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INFLUENCES OF ALCOHOL UPON DRIVING IN AN INSTRUMENTED CAR

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16. Abstract

In each of two independent experiments, four high extraverts and four lower extraverts drove an instrumented car through a closed pylon-defined course, on each of two experimental days, after ingestion of alcohol and a placebo beverage, and with and without a concurrent mental loading task requirement. The direction and magnitude of the influences of alcohol upon tracking accuracy and control-use behavior depended upon the particular controls observed, and was associated with driver personality and driver priorities concerning accuracy and speed. Alcohol significantly increased accelerator use regardless of personality or priorities, whereas the influences of alcohol upon steering behavior seemed more susceptible to individual differences. In one study, the loading task requirement significantly reduced the accuracy-degrading effects of alcohol, whereas in the subsequent study, it did not. Heart-rate variation was reduced by alcohol.

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PREFACE

Only those experiments actually completed by the end of the first year of our three-year contract (FH-11-7469) are presented in this annual report. Those experiments which were still in progress or at a pilot level by the end of the reporting period will be included in the second annual report, due in March 1972.

Although this report includes a final section which outlines several conclusions and potential applications arising from the completed experiments, it did not seem appropriate to attempt formal recommendations at this early stage in the research program.

The contract technical manager during the first year was Mr. Peter N. Ziegler. We also wish to acknowledge the helpfulness and understanding of Dr. Robert Knaff and Dr. Robert B. Voas.

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1970 - 1971

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INTRODUCTION

Whatever the gratifications or virtues of drinking alcoholic beverages, their misuse constitutes the basis of an acknowledged social problem which has extensive ramifications in most areas of human activity. One of the major issues arises from the mounting evidence that alcohol misuse contributes significantly to serious and fatal injuries, both on and off the highways.

The experimental literature on "drinking and driving" is extremely limited and is not extensively reviewed here since several surveys and critiques are readily available elsewhere (Alcohol and Road Safety, 1969; Carpenter, 1962, 1968; 1968 Alcohol and Highway Safety Report, Chapter 3). Because of the obvious dangers in experimenting with drinking subjects on public roads in actual traffic, behavioral research in this area is effectively limited to: (1) closed driving courses, (2) driving simulators, or (3) laboratory experiments on assumedly relevant, but isolated components of the driving task. None of the published studies has investigated the same behavioral variables across all three of these conditions.

The vast majority of this experimental literature is comprised of studies which fall in the third category, and these laboratory experiments on the effects of alcohol range from simulated driving tasks (e.g., Chiles & Jennings, 1970; Gibbs, 1966; Landauer, Milner & Patman, 1969; Milner & Landauer, 1971; Mortimer, 1963) to simple sensory or psychophysical tasks (e.g. Carpenter, 1962, 1963). However, the latter type of study is not directly relevant here.

The second category of alcohol study, using the driving simulator, is next most frequent (e.g., Drew, Colquhoun, & Long, 1958; Hulbert, 1969; Loomis & West, 1958; Moskowitz, 1968). However, the relevance and the predictive validity of these simulator findings for actual driving behavior has yet to be conclusively demonstrated. In fact, Edwards, Hahn and Fleishman (1969) found a striking lack of correspondence between simulator "driving" and actual performance on the road.

Least frequent, but most pertinent are drinking-and-driving studies conducted with real cars on a closed driving course (e.g., Bjerver & Goldberg, 1950; Cohen, Dearnaley, & Hansel, 1958; Michon & Koutstaal, 1969; Seehafer, Huffman, & Kinzie, 1968). Given the potential hazards and liabilities of drinking experiments conducted on public roads, the significance and strength of this type of research arises from the achieved compromise between the actual highway driving situation with its attendent traffic-associated dangers, and the secure, artificial, and cue-deprived environment of the driving simulator. That is, in terms of potential application of obtained information to the real world, a real automobile (which is highly instrumented) should be used instead of a highly instrumented but contrived simulator; and a closed course should be substituted for the public highway.

The scope and validity of closed-course drinking studies have been greatly limited in the past by lack of sufficiently sensitive and relevant measures. Within the past few years, however, this limitation has been substantially reduced by the development of a commercially available car equipped to obtain and continuously record selected control-use and physiological measures, i.e., the Highway Systems Research Car, or HSR car (Greenshields & Platt, 1967; Platt, 1968).

Specific aims

The flexibility of the apparatus in the HSR car encourages a number of different approaches to investigating driver behavior. However, due to the demonstrated relation between alcohol and automobile crashes and to the potential usefulness of identifying personality "types" which differ in susceptibility to crashes under various driving circumstances, our investigations were primarily concerned with possible interactions between three parameters: (1) blood alcohol concentration, (2) the complexity of the driving task, and (3) individual differences.

Blood alcohol concentration. In the two experiments discussed here, two values of blood alcohol concentration have been compared: 0 and 100 milligrams per milliliter (mg%). These values were selected because 100 mg% represents the blood alcohol concentration specified by the United States federal standard on alcohol as the criterion for presumptive impairment, and 0 mg% provides a necessary baseline condition.

