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16. Abstract

The purpose of this experiment was to determine a) the magnitude of alcohol impairment of driving skills as BACs varied from zero to 0.10% and b) whether age, gender, and drinking practice characteristics of the subjects would differentially affect alcohol impairment in a sample of subjects who were broadly representative of the driving population. Using a driving simulator and a divided attention task, 168 subjects were examined at BACs to 0.10% for moderate and heavy drinkers and to 0.08% for light drinkers.

Alcohol significantly impaired performance on some measures at all examined BACs from 0.02% to 0.10%. The magnitude of the impairment increased with increasing BAC. Differences in the magnitude of alcohol impairment between categories of age, gender, and drinking practices were small, inconsistent in direction, and did not reach statistical significance. It is possible that significant differences would have emerged if a wider range of subject characteristics and BACs had been examined. BACs over 0.10% were not tested, and the sample did not include subjects under 19 years and over 70 years, or very light and very heavy drinkers. Within those limits, no significant differences in the magnitude of alcohol impairment within the categories of age, gender, and drinking practice appeared for this diverse sample.

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TECHNICAL SUMMARY

Background

It became evident soon after the introduction of motor vehicles that drivers' use of alcohol increases the risk of crashing, and laws prohibiting alcohol-impaired driving were enacted during the early 1900s. Enforcement of those laws by police officers was the primary approach to prevention, but roadside evaluations of drivers' fitness to drive proved to be a difficult task. During the 1940's, officers identified alcohol involvement in only three percent of traffic collisions whereas epidemiological studies using breath and blood measurement of alcohol levels showed much greater alcohol involvement (Borkenstein et al., 1964, 1974).

The evidence that alcohol was causally involved in a significant proportion of crashes led to the enactment of blood alcohol concentration (BAC) limits for driving. The first such law was passed in 1939 by the State of Indiana with the limit set at 0.15% BAC. Although the laws subsequently passed throughout the United States lowered the limit to 0.10% or 0.08%, scientific studies of alcohol effects on driving skills demonstrate that impairment also occurs at even lower BACs. This study addressed the question of alcohol impairment at BACs as low as 0.02%.

A broadly representative sample of the driving population served as subjects in this study. Because a driver's age, gender, or drinking practices may affect his or her response to alcohol, the sample included a wide age range, both genders, and light to heavy drinkers. They were trained on a driving simulator and a divided attention test, and were tested on those tasks with and without alcohol under controlled laboratory conditions.

Objective

This laboratory study examined the effects of alcohol on driving skills at BACs of 0.00% to 0.10% in a sample of 168 subjects assigned to age, gender, and drinking practices groups. The study was designed to determine the BACs at which impairment of specific experimental tasks occur and the interaction of age, gender and drinking practices with BAC on the magnitude of impairment.

Method

The driving simulator (SIM) and divided attention test (DAT) were used to examine the effects of alcohol on driving skills and to examine whether alcohol effects differ for subjects of different ages, gender, and drinking practices. Equal numbers of men and women (n=84 each) were assigned to four age groups (n=42 each): youthful drivers, young adult drivers, middle age drivers, and older drivers. They were classified as light, moderate, or heavy drinkers (n=56 each) by a Quantity-Frequency-Variability scale of alcohol consumption.

Subjects were trained at two sessions during the week prior to the first treatment session. In counterbalanced order, they were tested during two sessions, one with a placebo treatment and one with an alcohol treatment. The two sessions were separated by one week.

The alcoholic beverage was 80 proof vodka and orange juice. To insure testing at a mean BAC of 0.10% (moderate and heavy drinkers) or 0.08% (light drinkers), subjects were dosed to BACs 0.01% above those levels. The first testing was initiated when the measured BAC declined to 0.105% or 0.085%, respectively. Testing was repeated at 0.02% intervals as BACs decreased to zero. Breath specimens for BAC measurement were obtained with an Intoxilyzer 5000 at the beginning and at the end of each of the five test batteries. The means of those two measurements across subjects were 0.098%, 0.078%, 0.059%, 0.040%, and 0.020%.

The placebo beverage (water, orange juice, 10 ml vodka) matched the alcohol beverage in volume, appearance, and initial taste. The testing schedule for placebo sessions paralleled the test times of the alcohol session.

Results

The data obtained with 168 subjects demonstrate that alcohol impairs driving-related skills at 0.02% BAC, the lowest tested level. The magnitude of impairment increased consistently at BACs through 0.10%, the highest level tested.

