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Signal Detection Analysis of Ethanol Effects on a Complex Conditional Discrimination

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MELIA, K. F. AND C. L. EHLERS. *Signal detection analysis of ethanol effects on a complex conditional discrimination.* PHARMACOL BIOCHEM BEHAV **33**(3) 581–584, 1989.—The effects of ethanol on a conditional object identification task were investigated using an operant analog of Signal Detection Analysis. Water and three doses of ethanol (0.40, 0.75 and 1.5 g/kg) were orally administered on three separate occasions to three adult squirrel monkeys. Significant discrimination impairment as a function of increasing ethanol dose was observed. At the 1.5 g/kg dose, impairment extended to nonspecific effects, with subjects ceasing to respond early into the session. Subsequent signal detection analyses revealed that the reduction in performance resulted from losses in discriminability. Response bias was found to change unpredictably and independently of ethanol administration. Reaction time measures also showed no changes except a moderate, nonsignificant, facilitation in speed at the lowest (0.40 g/kg) dose. Taken together, these data suggest that ethanol acts to impair complex, or cognitive, performance by disrupting current sources of stimulus control within the range of doses tested.

Ethanol Signal Detection Analysis Complex stimulus control Squirrel monkey

THE reported effects of ethanol upon cognition are quite variable and seem to depend on the dose and the circumstances. For example, performance on some memory tasks has been shown to be negatively affected by even low to moderate doses of ethanol (24,28), but ethanol-induced facilitation on other memory tasks can occur as well (24). In the same way, in animal studies, Devenport and colleagues have reported both enhancement and impairment depending upon the response required (4,5). An absence of ethanol effects is also possible. Schandler *et al.* (23) found no ethanol effect on a complex learning task at doses which reliably increased autonomic arousal. These examples of diverse results suggest that there may be multiple determinants to ethanol's effects on complex, or cognitive performance.

In the present study, a signal detection analysis was used in order to tease apart these potentially confounded determinants. The Theory of Signal Detection (TSD) assumes two independent characteristics of behavior: sensitivity and bias (13,15). Sensitivity is a function of stimulus factors. It relates behavior solely to the task's stimuli. Bias accounts for behavior's susceptibility to perceived rewards and costs. While sensitivity varies as a function of the characteristics of the stimuli, bias varies as a function of the consequences that follow a choice response.

Signal detection procedures have been used successfully in past studies of behavior-drug interactions to demonstrate drug effects unique to either sensitivity or bias [for a review, see (1)]. For example, it has been shown that lysergic acid diethylamide's effects on auditory discriminations are primarily on bias and not sensitivity (6). In contrast, other investigators (2,26) have shown that the cholinergic agents, scopolamine and physostigmine, have their discrimination effects upon sensitivity. More recently, TSD has even been used to elucidate the role of opiates in pain sensitivity (11,12).

The present study takes advantage of the power available in the signal detection paradigm to address the issue of ethanol's seemingly conflicting effects on complex stimulus control. We report here some quantitative, independent effects of ethanol on a complex conditional discrimination in squirrel monkeys.

METHOD

Subjects

Three adult male squirrel monkeys *(Saimiri sciureus)*, weighing 888, 1445, and 850 g at the start of the experiment, served as subjects. All were experimentally-naive before the onset of the study. Following a routine two-week quarantine for health inspection, the animals were brought into the squirrel monkey colony, where they lived in pairs on a 12-hour light/12-hour dark (12:12 LD) schedule. Purina monkey chow was provided each day, along with ad lib water. Prior to, and during the course of the study,

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subjects were under veterinary observation to assure their health status. The design of the study had prior approval by the Scripps Clinic Animal Care and Use Committee and all procedures were in compliance with the Animal Welfare Act and Public Health Service Policy.