Complexity of the driving task. The influence of alcohol upon driving behavior was tested in two different task conditions. First, a difficult driving task was used, requiring attention only to manipulation of the automobile. Second, concurrent with driving, the subject was required to perform a mental arithmetic or number detection task.

Individual differences. An attempt was made to investigate the influence of selected individual differences on the basis of a personality dichotomy. It has been shown that the influences of alcohol upon driving behavior are associated with extraversion scores on the Eysenck Personality Inventory (Drew, et al. 1958); therefore, degree of extraversion may provide a feasible means of identifying those individuals who stand an elevated risk of having an alcohol-involved highway crash. Consequently, it seemed promising to examine the relation between the personality of the driver (i.e., the degree of extraversion) and the influence of alcohol upon driving performance.

EXPERIMENT I

This study was the first in a series (only two of which are reported here) conducted at this laboratory investigating the influences of alcohol upon driving behavior. Its overall objective was to determine the usefulness of the instrumented car as a research tool for the systematic investigation of driving behavior. Specific aims were to examine the influences of alcohol and a concurrent mental-arithmetic loading task upon closed-course driving behavior.

Method

Subjects. Eight, paid male volunteers between 21 and 28 years of age served as subjects. Each had near and distant visual acuity equal to 20/20, with correction if necessary; and all subjects were familiar with alcoholic beverages to the extent that each occasionally drank the equivalent of four ounces of 86-proof alcohol in an evening at social affairs.

Apparatus. The principal equipment was a 1969 Mercury equipped with automatic transmission, power brakes, and power steering, as well as a multi-channel event-recording system. This vehicle was a prototype of the present Highway Systems Research car and had been evolved from the drivometer-equipped vehicle developed earlier by Greenshields. Using this prototype system, the following driving behavior information was continuously monitored, recorded, and displayed on digital counters mounted on the far right side of the dashboard:

1. Fine steering reversals: indicated the number of times the steering wheel was reversed 2 degrees or more in either direction.
2. Coarse steering reversals: indicated the number of times the steering wheel was reversed 12 degrees or more in either direction.
3. Brake applications: indicated the number of times the brake was depressed 1/8 inch or more.
4. Accelerator reversals: indicated the number of accelerator reversals of 1/4 inch or more.
5. Total time the recording system was in operation.
6. Total time the car was going forward more than 5 miles per hour.
7. Number of times the speed of the car increased or decreased at least two miles per hour.

The driving task. All driving trials were conducted during daylight hours on a gymkhana course (Figure 1) which was located on a large, private, gravel parking lot. The course was 0.38 miles long

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Insert Figure 1 about here

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and included two stop-lines, two sets of slalom-gate sequences, and a figure-eight. The course was tight enough to keep speeds below 20 mph and to maximize the difficulty of driving it without hitting the 68 pylons which defined the path to be driven.

Two sets of driving-task measures were obtained. The first consisted of those instrumented measures entered directly on the digital display. The more traditional second set included the following measures which were observed and recorded by one or more of the seven assistants: (1) the number of pylons upset, (2) the distance in inches the car was halted from each of the two stop-lines, and (3) the number of omissions and incorrect responses on the mental loading task.

Loading task. Each subject was asked to do a mental-arithmetic task during one-half of the driving trials. This loading task required the subject to attend to tape-recorded,two-digit numbers presented every four seconds and verbalize the sum of the two digits in the presented number during the interval preceding the next stimulus. On the day prior to driving each subject practiced the task until 75 consecutive additions could be performed without error.

