Alcohol and motion perception

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Three motion perception skills were measured under different levels of alcohol ingestion. Our method for detecting decrements in visual information processing proved sensitive to blood alcohol levels as low as .02%. Alcohol in small doses increased reaction times to the onset of motion, particularly to slow speeds, but did not reduce the ability to allocate attention effectively. In view of these findings, certain motion perception tests may be valuable assays for detecting impaired performance with low blood alcohol levels.

Among the serious consequences of alcohol abuse is reduced ability to process visual information. Diminished vision from excessive consumption of alcohol has been implicated in industrial, home, and automobile accidents (Ryan, Salter, Cox, & McDermott, 1976). However, impaired performance associated with low levels of alcohol intoxication has often been difficult to measure and quantify. This has been particularly true for tests involving temporally modulated stimuli. For instance, Hill, Powell, and Goodwin (1973) reviewed findings from seven studies of the effect of alcohol on critical flicker fusion thresholds in subjects with unspecified drinking histories. Alcohol doses in the studies ranged from .4 g ethanol/kg body weight to 1.3 g/kg, yielding maximum blood alcohol levels between .03% and .08%. The findings, even at the higher doses and blood alcohol levels, were inconsistent, ranging from decrease in fusion threshold through no effect to an increase in fusion threshold.

The present research examined the effects of alcohol ingestion upon three measures of visual function. We wished to determine which, if any, of these three visual capacities might be diminished by ingestion of alcohol. This determination could establish more precisely the mechanisms by which alcohol ingestion actually contributes to risk of accidents. In one test, we measured the ability of an observer to pay attention to two different directions of movement. A related test has been used to work on selective auditory attention designed to predict road accident frequency

(Kahneman, Ben-Ishai, & Lotan, 1973). In fact, it has been claimed that "alcohol reduces our ability to effectively allocate our attention" (Shinar, 1978). We sought to put the generality of such a claim to the test.

We used two additional tasks specifically designed to measure possible impairment of response to motion with alcohol ingestion—the precision with which an observer could judge the direction of a target's movement and his speed of response to targets moving at different velocities. Performance on all three tasks was compared with and without alcohol ingestion.

METHOD

Apparatus

In all of the experiments reported here, stimuli were random dot patterns presented under computer control on the face of a cathode ray tube (CRT). At any given moment, between 400 and 500 random dots were visible to the observer. The dots were centered within an 8-deg circular aperture. The computer controlled precisely both direction and speed with which the dots moved across the CRT (see Ball & Sekuler, 1979, for further details of the display). Dots in all three tasks were presented at a luminance sufficient to make them approximately 50 times their own detection thresholds. Thus, the observer was asked either to judge the direction, in the first task, or to make a response to motion onset, in the second and third tasks, to dots that were highly visible. Reaction times were defined by the elapsed time between onset of motion and the observer's response. Observers viewed the CRT display monocularly from a distance of 57 cm. A small black dot in the center of the CRT provided a fixation point upon which observers were to hold their gazes.

Subjects

We tested nine male observers, averaging 24 years of age. Each had visual acuity of 20/20 or better (or corrected to 20/20 or better). The mean acuity, measured just prior to the experiment by means of a Bausch & Lomb Orthorater, was 20/18. In addition, all observers considered themselves to be light to moderate drinkers, consuming an average of four drinks per week (range: one to eight).

Procedure

Conditions of alcohol ingestion. We tested observers under three conditions of alcohol ingestion. All doses were administered in a drink that had a total of 3 ml liquid/kg body weight. The highest dose consisted of 1 g/kg body weight of 190-proof ethanol, diluted 1:2 with Hawaiian Punch to produce the required total vol-

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ume of liquid. The second dose consisted of .5 g/kg body weight of alcohol diluted 1:5 with Hawaiian Punch. We also administered a placebo consisting of Hawaiian Punch alone. Thus, in the high-dose condition, observers received between 64 and 89 ml of 190-proof ethanol, depending on body weight. In every case, though, the high-dose drink was 32% ethanol. The amount and percentage of ethanol in the low-dose condition were exactly half those in the high-dose condition.