Alcohol Dose

Water and three ethanol doses, 0.40, 0.75, and 1.5 g/kg, were each administered in solutions of equal volume on three separate occasions. This is a dose range frequently studied in human cognitive research [see (21, 24, 28)]. In addition, in previous studies it had been determined that 0.75 g/kg was a "threshold" dose for EEG effects in these monkeys, whereas at 1.5 g/kg, the animals began to show EEG signs of sedation (8). One dose lower than 0.75 g/kg (0.40 g/kg) was then included for comparison. On test days, monkeys were chaired briefly for drug administration. Ethanol was diluted with water to a 5 ml volume and administered orally through an infant feeding tube. The order of dose presentations was randomized.

The Task

Training and testing was conducted in a Wisconsin General Test Apparatus (WGTA) (14). Small bits of preferred food were used as reinforcers. The WGTA stimuli were three small white objects (approximately 3 cm in height) mounted onto thin black opaque squares (6 cm × 5 cm × 3 mm). Two of these objects, a cube and a thin square, served as the choice objects; the third object, a sphere, served as a cuing stimulus. The task was a conditional discrimination because the correctness of the choice object was conditional upon the presence or absence of the sphere. When the sphere was present, the square was correct. When the sphere was absent, the cube was correct. This is formally analogous to concept identification tasks found in the human literature [see for example, (19,22)].

Procedure

To control for gradual improvements in performance, baseline data were taken each day before a drug day. Drug days occurred no more than once every seven days. Test sessions contained 30 randomly presented trials, with 15 "cube-correct" trials and 15 "square-correct" trials. Reaction time data were collected on the last 2 out of the 3 sessions for each drug. Subjects were meal-deprived (i.e., ad lib food was removed the evening prior to the 9:00 a.m. test session), but never food-deprived and remained at, or above, free-feeding weights.

Signal Detection Analysis

An operant analog of TSD, behavior detection theory, was utilized [see (3, 16, 17) for reviews]. Behavior detection theory's index of bias is response bias (log b), and is calculated as: log b = 0.5 [log (Hits/Misses) + log (False Alarms/Correct Rejections)]. The index of sensitivity is discriminability (log d) and is calculated as: log d = 0.5 [log (Hits/Misses) − log (False Alarms/Correct Rejections)]. In the present study, the range of possible log d and log b point estimates was −2.999 to +2.999. At chance performance, Log d=0. As discriminability increases, log d scores increase. At log b=0, there is zero response bias. Positive log b scores indicate a bias towards choosing the cube more often, while negative log b scores indicate a tendency to choose the thin square. Each subject's data were summed across sessions to give point estimates of log b, log d, and percent correct for the doses: 0, 0.40, and 0.75 g/kg. A similar pooling and computation was conducted on the baseline data. The 1.5 g/kg ethanol dose proved to be behaviorally toxic, with all subjects stopping early into the test sessions. Consequently, these few data were not considered for analysis.