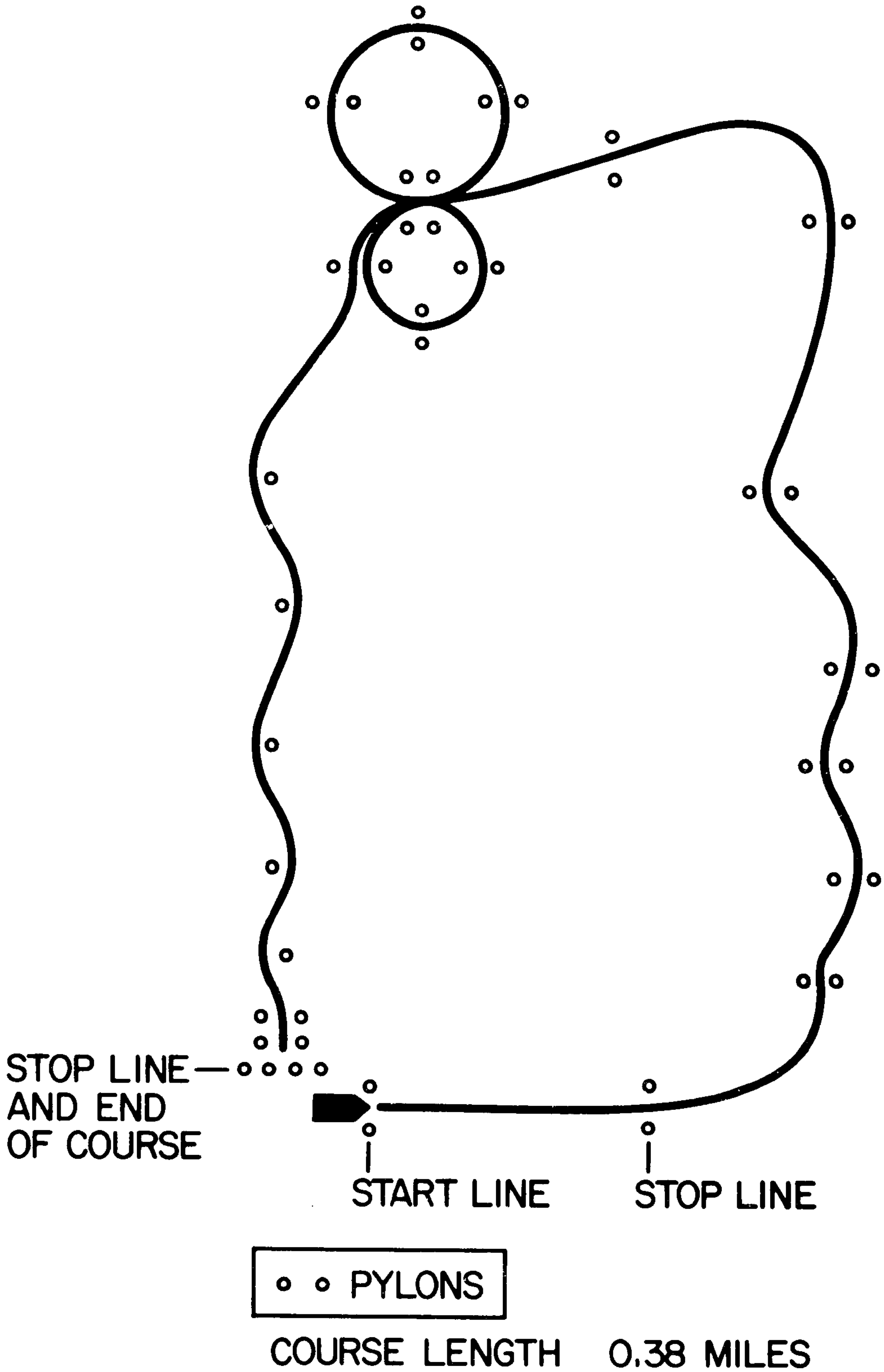

Figure 1: Plan of closed driving course used in Experiment I

Instructions. Prior to each driving trial, the subject was instructed: (1) that his primary goal was "to drive the course as fast as you can without missing any gates, hitting pylons, or going off the course," and (2) that the arithmetic task was to receive second priority, after first attending to the driving task itself.

Design. The driving sessions for each of the eight subjects consisted of six consecutive runs through the course. The first two runs (the second of which was done while performing the loading task) were considered practice and were not analyzed. The remaining four runs were test trials, and differed in the presence or absence of the mental-arithmetic loading task requirement which was scheduled in ABBA sequence for these four trials and was counterbalanced across subjects. The subjects were randomly and equally assigned to one of the two sequences. Two of the four subjects from each sequence were given alcohol the first day, but no alcohol the second day. The other two subjects in each sequence received the beverage treatments in the reverse order.

Alcohol. Alcohol dosage levels of 0.00 and 1.21 ml. of 95% ethanol per kg. of body weight were used to produce the target blood alcohol concentrations of 0 and 100 mg% respectively. The alcoholic beverage consisted of ethanol and cranapple juice mixed in a 1-to-6 ratio. The non-alcoholic beverage consisted of an equivalent volume of pure cranapple juice. Subjects were not informed with respect to the contents of the beverages. During task performance in the alcohol condition, the mean blood alcohol concentration was 108 mg% as estimated from breath samples taken immediately prior to and upon completion of the driving task using a Borkenstein Breathalyzer.

Results

Alcohol. The mean scores per trial for each of the eight performance measures are shown in Table 1. Control-use scores have not been converted to rates as is frequently done, since distances driven were constant across test conditions and neither alcohol nor the loading task requirement had a significant influence ($p > .05$) upon elapsed time, i.e., driving speed. The significance of differences between treatments was determined using the Wilcoxon matched-pairs signed-ranks test (Siegel, 1956).

As can be seen in Table 1, alcohol was associated with increased scores (i.e., decreases in performance) on all measures except elapsed time and fine steering. However, not all changes were unidirectional across subjects. For example, although alcohol was associated with a mean increase in coarse-steering reversals of over 17% for some subjects, it was also associated with decreases of approximately the same magnitude for others. Consequently, the influence of alcohol upon such measures did not reach statistical significance.