Since data obtained at placebo sessions showed performance differences as a function of age, gender, and drinking practices, it was concluded that the SIM and DAT measures were sufficiently sensitive to detect between-group performance differences in response to alcohol. Data obtained at alcohol sessions, however, provided no evidence of differential alcohol effects within age, gender, and drinking practices groups.

Conclusions

While there is partial evidence of impairment at 0.02% BAC, a major conclusion of this study is that by 0.04% BAC, all measures of impairment that are statistically significant are in the direction of degraded performance. The data provides no evidence of a BAC below which impairment does not occur. Rather, there was evidence of significant impairment throughout the BAC range of 0.02% to 0.10%, with increasing percentage of subjects impaired and increasing magnitude of impairment at higher BACs. These conclusions, which are consistent with findings from the analysis of crash data (Allsop, 1966; Hurst, 1973; Zador et al., in press), are directly relevant to the issue of BAC limits for driving. Note that these results were obtained with subjects whose BACs were declining from 0.10% (or 0.08%) to zero. Greater impairment would be expected from drivers during alcohol consumption and absorption when BACs are rising.

Although some epidemiological studies have suggested possible differences in degree of alcohol impairment as a function of differences in age, gender and drinking practices, this laboratory study failed to detect such differential impairments. Within the limits of the population represented by the study sample, impairment differences between subjects were insignificant and solely determined by BAC. It should be noted that although the sample reflects possibly 80-90% of alcohol consumers who drive, it did not include drivers under age 19 or over 70. Furthermore, no very heavy drinkers or alcohol abusers were accepted

as subjects, and the maximum BAC examined was 0.10%. It is possible that drivers not represented in the sample population would be differentially affected by alcohol, but an examination of this would require separate studies of those specific populations. It should be noted that epidemiological studies can produce correlations due to uncontrolled co-variates, a problem avoided by controlled laboratory studies. Finally, this laboratory study indicates that some important driving skills are impaired when there has been use of even small amounts of alcohol.

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I. INTRODUCTION

It has been almost 100 years since it became apparent that drivers' use of alcohol leads to an increased risk of crash (See Borkenstein, 1985). Traffic codes prohibiting alcohol-impaired driving had appeared in the United States by 1910, and the major approach to prevention then, as now, was deterrence by legal prohibition and law enforcement. By the 1940's, only three percent of traffic collisions were reported as being alcohol-related, due largely to officers' difficulties in assessing drivers. In the 1930s, epidemiological studies, which are studies examining the distribution of an event in a population, had begun to use breath and blood specimens to measure blood alcohol concentration (BAC) in crash-involved drivers. The measured BACs showed alcohol involvement in crashes to be much greater than three percent, and it was on the basis of those studies that the states began to establish BAC limits for drivers.

The first law in the United States establishing a BAC limit was enacted in 1939 in Indiana. Initially, the limits in Indiana and in other states were set at 0.15%[1], but they now have been lowered nationwide to either 0.10% or 0.08%. In other countries they are even lower. Limits defined by BAC assist with enforcement problems and also aid drivers in assessing their own impairment. There is worldwide agreement that alcohol-involved driving is curtailed when BAC laws are enacted and enforced.

The reduction of limits from the initial 0.15% BAC was prompted by evidence obtained from experimental and epidemiological alcohol research. As research continued over several decades, and as scientific investigators improved their techniques for examining relevant driving behaviors, evidence of significant driving impairment was reported at even lower BACs.

Studies have reported that the degree of impairment produced by alcohol may be modified by other variables. For example, the Grand Rapids study, which was the largest epidemiological study, suggested that the variables, age, gender, and drinking practices, produce differential impairment at similar alcohol levels (Borkenstein et al., 1964). Firm conclusions about those three variables on the basis of epidemiological data are difficult, however, because each is also associated with other variables which influence crash rates. For example, young people show a differentially high crash rate under alcohol, but they are also less experienced drivers. Also, when the Grand Rapids study was executed in 1962, women drove far less frequently and for shorter distances than men, possibly making them more susceptible to alcohol effects on driving. Analysis of the study's data relied primarily on uni-variate statistical methods, which could not isolate the effects of age, gender, and drinking practices from the effects of other variables.