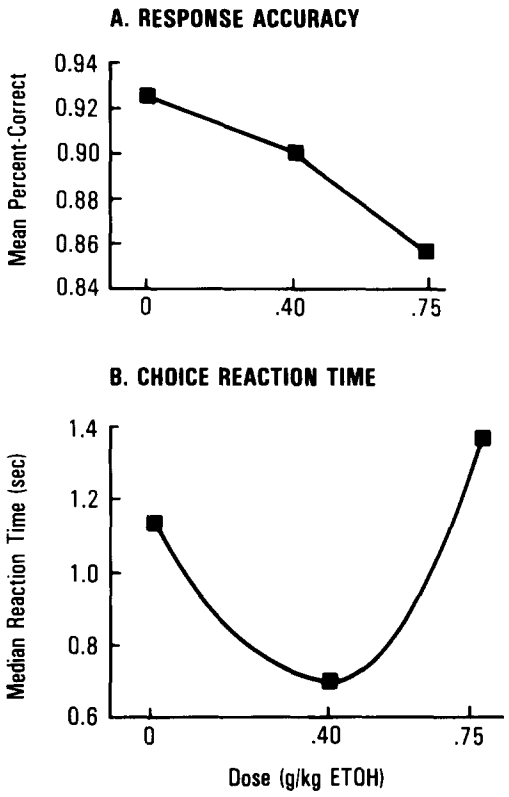

FIG. 1. (A,B) Drug-day performance after administration of 0.0, 0.40, and 0.75 g/kg ethanol. (A) Mean drug-day percent correct. Scores are: 93 ± 3 SEM, 90 ± 4 SEM, and 86 ± 5 SEM for 0.0, 0.40 and 0.75 g/kg ETOH respectively. (B) Median reaction times in seconds. Scores are: 1.13 ± 0.15 SEMd (J. W. Tukey's pseudostandard error of the median), 0.70 ± 0.07 SEMd, and 1.37 ± 2.34 SEMd for 0.0, 0.40 and 0.75 g/kg ETOH respectively.

Data were analyzed with nonparametric statistics. Initial tests of significance considering the general performance measures of percent correct and reaction time were conducted using a randomization test equivalent to the repeated measures ANOVA (7). Nonparametric monotonic trend tests for correlated samples (9) were then used to confirm these findings.

RESULTS

Figure 1A illustrates the relationship obtained between dose and percent correct. At increased ethanol doses, performance declined accordingly (randomization test ANOVA, $p \leq 0.05$). Note that despite significant declines, performance levels remained relatively high throughout, suggesting that the decline was not due simply to generalized incapacitation. A subsequent trend test conducted on the delta (Δ) percent scores (drug-day minus day-before) demonstrated a statistically significant effect of ethanol dose on performance ($z = 2.11$, $p \leq 0.05$, unidirectional test).

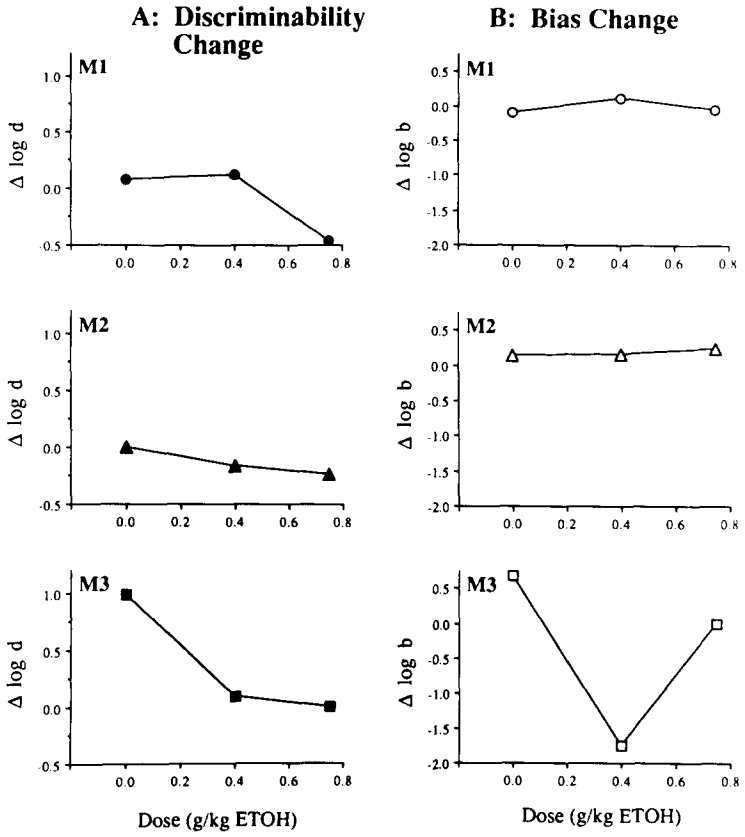

FIG. 2. (A) Change in discriminability (Δ log *d*) as a function of ethanol dose for each subject. Each data point is a point estimate based on 3 sessions, with 30 trials each session. (B) Change in response bias (Δ log *b*) as a function of ethanol dose for each subject. Each data point is a point estimate based on 3 sessions, with 30 trials each session. Note that these are change scores and so do not reflect drug-day response bias alone.