In contrast, alcohol increased the number of accelerator reversals ($T = 0$; $N = 8$; $p < .01$) for all eight subjects. In addition, alcohol was associated with an increased number of brake responses for seven of the subjects. However, because of large alcohol-associated reduction

TABLE 1

Means and Differences between Means of Number of Control Reversals, Speed Changes, Elapsed Time, Number of Pylons Upset and Stop Accuracy for Alcohol and No Alcohol Conditions in Experiment I

	Alcohol	No Alcohol	Difference	% Change
Control reversals				
Fine steer (2°)	33.50	35.10	-1.56	4.44
Coarse steer (12°)	70.00	67.84	+2.15	31.69
Brake (.13")	15.22	12.11	3.16	26.09
Accelerator (.25")	15.87	11.07	4.8*	43.36
Speed changes (2 mph)	47.28	38.94	8.34	21.42
Elapsed time (min.)	1.76	1.78	-0.02	1.12
Pylons upset	11.62	5.78	5.84	101.04
Stop accuracy	22.77	11.92	10.85*	91.02

*$p < .05$

in the number of brake responses of one subject, this effect failed to reach statistical significance. Thus, with the single exception of that one subject's deviant brake responses, alcohol was associated with a general increase in the use of both foot-controls.

Although alcohol was associated with a 100% increase in the number of pylons upset,this increase was not statistically significant, again because of substantial individual differences. Thus, one subject upset 9 times more pylons in the alcohol than in the placebo condition, whereas another subject upset approximately 2 times fewer pylons in the alcohol condition.

In contrast, stopping accuracy was significantly reduced by alcohol ($T = 4$; $N = 8$; $p < .05$).

Mental arithmetic performance was not appreciably influenced by alcohol. The mean error rate on the loading task was approximately 10% under alcohol, whereas in the placebo condition, approximately 5% of the additions were done incorrectly.

Loading task. The requirement to perform the mental arithmetic task while driving had no significant effect upon control-use behavior or elapsed time. Nevertheless, as shown in Table 2, fewer pylons were upset when the arithmetic task was required than when it was not, although this effect of the loading task was not statistically significant. However, when these data were examined as a function of beverage condition under which the driving was performed, an apparent alcohol effect was found. Thus, under the alcohol treatment significantly fewer pylons were upset when the

TABLE 2

Mean Number of Pylons Upset Per Trial in Each Beverage and Load Condition of Experiment I and Experiment II

	Load	No Load	Difference
Experiment I			
Alcohol	9.87	13.37	-3.50**
No Alcohol	5.50	6.06	- .56
Experiment II			
Alcohol	5.00	4.69	+ .31
No Alcohol	3.18	4.25	-1.07

$^{**}p < .01$

loading task was required (T = 2; N = 8; $p < .02$), whereas in the placebo treatment, this difference was not significant.

Personality. In order to examine possible relations between personality aspects and the influences of alcohol upon the various performance measures. Spearman rank correlations were computed between degree of extraversion (i.e., scores obtained on the Eysenck Personality Inventory) and alcohol-associated changes in driving behavior. A significant correlation was obtained with alcohol-associated decreases in driving accuracy ($r_s = .67$; $p < .05$), as indicated by alcohol/placebo differences in the number of pylons upset. Thus, after drinking alcohol, more pylons were upset by subjects with higher extraversion scores than by those with lower extraversion scores. An explanation of this relation was sought in the post test-interview data which revealed that most subjects actually felt impaired following consumption of the alcoholic beverage, and consequently felt compelled to compensate for the influences of alcohol in some manner. The two compensatory procedures most commonly used were: (1) driving more slowly in order to maintain an "acceptable" level of driving accuracy, and (2) just the opposite, i.e., sacrificing accuracy in order to maintain an "acceptable" level of speed. High extraverts most frequently chose to do the latter.

Summary of Results

Alcohol has been shown to reduce driving accuracy and to modify control-use behavior. Regarding the former, it was shown that driver personality characteristics may accentuate the degrading effects of alcohol upon accuracy, but that concurrent loading task demands may actually attenuate these same degrading effects. In addition, influences of alcohol upon control-use behavior were dependent upon driver personality variables and the specific controls observed. Thus, the direction of alcohol-associated changes in steering wheel use was subject to individual differences, whereas alcohol was associated with a general increase in the use of foot controls.

EXPERIMENT II

Experience with the HSR car prototype provided convincing evidence of the system's sensitivity to the influences of certain variables (e.g., alcohol) upon driving behavior. Consequently, a production model of the HSR car was obtained for use in further driving studies. The most important differences between the two cars were: (1) the instrument system in the production version was capable of recording the driver's heart rate either by using electrodes attached to the subject's chest or by using the gold-plated steering wheel as electrodes; (2) rather than being housed in a prestigious convertible as the old apparatus had been, the new HSR equipment was installed in a safer four-door sedan (1970 Ford Galaxie); (3) the new car was provided with a heavy-duty suspension system; and (4) in further interest of safety, a brake pedal and an emergency ignition switch were installed on the passenger side of the car.

Experiment II was designed to investigate the influences of blood alcohol concentration, extraversion, and a mental loading task upon heart rate and driving behavior in a closed-course driving task.

Method

In the interest of validating the findings of Experiment I and of using the new HSR car in a familiar experimental situation, the present study was a partial replication of Experiment I and therefore shared several common features with it. The most notable commonalities were as follows:

(1) Although different in many details, a closed-course, gymkhana driving task was also used (see Figure 2).