The literature reporting data from laboratory research contains only equivocal evidence for an age interaction with alcohol (Jones and Neri, 1994; Morrow et al., 1990; Collins and

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[1] The measurement unit used in this paper for blood alcohol concentration is "percent" (%). This metric stands for grams of ethanol in 100 milliliters of blood. Although this is typical usage in the United States, other measurement units are prevalent in other countries.

Mertens, 1988). These studies, which included no subjects under age 21 and few subjects over age 55, do not resolve the issue, however, since it was drivers under age18 and over age 70 for whom the Grand Rapids study suggested an age and alcohol interaction. The question of whether young drivers are differentially sensitive to alcohol also remains unanswered by the current study. Because alcohol cannot be administered in the United States to anyone under age 21, the youngest subjects were ages 19 and 20. They were tested in Ontario, Canada where the alcohol age limit is 19 years.

In the Grand Rapids study, a gender and alcohol interaction did not occur until the BACs reached 0.08% and above. At those levels, women were more frequently accident-involved than men. Laboratory studies of the responses by men and women to alcohol, however, provide inconclusive results. As Sutker et al. (1983) noted, most experiments have given men and women the same alcohol dosage. Since the body fat and total body water of men and women differ greatly even when they are the same age, height and weight, women reach a higher BAC than men for the same alcohol amount. Many early studies failed to take this into account, but more recent studies have used comparable BACs rather than equivalent doses. These studies failed to find significant difference between male and female subjects (Burns and Moskowitz, 1978; Mills and Bisgrove, 1983; Oei and Kerschbaumer, 1990).

More reliable evidence exists for an interaction between alcohol and drinking practices. The Grand Rapids study reported that the likelihood of involvement in a collision for drivers at the same BAC was greatest for the drivers with the lowest daily alcohol consumption. A study by Moskowitz, Daily and Henderson (1974) supported this finding with a comparison of extremely heavy drinkers (recruited from bars) and moderate drinkers. They reported that heavy drinkers were less impaired than moderate drinkers at equal BACs on several psychomotor tasks. Also, a mean ethanol clearance rate of 0.020% per hour for the heavy drinkers, in comparison to a rate of 0.017% per hour for the moderate drinkers, demonstrated a physiological difference between the heavy and moderate drinkers.

This study examined skills performance of a representative sample of the driving population at BACs from 0.02% to 0.10%. It also examined whether variations in drivers' age, gender, or drinking practices interacted with BAC and resulted in variability in the impairment produced by alcohol. One hundred sixty- eight subjects were classified by four age groups, two genders, and three drinking practice categories. The three variables of age, gender, and drinking practice dictated the assignment of subjects to 24 groups of 7 each (Figure 1).

The youngest subjects in the study, who were ages 19 and 20, were tested at Human Factors North (HFN) in Ontario, Canada. Also, although evidence of an interaction of gender and alcohol is less substantial than the evidence of interactions of age and drinking practices and alcohol, the study included equal numbers of men and women in order to examine the issue.

II. STUDY OBJECTIVES

This laboratory experiment had two major objectives. The first was to determine the BACs at which driving-related behavioral impairment appeared for the majority of subjects (Ss) in a representative sample of the population. The second objective was to determine whether and to what degree driving-related impairment by alcohol was differentially affected by differences in age, gender, and drinking practices.

Ss ages 21 and older were studied in Los Angeles at the laboratories of the Southern California Research Institute. Ss ages 19 and 20 were studied in Toronto, Ontario, Canada. Ontario law permits the administration of alcohol to Ss at age 19 years and older. The data collected both in the U.S. and in Canada were analyzed by Westat, Inc. in Rockville, Maryland.

III. METHOD

A. Experimental Design

Ss' driving-related behaviors were examined using a driving simulator (SIM) and a divided attention test (DAT). They were administered alcohol to produce mean test-time BACs from 0.00% to 0.10% for moderate and heavy drinkers and from 0.00% to 0.08% for light drinkers.

Figure 1 outlines the factorial design of the experiment with three factors (age, gender, drinking practice). Each S was tested under a placebo and an alcohol treatment at two sessions separated by a week. Statistically, the alcohol treatment comparisons were nested within each of the cells created by the age X gender X drinking practices factorial design.