Reaction times also changes as a function of dose, although not linearly. In general, reaction times were fairly low, but they were lowest under 0.40 g/kg ethanol (see Fig. 1B). Median reaction times between doses were not significantly different (randomization test ANOVA, $p \leq 0.19$). Median reaction times under all three doses and all response types were similar and well within 1 sec of each other, except for the median "miss" response time under 0.75 g/kg ethanol, which was 9.3 sec. This outlying reaction time, however, was due only to one monkey's responding unusually slowly on two trials.

Ethanol significantly affected the discriminability index, log *d*. The trend test conducted on the Δ log of *d* scores indicated a significant linear trend ($z = 1.81$, $p \leq 0.05$, unidirectional test). With increasing ethanol dose, mean Δ log *d* scores became increasingly negative. This change in the discriminability index mirrors the change seen in the Δ percent correct scores: the higher the level of intoxication, the greater the debilitation relative to baseline. Figure 2A shows this loss in discriminative control for each monkey.

In contrast to discriminability, response bias did not change in an orderly fashion as a function of ethanol dose (unidirectional trend test, $z = 0.603$, $p \leq 0.26$, for Δ log *b*). The largest shift in response bias away from baseline levels occurred under 0.40 g/kg ethanol, but the variance was considerable under all doses. As can be seen in Fig. 2B, there were no systematic effects on bias as a function of the experimental treatment in these dose ranges.

DISCUSSION

Numerous studies investigating ethanol and complex behavior have reported that ethanol can modify such processes as memory storage (10, 18, 21, 27). Fewer studies have focused on which specific aspects of the behavior are affected by ethanol exposure (4,5). The present study represents an attempt to separate and identify some of these behavioral effects by the use of a signal detection paradigm.

In the present study, low to moderately-high doses of ethanol were administered prior to tests of a conditional discrimination. Significant performance declines occurred following the moderate dose (0.75 g/kg). A measure of stimulus control, discriminability, was also markedly affected by 0.75 g/kg ethanol, while the measure of bias changed unpredictably and independently of dose. No statistically significant reaction time declines were obtained and in fact, reaction times were actually accelerated under the 0.40 g/kg dose of ethanol. Thus, the possibility that ethanol produced its effects through indirect, psychomotor actions is unlikely.

Since several of the behavioral effects of ethanol have been described as "disinhibiting" (25,29), one might have predicted that the observed performance declines were a function of changes in response bias. However, the significant and orderly changes present in Δ discriminability, with the absence of any orderly change in Δ response bias, strongly suggests that the drug effects were confined solely to current levels of stimulus control.

The dose-dependent effects found in this study are consistent with other data on ethanol and primate complex discriminations. Mello (18) has reported slight, but reliable, debilitating effects of increased ethanol on a delayed matching-to-sample task in the rhesus monkey. Geller *et al.* (10) also found ethanol-induced impairment of matching-to-sample, but only at the highest doses examined. The decline in discriminability found in the present study is consistent with the human TSD literature on ethanol and complex stimulus control as well. For example, Wickelgren (27), using a word recognition task, found that ethanol produced a significant decrease in d_a (Wickelgren's analog to sensitivity, or d′). Similarly, Williams and Rundell (28) found dose-dependent declines in sensitivity (d′) on a recognition task, with no attendant changes in bias (β). Parker (20) has also noted that ethanol seems to have its primary amnesic effects on encoding, and that "consolidation" and "retrieval" are not as sensitive to ethanol's effects. Even though the stimulus relations controlling concept identification are not the same as those controlling delayed recognition, it is clear that the first stage in remembering (e.g., "encoding") must entail attention to the task stimuli. Thus, the two findings of a sensitivity decrement in the human literature and a discriminability decrement in the present report may represent a common basis of effect.

The present application of behavior detection theory to the study of ethanol and cognitive performance strongly suggests discriminability as the critical substrate for ethanol's effects in the dose range tested. Moreover, because of the nature of TSD, this determinant of behavior should not be expected to change as a function of either species or task parameters. This is a consistency that is intrinsic to the TSD paradigm and which can be contrasted with the multiplicity of findings typically associated with behavioral effects of ethanol.

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