(2) In order to test the reliability of the alcohol-loading task interaction obtained in Experiment I, a mental loading task was also used in the present study.

(3) A counterbalanced factorial design was used.

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Insert Figure 2 about here.

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Notable differences between the pilot study and the present investigation were as follows:

(1) In the first study, no priorities were specified with respect to the relative importance of the speed and accuracy. This low degree of instructional set had been expected to facilitate the contribution of personality differences to driving behavior, and such differences were obtained. In contrast, all subjects in the present study were specifically informed that accuracy was the most important part of the task. Furthermore, they were instructed to maintain a driving speed of 10 mph whenever possible.

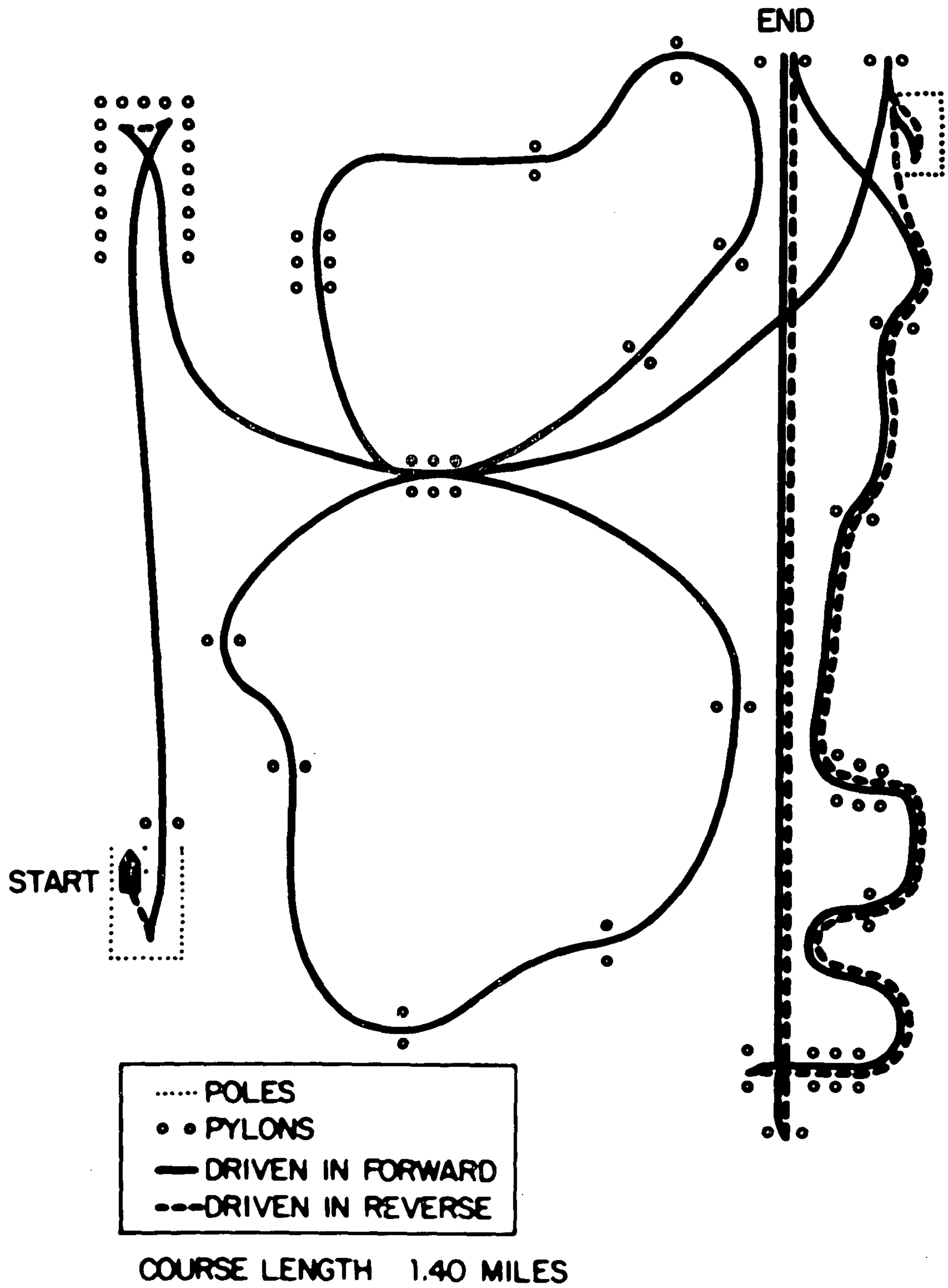

Figure 2: Plan of closed driving course used in Experiment II

(2) Experiment I was conducted on a rutty gravel surface which necessitated relatively frequent use of the foot controls and which may have contributed to the observed influence of alcohol upon the use of these controls in that study. The route to be driven was approximately one third of a mile long. Experiment II was conducted on a smooth concrete surface, and the route to be driven was approximately one mile long.