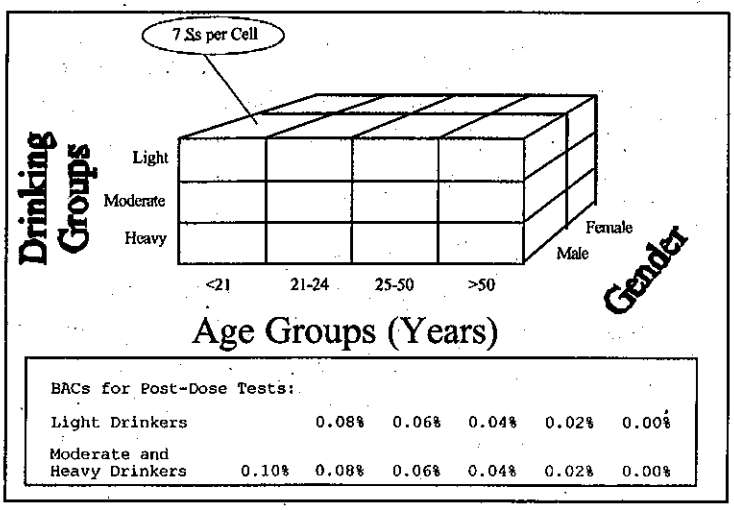


Figure 1. Experimental Design

The placebo and alcohol treatments were administered at two sessions in counterbalanced order. Half the Ss received the placebo treatment first and the alcohol treatment second, and half the Ss received the alcohol treatment first and the placebo treatment second. Ss in the moderate and heavy drinking categories were tested on the SIM and DAT prior to receiving alcohol and at mean BACs of 0.10%, 0.08%, 0.06%, 0.04%, and 0.02%, and at a final 0.00% on DAT only (Table AP-I-1).

Light drinkers were tested on the SIM and DAT prior to receiving alcohol and at mean BACs of 0.08%, 0.06%, 0.04%, and 0.02%, and at a final 0.00% on DAT only. BACs declined approximately 0.01% during a test battery of slightly more than 30 minutes. Since the aim was to test at mean BACs of 0.10%, 0.08%, 0.06%, 0.04%, and 0.02%, Ss were dosed to a BAC 0.01% above the testing level. They were examined repetitively with a breath-sampling instrument, and testing actually began when BACs were 0.005% above the desired mean level. As will be seen in the results, this procedure produced mean BACs extremely close to the desired levels.

The first post-alcohol testing for moderate and heavy drinkers, who were dosed to 0.11%, began when their BACs dropped to 0.105% and for light drinkers, who were dosed to 0.09%, when their BACs dropped to 0.085%. Two consequences should be noted. First, all Ss began their treatments at roughly the same time of day with the result that moderate and heavy drinkers were tested at 0.10% BAC at the same hour that light drinkers were tested at 0.08% BAC. Secondly, and of greater importance, all Ss were tested on the descending blood alcohol curve, because it is extremely difficult to pace alcohol consumption and track a rising alcohol curve for the purpose of behavioral testing at specified BACs (see Moskowitz, Daily, and Henderson, 1974 for such a procedure). As has been well established by the literature on acute tolerance to alcohol, however, Ss exhibit less impairment on a descending than on a rising alcohol curve. This means that during alcohol consumption and absorption, on the ascending limb of the BAC curve, impairment would be greater than what has been shown by this experiment.

During placebo sessions, Ss were tested at times which paralleled the testing times of the alcohol sessions. Based on an assumed mean ethanol clearance rate of 0.017% per hour, a 0.020% decrease in BAC would require approximately 70 minutes. Therefore, at placebo sessions Ss were tested at 70-minute intervals.

B. Regulatory Compliance

The study protocol and informed consent documents were reviewed by the NHTSA Human Use Review Panel (HURP), the SCRI Institutional Review Board (IRB) and the HFN IRB. Conduct of the study was approved by all panels prior to initiating the study. At regular intervals during the course of the study, members of the SCRI IRB were informed of the progress of the study, and they were advised when the study was completed.

C. Pilot Study

Before initiating the main study, pilot studies were performed to clarify two issues. The first issue concerned the advisability of administering an alcohol dose that would produce 0.11% BACs to light drinkers. The second issue was the sensitivity of the SIM response measures using the driving scenarios which had been constructed for this experiment.