To minimize olfactory and visual cues, each drink was presented in an opaque, lidded cup through which a straw protruded. Two ice cubes were put into each drink. Observers were allowed 20 min in which to consume the drink through the straw. Each observer received all three doses, with the order of the dose individually randomized. Only one dose was given per day. Test periods began immediately before ingestion and at 30, 75, 120, and 180 min after the 20 min allowed for ingestion of the drink had expired. During each test period, all three tasks were run in a single, 15- to 20-min session. The order of tasks within a test period was randomized.

The experiment always began at 1:00 p.m. and ended at approximately 5:00 p.m. Since we wished to minimize the chances that observers would become nauseated by the alcohol, they were instructed to eat lunch before coming to the laboratory. The importance of keeping time and amount of intake constant was stressed to them. Observers gave an oral description of the time and content of meals prior to the start of the experiment, and we found that they consistently had followed instructions. These steps were taken to try to keep each observer's rate of alcohol absorption as constant as possible from day to day.

Practice sessions. Initially, each observer had three practice sessions on all the experimental tasks. These practice sessions, designed to familiarize the observers with the three tasks and to stabilize performance, were conducted over either 1 or 2 days. Practice was completed between 1 and 7 days prior to the collection of actual experimental data.

Breath analysis. All blood alcohol levels were estimated by using a Breathalyzer (Alco-Tector, Decatur Electronics). Measurements were made immediately before and immediately after each period, and the mean of the two was calculated. Mean blood alcohol levels were somewhat lower than would have been the case if subjects had fasted before the experiment began. Furthermore, the peak of intoxication is likely to have occurred sometime between the first two test periods after drink consumption, and sampling when we did yielded points on either side of the peak (see Table 1). The peak mean readings were .02% and .06% for the .5-g/kg and 1.0-g/kg doses. Standard deviations associated with these peak scores were .008 and .017, respectively.

Tasks. One task, "direction judgment," required the observer to estimate the direction in which dots moved across the CRT. Five trials were presented at each of 10 possible directions ranging from 9 deg right to 9 deg left of vertical (at 2-deg intervals). Directions were presented in a random order. Each presentation lasted 1.2 sec, with an intertrial interval of 2.2 sec. The speed of movement was 4 deg/sec. Observers were instructed to hold their gazes on the fixation point as long as the dots were visible. After the dots had been extinguished, observers moved their gazes to a protractor encircling the CRT and read off the perceived direction of the dots' movement. These numerical reports constituted the data for this task.

In the second task, "reaction time to movement," the observer was required to react to the onset of dot movement across the

CRT. In each sitting, the observer was tested on a total of 96 trials, 12 at each of 8 speeds: .125, .25, .5, 1, 2, 4, 8, and 16 deg/sec. On each trial, the dots first appeared on the screen as a stationary pattern. Then, after a random foreperiod lasting between 1 and 2 sec, the dots instantly accelerated to the required speed and moved rightward across the screen. The interval between trials was 1.5 sec. Note that the observer could not predict from one trial to the next the speed of movement to which he would have to respond. The response was a buttonpush that observers were to make as rapidly as possible to the onset of movement, ignoring the speed insofar as possible. Although the dots actually did move on each trial, observers were told that sometimes a trial with no movement might be presented. This misinformation was given to insure that, especially at the slowest speeds, observers would not respond until they actually had seen motion.

The third experimental task, "direction uncertainty," compared reaction times to onset of movement under two basic conditions—one in which the observer could be certain from trial to trial of the direction the movement would take, and another in which from trial to trial the observer was uncertain as to the direction the movement would take. Certainty blocks had 24 trials, all with rightward movement; uncertainty blocks had 24 trials, with movement either to the right (12 trials) or to the left (12 trials), in random order. Before each block, the observer was told in which condition he would be tested. Two blocks of certainty alternated with two blocks of uncertainty in an ABBA fashion, with a total of 96 trials run in any test period. On each trial, the dots first appeared as a stationary pattern and then, after a random period of between 2 and 3 sec, instantly accelerated to 4 deg/sec. The observers were instructed to push a button as soon as the dots began to move, ignoring the movement's direction. The intertrial interval was approximately 3 sec.¹

