast, a change in performance *efficiency* is demonstrated by a shift in performance from one speed-accuracy tradeoff function to another. Combined changes in efficiency and criterion may be observed when changes in the speed-accuracy tradeoff function are combined with changes in the relative position of obtained RTs along the function.

When the effects of alcohol in the present experiment were analyzed using the tradeoff function approach, alcohol in the dose range from 0 to 1.33 ml/kg was found to produce changes in both performance efficiency and speed-accuracy criterion. Alcohol was shown to influence performance efficiency first in analyses of the slope and intercept parameters of the tradeoff functions. These results suggested that alcohol produced a decrease in the rate of growth of accuracy over time, but had no significant effect on the point in time following stimulus onset at which such growth began. A second means of comparing the tradeoff functions which incorporated both slope and intercept parameters confirmed the effects of increasing doses of alcohol seen in the separate slope and intercept analyses. This second set of analyses involved the formation of "equal-RT contours" by using the linear tradeoff equations to hold RT constant and compute corresponding accuracy values for different alcohol doses. The equal RT contour data demonstrated that the effect of alcohol on performance efficiency was dependent upon the levels of accuracy and RT at which performance was measured. Alcohol did not significantly influence relatively fast and inaccurate responses. This conclusion is evident in the nonsignificant intercept results discussed above, since the intercept represents the fastest and least accurate region of the tradeoff function. Alcohol did, however, produce large performance decrements in the relatively slow and accurate responses. This conclusion is implicit in the decrease in slope with increasing dose, which implies that the decrement in performance becomes progressively larger at higher levels of accuracy and RT.

Evidence for changes in subjects' criteria or tradeoff bias for speed vs. accuracy was most obvious at the 1.33-ml/kg dose, where performance was least efficient but where mean RT appeared faster than any other dose. More generally, some degree of bias for speed relative to accuracy was observed at all alcohol doses, in that mean RTs remained equal or faster than the placebo condition (Figure 1a) despite the progressive decrease in performance efficiency. A possible exception to this general trend occurred at the 1.00-ml/kg dose, where a tendency toward decreased bias for speed was evident in both the mean RT for the 175-msec deadline condition and also in the intercept data shown in Table 1. These results may reflect either a direct effect of alcohol on speed-accuracy criterion or an interaction of alcohol with the specific experimental demands of the deadline procedure. The possibility of alcohol effects on the speed-accuracy criterion and on response biases in general would appear to merit systematic investigation.

Two aspects of previous results on alcohol and choice RT are clarified by relating them to speed-accuracy tradeoff concepts. First, with regard to the inconsistency of alcohol effects on RT, the obtained decrease in performance efficiency under alcohol strongly supports the conclusion that alcohol decreases choice RT performance (e.g., Carpenter, 1962; Tharp et al., 1974). Unassessed changes in speed-accuracy criteria may have obscured efficiency effects and may account in part for the inconsistency of previous results. As noted earlier, the role of alcohol in such tradeoff bias effects is an important but relatively unexplored issue. The second aspect of previous work concerns the issue of whether progressive increases in alcohol dose produce progressive decrements in choice RT performance. Some experiments have suggested that blood alcohol levels in excess of 80 mg% (approximately the current 1.00-ml/kg dose) are required before any decrease in RT may be observed (Carpenter, 1962; Shillito et al., 1974). In contrast, the present results demonstrated a roughly linearly increasing effect of alcohol over the entire dose range from placebo through 1.33-ml/kg. The absence of effects at low doses in previous experiments may have been associated with unassessed changes in speed-accuracy criterion at these doses.

Finally, although the present results clarify the influence of alcohol on choice RT performance, they do not identify the specific functional processes impaired by alcohol. Some directions toward this goal, however, may be suggested. Since there was no decrement in mean RT with increasing dose, it is unlikely that alcohol produced a simple motor effect. Based on research using the Sternberg (1969) additive factor technique, Huntley (1972) and Tharp et al. (1974) have suggested that comparable alcohol doses do not affect the very initial stages of stimulus processing. The results of these two studies suggest that alcohol may primarily affect more central information processing stages, perhaps related to decision or response selection. The decrease in the rate of growth of accuracy per unit time in the present experiment is not inconsistent with this interpretation. However, since the present results are also consistent with a variety of other interpretations, additional experiments are required to specify more thoroughly the functional processes impaired by alcohol. Such experiments might profitably combine such techniques as Sternberg's additive factor approach with the use of speed-accuracy tradeoff functions.

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NOTES

1. To insure that the alcohol effects to be reported were not specific to the U(x:y) transform, tradeoff functions were also computed using the accuracy measure $-\ln\eta$ of Luce's (1963) choice theory. In order to compute $-\ln\eta$, all $P(C) = 1.00$ were artificially reduced to .99. The $-\ln\eta$ measure is monotonically related to d', is simple to compute, and also appears to provide an adequate fit to empirical speed-accuracy data as noted above. Similar effects of alcohol dose were obtained using both the U(x:y) and $\ln\eta$ measures. Finally, in spite of the nonlinear relationship between P(C) and RT, linear equations were also fit to the P(C) data in order to provide an approximate indication of the alcohol effect on functions based upon raw P(C). Even with marked nonlinearities in some cases, similar patterns of results were obtained using raw P(C) as with the other two measures, although the differences were not statistically significant. In order to permit comparison of the U(x:y) values with untransformed P(C), the following approximations are provided. Under conditions of equal stimulus and response frequencies, P(C) values of .50, .60, .70, .80, .90, and .95 are equivalent to U(x:y) values of 0.00, .03, .12, .28, .53, and .72, respectively. These values are only approximations for data like those in Figures 2 and 3, in which stimulus and response frequencies were not always precisely equal.

2. Degrees of freedom (df) were reduced according to the decision rule proposed by Collier, Baker, Mandeville, and Hayes (1967). Each factor was first tested with the full df to examine whether it was significant under the most favorable conditions for that judgment. If significant, the factor was retested with the conservative df test of Box (see Winer, 1962). If the factor was significant using the conservative test, the null hypothesis was rejected. If not significant according to the conservative test, then an exact test based on df reduced by an empirical value ε was used. If this exact test was significant, the null hypothesis was rejected. The value ε is an index of the relative homogeneity of the variance-covariance matrix associated with the factor being tested. The basic development of the ε-adjustment procedure is found in Greenhouse and Geisser (1959), while Collier et al. (1967) present simulated data supporting its validity.

3. Figure 2 illustrates a potential problem with fitting a single linear function to the speed-accuracy data. In order to estimate reliably the point at which accuracy increases above chance (i.e., the intercept), the low-accuracy, fast-RT region of performance must be sampled with much greater precision than the one or two data points available for each subject and alcohol dose in the present experiment. Since the lower bound on accuracy is approximately $U(x{:}y) = 0$, further decreases in the RT beyond the intercept produce no additional decreases in accuracy. Therefore, fitting a single linear function to data in which the intercept is not estimated precisely may result in underestimation of both the intercept and slope parameters. For example, the function for the 1.33 ml/kg dose in Figure 2 may have been flattened to some degree due to the two points with very fast RTs and chance accuracy. To assess the influence of this potential difficulty, linear functions were fit to the data for each subject and alcohol dose excluding those data points in each function having accuracy values of less than $U(x{:}y) = .05$. Functions fit in this manner showed the same general effects with increasing alcohol dose as the data based on functions fit to all of each subject's data.

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