1. Light Drinkers

This study was originally designed as a factorial experiment with equal numbers of light, moderate, and heavy drinkers to be dosed to a BAC of 0.11% (0.01% above the desired mean peak BAC). SCRI's prior alcohol experiments have shown repeatedly that moderate and heavy drinkers can reach that level without ill effects. Note that the definitions of drinking categories are derived from a scale from Cahalan, Cisin, and Crossley (1969), which relies on Ss' statements about the quantity and frequency of their drinking. It appeared most unlikely that light drinkers, as defined by their statements, would be able to reach a 0.11% BAC. Although the possible adverse effects of alcohol consumption could have been mitigated somewhat by very slow drinking, the change in time allowed for drinking would have disrupted the session schedule.

A pilot experiment was performed with nine light drinkers (8 females, 1 male) to determine the BAC that could be achieved. Three Ss in each of three age groups (21-24 years, 25-50 years, 51 years and above) participated in one session at the SCRI facility. Based on their height and weight, each was given sufficient alcohol over a 45-minute drinking period to produce a 0.09% peak BAC. They were advised to cease drinking if they began to feel uncomfortable. Eight of the nine completed the drinks and reached 0.09%. The peak level of 0.09% BAC was selected for light drinkers based on their comments and the pilot experiment drinking experience.

2. Simulator (SIM) Measures

In view of the low BACs to be examined in the study, it was assumed that skills performance differences between cell groups in response to equal BACs might be quite small, albeit significant. It was essential, therefore, that the SIM driving scenarios be examined prior to beginning the study to determine sensitivity to alcohol effects.

To examine the SIM scenarios, six females and two males attended two training sessions to learn to drive the simulator. After training, these pilot Ss, who ranged in age from 23 to 68 years, were tested on the SIM in a single day. They were first tested prior to receiving alcohol and then on a declining alcohol curve at 0.02% intervals. Five of the Ss were light drinkers and began post-dose trials at 0.085% BAC. Three moderate drinkers began post-dose trials at 0.105% BAC.

Ss in the pilot test exhibited performance impairment at all active BACs, in comparison with the initial, pre-alcohol test. Therefore, the simulator scenarios were considered sufficiently sensitive to be used in the main study.

D. Apparatus

As previously discussed, a simulator and a divided attention task were selected for this study. A literature review by Moskowitz and Fiorentino (2000) identifies these as the most sensitive of currently-available tasks for the examination of low BAC effects. They were selected not only because they are sensitive to alcohol but also because of their relevance to driving.

1. Driving Simulator (SIM)

The driving simulator was constructed by Systems Technology, Inc. of California with scenarios and secondary tasks developed by SCRI personnel. SIM is a computer-based system, which uses three video monitors in a horizontal arc presenting a 110° angle view of the driving scene. The image responds to input from the steering wheel, accelerator and brake, and there is appropriate visual and sound feedback. A concurrent secondary task requires the detection of visual signals in peripheral vision. The driving scenarios include rural, suburban and urban segments. The total travel distance is 63,000 feet, and the drive typically requires 18 to 20 minutes. The simulator provides a variety of response measures from which a representative subset was selected for this experiment.

The *rural* segment is a straight one-lane road with shallow curves. Periodic cross traffic tests Ss' perception of speed and distance, and wind gusts increase steering difficulty. Since this segment lacks confounding variables, speed and lane position can be measured.

The *suburban* segment markedly increases driving demands. Ss drive a three-lane expressway at 55 mph, slowing to 45 mph for posted curves. They make frequent lane changes to pass other vehicles and to avoid cross traffic, entering traffic, and stalled cars.

In the *urban* segment, the driver attempts to maintain the posted 45 mph speed limit and slows to 25 mph for curves on a two-lane roadway through a city with 11 signal-controlled intersections. Pedestrians enter and cross in walkways at the signals.

The secondary task mirrors the information-processing demands and the dual-task nature of actual driving. Ss monitor the periphery of the visual display and respond to signals which appear at the extreme right and left. The signals are a left arrow, a right arrow, and a horn. Ss respond to a left or right arrow with the corresponding turn signal and to the horn sound with the horn button. In total, 72 signals occur at random intervals during the drive. Measures include response time and number of incorrect responses.

The following SIM response measures were analyzed:

- Reaction time to peripheral signals (sec)
- Incorrect responses to peripheral signals (number)
- Speed deviation (mph)
- Lane position deviation (ft)
- Collisions (number)
- Times over speed limit (number)

2. Divided Attention Test (DAT)

Stephens and Michaels (1963) characterized driving as a time-shared activity between a visual search-and-recognition task and a tracking task. The DAT used in this study is conceived as an analogue of the time-sharing and information-processing demands of driving.