RESULTS

Before the results are described, a word is in order about the processing of data from each experimental task. For judgments of direction, we calculated the mean judgment for each of the 10 possible directions presented in any block of trials. For the reaction time to various speeds, we identified the highest and lowest reaction times to each of the eight speeds and discarded them; we also discarded reaction times less than 100 msec or greater than 900 msec (see below for justification). From the remaining reaction times, we computed the geometric mean for each speed. Because distributions of reaction times tend to be skewed, the geometric mean more validly reflects the central tendency of the reaction time distributions than does the arithmetic mean (Woodworth & Schlosberg, 1954). With the uncertainty procedure, we also identified the highest and lowest reaction times for each direction within each block and discarded them prior to data analysis. From the remaining reaction times, we calculated the geometric means.

Direction Judgments

The data were converted to error scores defined by the absolute value of the difference between the observer's judgment of direction of the movement and the actual direction. The absolute (or unsigned) error was chosen as the response measure because the symmetrical distribution of our observers' errors would have given mean errors of approximately 0 deg if the signed error had been used instead.

Table 1
Mean Percent Blood Alcohol Levels at Various Times

Dose*	Time Since Drink (in Minutes)				
	0	30	75	120	180
.5	.00	.02	.02	.01	.00
1.0	.00	.06	.05	.05	.04

*In milliliters per kilogram of body weight.

Since only five judgments had been obtained for each direction, we collapsed all directions before data analysis began. Error scores were entered in an analysis of variance (ANOVA) with two factors—dose of alcohol (three levels) and time of testing (five times). This ANOVA revealed one source of variance, that of alcohol dose, to be statistically significant [$F(2,16) = 4.50$, $p < .03$]. Surprisingly, with alcohol the errors actually decreased slightly. The mean error was 3.0 deg for the placebo condition, 2.6 deg for the half-dose condition, and 2.7 deg for the full-dose condition.

Reaction time to movement. Again, an ANOVA was done. Here the design included velocity (eight levels), dose (three levels), and time relative to dose (five times). Significant sources of variance were the main effect of velocity [$F(7,56) = 128.00$, $p < .001$], the main effect of the linear component of dose [$F(1,8) = 11.53$, $p < .01$], the interaction of the linear component of dose and velocity [$F(1,8) = 6.07$, $p < .04$], the interaction of the linear component of dose and the quadratic component of time relative to dose [$F(1,8) = 9.93$, $p < .02$], and the three-way interaction among the linear component of velocity, the linear component of dose, and the quadratic component of time [$F(1,8) = 6.91$, $p < .03$].

As velocity increased from .125 deg/sec through 16 deg/sec, mean reaction times decreased from 613, through 447, 362, 310, 283, 264, and 257, to 254 msec. Increasing doses of alcohol produced an overall elevation in reaction times. From placebo through 1.0 g/kg, the times increased from 335 through 351 to 360 msec. Not unexpectedly, then, alcohol seems to increase reaction time to onset of movement. But the patterns of statistically significant interactions require that this overall effect of alcohol be considered in more detail. For instance, the interaction between dose and velocity reflects the fact that alcohol pri-

marily elevated reaction times to the slower speeds of movement. Thus, reaction times to the slowest speed increased by nearly 50 msec as one went from the placebo to the 1.0-g/kg dose, while reaction times to the most rapid speed increased by only 16 msec over the same range of conditions. The triple interaction among velocity, dose, and time reflects the fact that alcohol had its primary effect on measurements between 30 and 75 min after completion of drink. In other words, as one would expect, the effect of alcohol was a quadratic function of time, first increasing and then decreasing. These relationships are shown in Figure 1 for three of the times of testing. Note that the reaction times at 180 min for the .5-g dose are equal to or slower than the times for the 1.0-g dose, despite the fact that the blood alcohol level is 0 in low-dose subjects and .04 in high-dose subjects. This unexpected result might indicate that other factors, such as fatigue, are exerting a large effect in the later stages of the experiment, causing the reaction times to cluster and masking any smaller effect of alcohol.