(3) The driving task in the present experiment included parallel parking and driving in reverse gear.

(4) In order to re-examine the alcohol-extraversion interaction found in Experiment I, the present subjects were specifically selected with respect to extraversion scores on the Eysenck Personality Inventory. In the present study, these scores ranged from 12 to 21 with a mean of 18, whereas in Experiment I, they ranged from 3 to 18 with a mean of 11.

(5) The loading task in the present study was a memory rather than an arithmetic task, and involved the comparison of consecutive pairs of seven-digit numbers, one digit of which was different and had to be identified (Brown & Poulton, 1960).

(6) The mean blood alcohol concentration of Experiment II subjects was 43 mg%, as determined from the individual means of pre- and post-test samples of alveolar air using a Borkenstein Breathalyzer. This unexpectedly low value resulted from an unavoidable (but constant) delay between consumption of the experimental beverage and the time of actual testing; the delay consisting of: (a) the time during which the subject

was transported from the laboratory to the track (at which consumption of alcohol was prohibited), and (b) the time required to drive the practice trial.

Results

Alcohol. The mean scores per trial for each of the seven performance measures are shown in Table 3. Since elapsed time was not significantly different in the two beverage conditions, control-use scores were not converted to rates. The significance of the difference between beverage treatments was assessed for each performance measure by using the Wilcoxon matched-pairs signed-ranks test (Siegel, 1956).

As in Experiment I, alcohol was associated with a general increase in the use of controls and a decrease in driving accuracy as indicated by the number of pylons and poles upset. However, because of substantial differences in the nature of the influences of alcohol upon the different subjects (as also in Experiment I), only two changes were statistically significant.

It may be seen in Table 3 that under alcohol, accelerator reversals increased significantly ($T = 3$; $N = 8$; $p < .05$) and, perhaps consequently, the number of speed changes also increased significantly ($T = 3$; $N = 8$; $p < .01$).

Regarding the influence of alcohol upon driving accuracy, it was found that 44% more poles and pylons were upset in the alcohol than in the no-alcohol condition. However, due to large individual differences, this amount of change failed to reach statistical significance.

Loading task. Performance on the loading task was almost perfect

TABLE 3

Means and Differences between Means of Number of Control Reversals, Speed Changes, Elapsed Time, and Number of Pylons Upset for Alcohol and No Alcohol Conditions in Experiment II.

	Alcohol	No Alcohol	Difference	% Change
Control reversals				
Fine steer (2°)	159.28	147.70	11.58	7.84
Coarse steer (12°)	225.58	209.31	16.27	7.77
Brake (.13")	48.84	47.00	1.84	3.92
Accelerator (.25")	39.34	32.09	7.25*	22.58
Speed changes (2 mph)	72.06	56.93	15.13*	26.57
Elapsed time (min.)	10.65	11.03	-.38	-3.44
Pylons & poles upset	4.85	3.71	1.14	30.73

*$p < .05$

(98%) on all test trials, was not measurably influenced by alcohol, and was not significantly associated with changes in driving performance. These results and post-experimental comments made by the subjects indicate that the loading task became automated after only a few minutes of practice and that its execution required little attention.

In order to facilitate comparison between the influences of the loading task requirement and alcohol upon driving accuracy in each experiment, the mean number of pylons upset in a single trial is shown in Table 2 for each of the four combinations of loading task and beverage conditions in Experiment II.

Personality. Spearman rank correlation coefficients (rho) between the extraversion scores and the alcohol-no-alcohol difference scores for each of seven measures of driving performance are shown in Table 4. Alcohol was significantly correlated with coarse-steering reversals and accelerator reversals (but not speed change). More specifically, alcohol was associated with an increase in the number of coarse-steering responses of subjects scoring highest on the extraversion scale (20-21), whereas the converse obtained for subjects scoring lower on the extraversion scale (12-18). In comparison, alcohol caused a general increase in accelerator reversals for all subjects, but the magnitude of the increase was greater for subjects with the higher extraversion scores.

Heart rate. The heart rates of four subjects were obtained using the steering wheel electrodes, whereas chest electrodes were used for three subjects, and the heart-rate data from one subject was lost due

TABLE 4

Spearman Rank Correlation Coefficients Calculated between Alcohol Associated Changes in Driving Performance and Extraversion Scores Obtained on the Eysenck Personality Inventory

Performance Measure	Correlation Coefficients (rho)
Control reversals	
Fine steer (2°)	.61
Coarse steer (12°)	.71*
Brake (.13")	.62
Accelerator (.25")	.82*
Speed changes (2 mph)	.30
Elapsed time (min.)	.61
Pylons and poles upset	.59

*$p < .05$

to an equipment malfunction. There were no obvious differences in the mean heart-rate data that could be attributed to the different recording procedures. However, the variability of the heart-rate estimates was considerably higher when the steering wheel electrodes were used.