The DAT shares the SIM hardware and requires Ss to allocate attention to multiple sources of information on three video monitors. The concurrent structure and task demands prevent parallel processing of information, and attention must be alternated between tracking and visual search.

A one-dimensional pursuit tracking task appears on the center screen. As a red ball moves horizontally in response to a forcing function, Ss use a joystick to try to keep a white cross superimposed on the ball. The distance between the ball and cross is recorded as tracking error. As Ss perform the continuous tracking task, they also monitor four arrays, each containing six numbers in a 2 X 3 pattern, which appear above and below center in left and right peripheral vision. The numbers change continually, and Ss' task is to detect the appearance of the number "2". Response requires selection of the button on a 4-button response pad which corresponds to a target's position. For example, a correct response to a target in the upper left array is made with the upper left button. A 12-minute trial presents two targets at each of 24 positions.

Recorded measures for DAT include:

- Response time (sec) with a Maximum Allowable Response Time of 10 sec
- Incorrect responses (number)
- Tracking error (cm)

E. Subjects

A total of 168 Ss participated in this study. These Ss were divided into 24 cells, defined by the four categories of age, the two categories of gender, and the three categories of drinking practices. Thus, there were seven Ss in each cell.

1. Gender

Eighty-four men and 84 women participated in the study. The average age of the men was 34 years 11 months, and the average age of the women was 33 years 2 months. See Table AP-I-2 for other characteristics of the Ss, including mean height, weight, and age for each of the classifications.

2. Age

Four age groups each contained 21 men and 21 women. These were youthful drivers (19-20 years), young adult drivers (21-24 years), adult drivers (25-50 years), and older drivers (51-69 years). The mean age for the four groups were 19 years 8 months, 22 years 5 months, 32 years 8 months, and 61 years 7 months, respectively.

3. Drinking Practices

Ss were classified as light, moderate, and heavy drinkers, with 56 Ss in each category. They were categorized by the Cahalan, Cisin and Crossley (1969) Quantity-Frequency-Variability scale. During the period of S selection, it was decided to exclude any applicant near the borderline of a category. This decision was based on the fact that the categorizations rely on self-reports of alcohol use, and the literature suggests that self-reports have considerable variability. Since comparisons were to be made between drinking categories, it was not advisable to include Ss who might be incorrectly characterized as a result of the variability of their responses. For that reason, whenever applicants' responses placed them at the border of light and moderate or at the border of moderate and heavy, they were not included. It should be noted that recruitment of volunteers for an alcohol experiment does not attract extremely light drinkers.

F. Procedures

The procedures described in the following sections were followed for the experiments in Los Angeles and in Toronto.

1. Subject Recruitment and Screening

Applicants responded to newspaper ads and were interviewed first by telephone and then in-person. They were screened in terms of health history, current health status, and use of alcohol and other drugs. Pregnancy, chronic disease, or evidence of substance abuse resulted in exclusion. Those applicants who met study criteria were enrolled to fill age, gender and drinking-practices cells as illustrated in Figure 1.

2. Training Sessions

To learn to drive the SIM and perform DAT, Ss attended two 4-hour training sessions during the week prior to their first treatment session. The training sessions were separated by at least one day. Instructions, demonstrations, practice trials, and feedback proceeded by a standard protocol.

a. SIM Training

A Research Assistant (RA) demonstrated basic operation of the SIM and observed a S's first drive through rural, suburban, and urban scenarios. The RA provided instruction as needed. Following the introductory drive, the RA instructed and demonstrated the secondary task. In a second drive, the S both drove the SIM and performed the secondary task. The RA continued to provide instruction.

b. DAT Training

The RA first instructed and demonstrated only the DAT tracking task, and the S performed a 6-min trial of tracking alone. The RA then instructed and demonstrated the visual search task, and the S performed a 6-min trial of visual search alone. The initial training ended with a 12-min trial of the combined task.

c. Practice Test Batteries

After Ss had been trained on both SIM and DAT, they were required to rest for 30 minutes. They then performed the entire test battery without instruction or feedback. At the conclusion of the second battery, the RA discussed the S's performance with him or her, providing positive reinforcement for good scores and noting areas needing improvement.

Ss were given three DAT trials and four SIM drives on both training days. At the end of the second training day, Ss' scores were reviewed to determine whether criterion performance levels had been achieved. No S required an additional training session.