An ANOVA on the intraobserver standard error of the mean reaction times showed that the effect of velocity was significant, with higher standard errors being associated with the slower speeds of movement [$F(7,56) = 178.80$, $p < .001$], suggesting some heterogeneity of variance. However, the validity of inferences about alcohol's effect on RT is not compromised by that heterogeneity of variance because no term involving alcohol even approached significance in the ANOVA on standard errors.

Two classes of responses, premature and tardy, were examined. A premature reaction time was defined as less than 100 msec. A genuine response to movement would have required 150 msec at least (Woodworth & Schlosberg, 1954), so premature reaction times indicate that the observer was anticipating movement rather than actually responding to

Figure 1. Mean reaction time to motion onset as a function of velocity. Each panel portrays data at one time relative to the consumption of the drink (left panel: immediately preceding consumption; center panel: 75 min after consumption; right panel: 180 min after consumption). Within each panel, one curve is shown for each dose of alcohol.

its onset. A tardy reaction time was defined as more than 900 msec. Such a response time is more than three standard deviations greater than the mean of any of our reaction time distributions and shows that the observer had great difficulty in detecting the motion. Premature responses were rare (2%), and their frequency was unaffected by any other variables in the experiment. In other words, alcohol did not seem to increase impulsive behavior (see also Sekuler & MacArthur, 1977). The overall frequency of tardy responses for all but the slowest speed also was low (.3%); at that slowest speed, the incidence of tardy responses rose to 20%. However, alcohol did not have any obvious effect on the number or distribution of tardy responses.

Direction Uncertainty

As before, an ANOVA was done. The design included certainty vs. uncertainty blocks (2 levels), dose (3 levels), and time relative to dose (5 times). The mean reaction time to rightward movement in conditions of direction certainty was 253 msec, whereas the mean reaction time in conditions of direction uncertainty was 266 msec. The ANOVA showed this difference to be statistically significant [$F(1,8) = 27.59$, $p < .001$]. Thus, this 13-msec elevation in reaction time, although small, proved to be highly significant, confirming the results of Sekuler and Ball (1977). No effect involving dose of alcohol accounted for a statistically significant portion of the variance. Although observers were generally handicapped by having to pay attention to two different directions of movement, this handicap seemed not to be modulated by the dose of alcohol that they had ingested.

DISCUSSION

The following summarizes the main findings and implications of the present work. Alcohol, in low doses, significantly lengthens reaction time to visual movement. This effect is particularly strong with slower motion. Therefore, we feel this particular visual perception task may be a valuable technique by which to measure impaired performance with low blood alcohol levels. We should note that the results of Experiment 2 do not demonstrate an effect of alcohol that is specific to *motion* perception. In fact, it may be that the results reflect a general decrement in RT to stimulus change.

Contrary to previous claims, alcohol does not necessarily reduce our ability to allocate attention effectively (Kahneman et al., 1973; Moskowitz & Sharma, 1974; Shinar, 1978). In particular, alcohol, at least at low doses, did not affect observers' ability to pay attention to two possible directions of motion. Our results require that earlier claims about alcohol's effect on attention be restated in less general form.

Surprisingly, low doses of alcohol made observers' judgments of direction of motion more, rather than less, precise. Furthermore, the effect was not dose dependent, since the low and high doses of alcohol were almost equally effective in improving accuracy. These results may reflect an alcohol-induced potentiation of involuntary, tracking eye movements (Sekuler & MacArthur, 1977; Wilkinson, Kime, & Purnell, 1974). Although a fixation point always was present in the center of our screen, if the observer had traced by eye the movement from the fixation point to the protractor around the CRT, he could have virtually perfectly identified the direction of movement from the path. Observers did in fact comment that, with any dose of alcohol, they had considerable difficulties in maintaining fixation. However, in most other tasks, if alcohol diminished stability of fixation and rendered the observer more susceptible to involuntary tracking eye movements, this same effect would be deleterious to visual performance and could play a major role in reducing visual stabilization of posture.

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NOTE

1. Note that the length of the foreperiods and intertrial intervals differed between Experiments 2 and 3. The difference was necessary to allow the computer to perform the calculations required between trials. However, we did manage to keep constant the ratio of foreperiod to intertrial intervals between the two experiments.