Changes in mean heart rate showed no consistent trend that could be attributed to alcohol. More indicative of probable alcohol effects was the fact that for five of seven subjects, alcohol was associated with decreases in the standard deviations of the heart-rate estimates obtained each 6 seconds while the subject was driving. Computed across subjects, the mean decrease was 40%. Similarly, the range of the seven heart-rate estimates decreased an average of 39% for six of the seven subjects. Although the above differences were not statistically significant, these data do suggest an interesting possibility (i.e., that the influence of alcohol on heart rate is manifested as a reduction in the responsiveness of the autonomic nervous system to variations in demands of the driving task.

Summary of results

Alcohol was associated with a general increase in the use of controls and caused significant increases in accelerator use. However, the direction of change in number of control-use responses varied from subject to subject; more importantly, these changes were frequently in opposite directions for different controls. In addition, alcohol caused significant increases in speed changes.

Regarding individual differences, alcohol significantly increased coarse-steering reversals made by high extraverts and significantly decreased the number of these responses made by lower extraverts. Alcohol significantly increased the accelerator reversals of all subjects, but the magnitude of this increase was highest for the high extraverts.

Loading task performance was not influenced by alcohol nor did the loading task requirement alter driving behavior.

Alcohol did not have a significant influence upon heart rate. However, trends were observed indicating that heart-rate variability, recorded while driving, decreased under alcohol.

DISCUSSION

Alcohol

The finding that alcohol was associated with severe decrements in the driving accuracy for some subjects was expected, and it confirms the reports of other investigators. However, two factors were identified in Experiment I which may differentially modify the effects of alcohol upon driving accuracy (in terms of the number of pylons upset). First, in a situation that placed equal emphasis on the importance of driving accuracy and speed, it was shown that personality factors (i.e., extraversion) may accentuate the degrading effects of alcohol upon tracking accuracy. This evidence for an alcohol-personality interaction is similar to that reported by Drew, et al. (1958), who found that under alcohol, high extraversion scores were associated with decreased driving accuracy in a simulator.

Secondly, and by contrast, it was found that performance on a concurrent mental addition task may attenuate the accuracy-degrading effects of alcohol.

In Experiment II, in which the importance of driving accuracy was emphasized, alcohol did not appreciably alter tracking accuracy (in terms of number of poles and pylons upset). This discrepancy between the results of the two studies may be explained in terms of: (1) the difference in instructional priorities, and/or (2) the relatively low blood alcohol concentrations used in Experiment II.

In support of the former explanation, control-use was modified by alcohol in both studies; and in Experiment II, alcohol increased the number of speed changes as well. Thus, at least from the standpoint of control-use, the severity of the influences of alcohol manifested in the second study were no less than they were in the first. Furthermore, post-experiment interviews with the subjects revealed that in Experiment I, some subjects sacrificed accuracy for driving speed in the alcohol condition, whereas in Experiment II, all subjects were highly motivated to drive accurately in both beverage conditions. Therefore, it is assumed that the usual accuracy-attenuating influences of alcohol were reduced in the second study by the experimenter's instructions.

The influences of alcohol upon control-use were similar in both studies since only accelerator-use was significantly increased across all subjects, while the influences of alcohol upon the other controls were subject to substantial individual differences. The fact that alcohol also increased speed changes in Experiment II may have been a reflection of the differences in the two driving tasks. It will be recalled that subjects in the later study were required to park and to drive in reverse, as well as maintain a constant driving speed of 10 mph. These maneuvers require frequent manipulation of the accelerator and consequently provided a greater opportunity for alcohol to influence accelerator-use than was the case in Experiment I.

Loading task

The loading task requirement decreased the number of pylons upset in the alcohol condition in Experiment I, but did not do so in Experiment II. There are two explanations for this difference. First, since the loading tasks used in the two studies were not the same, it is possible that they differed with respect to that characteristic which served to offset the negative influences of alcohol observed in Experiment I. It is reasonable to expect this characteristic to be associated with the difficulty of the loading task. However, since both loading tasks were learned quickly and accomplished with a minimum of errors, there was probably no appreciable difference in the attentional demands each placed upon the driver.

A second and more likely explanation concerns the relative opportunity for accuracy improvement in the two studies. In the alcohol conditions of the first study, many more pylons (mean = 13.4) were upset during the relatively brief trials (mean duration = 1.46 minutes) than in the alcohol conditions of Experiment II, in which trials lasted as long as 11.65 minutes, but in which relatively few pylons and poles (mean of combined number = 4.7) were upset in the base line (no loading task) condition, thus allowing little room for improvement with the addition of the loading task requirement.

Thus, the differences in loading task effects obtained in the two studies are most simply explained in terms of relative opportunity for influence, i.e., since few pylons and poles were upset in the second study, there was little opportunity for potential performance-improving effects of the loading task to be manifested. Therefore, the validity of the loading task effect obtained in Experiment I should not be discounted on the basis of the second study alone; rather, further work on this effect is indicated.