3. Experimental Test Sessions

Each S was tested at two sessions, which were separated by one week. Half the Ss received placebo at the first session and alcohol at the second session; the other half of the Ss received treatments in the reverse order.

a. Alcohol and Placebo Beverage Administration

Ss' were tested on the SIM and DAT prior to being given alcohol, at the highest BAC for their drinking classification, and at 0.02% BAC intervals as their

alcohol levels decreased. They were tested on DAT when their BACs returned to zero. Note that testing occurred only on the descending limb of the BAC curve.

Calculations of alcohol doses were based on the amount of body water into which the alcohol would be distributed. Body water was estimated as a percentage of a S's body weight taking into account gender and age (Frisch, 1988), and the estimate was adjusted for frame size and body composition. To insure that alcohol was not administered to pregnant women, urine specimens were obtained from women of childbearing age and were tested for pregnancy prior to treatment administration.

The beverage was one part 80 proof vodka and 1.5 part orange juice for moderate and heavy drinkers, who received the beverage as three equal drinks at 10-minute intervals. The dilution was one part vodka to two parts orange juice for light drinkers, who received three equal drinks at 15-min intervals. Ss were instructed to pace each drink evenly over the entire drinking period, and they were monitored by an RA who periodically advised them of the time remaining to complete each drink.

The placebo beverage was identical to the alcohol beverage except that water was substituted for vodka. Vodka (10 ml) was floated on top of the beverage, and the edge of each cup was swabbed with vodka to produce an initial odor and taste of alcohol. Administration procedures were identical to those described for the alcohol beverage.

At both alcohol and placebo sessions, breath specimens were obtained with an Intoxilyzer 5000 for BAC measurements beginning 30 minutes after the end of drinking. If an initial BAC was lower than the target, breath sampling was repeated at 10-minute intervals until the target was reached or until successive tests showed that the BAC had begun to decline. In the latter case, a booster dose was given. A breath specimen was obtained at the conclusion of the first test battery, and BAC monitoring continued in the manner described above. The Intoxilyzer display of the measurements was shielded from the S's view.

b. Performance Testing

Table AP-I-1 displays performance testing schedules. At alcohol sessions, the batteries (SIM and DAT) were initiated within +/- 0.005% of the target BAC and were repeated at 0.02% intervals with the final DAT beginning at 0.00%. Testing was initiated at placebo sessions after obtaining the first breath specimen. Timing of subsequent test batteries allowed sufficient time for a 0.02% decrease with the interval calculated at a 0.017% per hour metabolism rate.

IV. RESULTS

A. Blood Alcohol Concentration

Table 1 presents the mean BACs measured immediately before and after each test battery. As can be seen in the table, the mean for each battery was within 0.002% BAC of the levels specified in the design of the experiment. The mean of 0.098% measured at battery 2 is for moderate and heavy drinkers only. Batteries 3 through 7 include all Ss.

Table 1

Blood Alcohol Concentrations (BACs), by Test Battery
168 Subjects

Mean BACs (%)			
Test Battery	Pre-Battery	Post-Battery	Battery Average
1	0.000	0.000	0.000
2	0.102	0.094	0.098
3	0.082	0.073	0.078
4	0.063	0.055	0.059
5	0.044	0.035	0.040
6	0.024	0.015	0.020
7	0.001	0.000	0.001

B. Sensitivity of Study Measures

It was necessary to determine whether the response measures for both SIM and DAT had proved to be sufficiently sensitive for detection of the differential effects of alcohol as a function of age, gender and drinking practice. The placebo scores were examined for this purpose and, in fact, demonstrated that the measures were capable of detecting differences between Ss classifications on these three variables. Although the results are of considerable interest, their presentation is deferred to a subsequent publication to avoid distraction from the main thrust of the experiment.

C. Ethanol Clearance Rate

The ethanol clearance rate is the BAC decline over time after alcohol absorption from the intestinal tract is complete. The rate varies as a function of age, gender, and drinking practices.

The rate for male Ss in this experiment was 0.0149% and the rate for female Ss was 0.0184%. The rates by age group were 0.0156% for Ss ages 19-20, 0.0156% for Ss ages 21-24, 0.0168% for Ss ages 25-50, and 0.0183% for Ss ages 51-69. The ethanol clearance rates for Ss as a function of drinking practices varied from 0.0157% for light drinkers to 0.0165% for moderate drinkers and 0.0176% for heavy drinkers.