Personality

Extraversion was found to be associated with the influences of alcohol upon control behavior in Experiment II, but not in Experiment I. As with the loading task effect, unequivocal explanations of the personality effects are not possible because of systematic differences between the two studies. Nevertheless, the following explanation is offered as being plausible, consistent with the data, and a stimulus for further research. Accordingly, it is proposed that the manner in which the degree of extraversion was manifested in the two studies was primarily the result of the experimental instructions used. Thus, in Experiment I, when accuracy and speed were given equal emphasis by the experimenter, subjects were free to compensate for the influences of alcohol either by retaining the speed performance of the non-alcohol trials at the expense of driving accuracy or by doing just the opposite. It seemed as though high extraverts tended to do the former, while lower extraverts did the latter. In contrast, the instructions used in Experiment II not only specified accuracy as a higher priority performance dimension, but also required that subjects drive the course at a prescribed speed. By so doing, the speed/accuracy compromise was eliminated as an acceptable means of compensating for alcohol influences. Perhaps consequently, the interaction between alcohol and extraversion was manifested in the form of changes in the use of the automobile controls. Thus, the extent and direction of the influence of alcohol upon accelerator and gross steering reversals were significantly correlated with extraversion.

The Meaning of Changes in Control-use

Greenshields and Platt (1967) have interpreted increases in control-use as indications of indecision and over-control. In support of this explanation, they found that inexperienced drivers and persons with poor driving records generally make more control reversals than experienced drivers and those with good driving records. Similarly, it has been shown that novice drivers manifest significantly higher steering reversal rates than experienced drivers (Ellingstad, Hagen, & Kimball, 1970), and that increases in accelerator use are directly related to increases in driving difficulty (Jones & Potts, 1962). A logical corollary of this explanation is that decreases in control-use reflect an increase in decisiveness and a reduction in control difficulty -- two performance characteristics which are not usually associated with medium-to-high blood alcohol concentrations.

Furthermore, such a general description of the influence of performance difficulty upon control-use implies that all controls are similarly influenced by the stressor, e.g., alcohol, a condition which has been shown not to be the case. Thus, in both experiments, alcohol was often associated simultaneously with decreases in steering-wheel reversals and increases in accelerator responses. Consequently, when evaluating the meaning of changes in the use of individual controls, not only must the particular controls be specified, but both the nature of the driving task and the personality characteristics of the driver should be identified as well. Furthermore, since it appears that the influences of alcohol upon the use of controls are subject to the goals of the driver, it is also important to identify these goals when trying to infer the driver's physical state from control-use information.

Conclusions and Potential Applications

Driving behavior was altered by relatively low blood alcohol concentrations (mean BAC = 43 mg%). Although this alcohol influence was not necessarily associated with a reduction in driving accuracy, it appears that such accuracy reductions as might occur could be minimized or avoided by allocating additional attention to the driving task. Support for this conclusion is indicated by the observed increases in use of the accelerator when driving speed was an important aspect of the task. Moreover, the fact that after alcohol ingestion, the driver performs differently (whether demonstrably better or worse) illustrates that alcohol indeed has some effect, thus raising questions about the driver's performance potential under alcohol.

Furthermore, the fact that these differences attributed to alcohol ingestion are manifested in the form of changes in control-use may provide the basis for developing a procedure to detect such "impairment."

However, the likelihood of finding or developing a simple indicator of alcohol impairment based upon these changes in control-use patterns is small because the use of the separate controls may actually be influenced in different ways (e.g., some used more and some used less) and these differences may also vary as a function of driver priorities and personality characteristics. Therefore, any valid system for detecting driving impairment which is based upon the analysis of control-use will probably have to be tuned in some fashion to the individual driver.

In any case, if a single indicator of driving impairment were to be selected at this point in time, accelerator-use would have the highest probability of success. In contrast to changes in steering wheel use, the influences of alcohol upon the use of the accelerator were always in the form of increases. Thus, although there is some reason to suspect that alcohol-associated changes in the use of the accelerator may have been artifacts of the particular experimental paradigms employed, the potential of accelerator-use as a solitary indicator of general driver impairment is greater than that of any other control response observed.

Two factors have been identified which can apparently modify the influences of alcohol upon driving behavior. First, it was shown in one study that alcohol-associated reductions in tracking accuracy were less when the driver was required to perform a concurrent mental task than when he was not. This effect suggests that for emergency use, special ancillary procedures could be incorporated into the driving task which would require greater involvement on the part of the driver and which would be triggered and added in response to predetermined changes in his control-use profile. This demanding supplement would raise the driver's level of alertness and consequently his readiness to respond to emergency situations. Although helping a motorist who has thus been identified as impaired to continue driving on public roads may be viewed as a questionable procedure, it is not difficult to imagine emergency situations in which such an approach might be the most desirable of a number of possible options.

Secondly, when measured in terms of tracking accuracy and increases in control response, the extent of alcohol-associated driving impairment increased with increases in degree of extraversion. The reason for this relation is not clear from the experiments; however, post-test interviews did indicate that the high extravert and lower extravert subjects may well have used different criteria for evaluating their own performance. Additional research should be conducted to explore the nature of these differences. It is possible that the critical differences, once identified, could be employed in both driver education and licensing programs and thereby serve to reduce driving risks.

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