The ethanol clearance rate shows an increase with greater frequency of alcohol consumption. This variability is due to the stimulation by alcohol of the production of a liver enzyme. Although the clearance rate for the moderate drinkers in this experiment was found to be very close to that which was anticipated, the rate for light drinkers was higher and the rate for heavy drinkers was lower than expected. The finding strongly suggests an under-representation of the lighter drinkers of the light-drinking category and of the heavier drinkers of the heavy-drinking category. The latter result may be the consequence of the SCRI practice of excluding alcoholics from alcohol experiments.

D. Sequence and Order Effects

Ss in this experiment received a placebo treatment and an alcohol treatment on test days separated by one week. In this repeated measures design, it is necessary to examine the data to determine whether the sequence of treatments affected the results. Was the effect of alcohol different for Ss who received placebo first and alcohol second in comparison to Ss who received treatments in the reverse order? A difference would indicate a sequence effect.

An additional question asks whether the average performance on test day one differs from the average performance on test day two, perhaps due to the difference in practice on the tests. A difference would indicate an order effect. It should be noted, however, that given the training sessions, such differences would be small, and the number of Ss per cell would limit the power of the test to detect such effects.

1. Sequence Effect

Half the Ss received treatments in the sequence placebo-alcohol, and half the Ss received treatments in the sequence alcohol-placebo. The mean scores for the two sequences were examined with statistical tests for each response measure at each BAC and across BACs. Table AP-I-3 presents the statistical analysis. Twelve response measures for SIM and DAT were examined. None of the tests for overall sequence effects were statistically significant. Two of 64 tests at separate BACs were significant at the .05 level. The finding of only two statistically significant tests of 76 total tests (12 across BACs plus 64 at separate BACs) suggests that the two were random occurrences, and it is concluded that there is no evidence of a sequence effect that might influence data analysis.

2. Order Effects

All response measures were examined for an order effect. That is, did the average performance score on test day 1 differ from the average performance score on test day 2? Figures AP-I-1a and AP-I-1b present the mean change in score from baseline for each measure for the two test days. Each figure has two lines, one representing the difference scores for each test time for day 1 and one representing the difference scores for day 2. Recall that a difference scores is the post-treatment test score minus the pre-treatment test score. For each line half the Ss are under placement treatment, and half are under alcohol treatment.

Table AP-I-4 presents the results of a statistical analysis, which controlled for the variables of alcohol, battery and the alcohol X battery interaction, and examined whether the mean difference scores on days 1 and 2 differed. Five of the nine response variables were not statistically significant, but four were. Three of the four significant measures were worse on day one and one was worse on day two. These somewhat contradictory results clearly cannot rule out the possibility of an order effect. Since the treatments in the study were counterbalanced, however, the existence of an order effect would have no influence on the analysis of the alcohol, age, gender and drinking practice variables or their interactions. Such an effect would only limit statements about the impairment by alcohol of each individual.

E. Alcohol Effects Analysis

One hundred sixty-eight Ss were tested six (or seven) times at two sessions, one with a placebo treatment and one with an alcohol treatment (Table AP-I-5). The DAT provided three response measures: reaction time to peripheral signals, number of incorrect responses to peripheral signals, and error on the tracking task in central vision. The SIM provided six response measures: lane deviation variability, speed variability, number of collisions, number of times over the speed limit, reaction time to peripheral signals, and number of incorrect responses to peripheral signals. Additionally, two performance indices were created by combining all measures for the DAT into one composite score and combining all measures for the SIM into another composite score. These two composites were also combined to create a single index of overall performance.

Figure 2 presents the average raw scores for the three DAT measures, and Figure 3 presents the average raw scores for the six SIM measures. In both figures the scores are shown by battery (seven for DAT, six for SIM) and by treatment condition. Battery 1 is the pre-test or the pre-treatment test. Battery 2 is the first post-treatment test at 0.10% BAC when only moderate and heavy drinkers were tested. Light drinkers were first tested post-treatment at battery 3 when all Ss were tested at 0.08% BAC. The mean BAC for battery 4 was 0.06%. For battery 5 it was 0.04% and for battery 6 it was 0.02%. The BAC was 0.00% for battery 7 when the only test was DAT.

Figure 2

DAT Raw Scores, All Subjects (N=168)

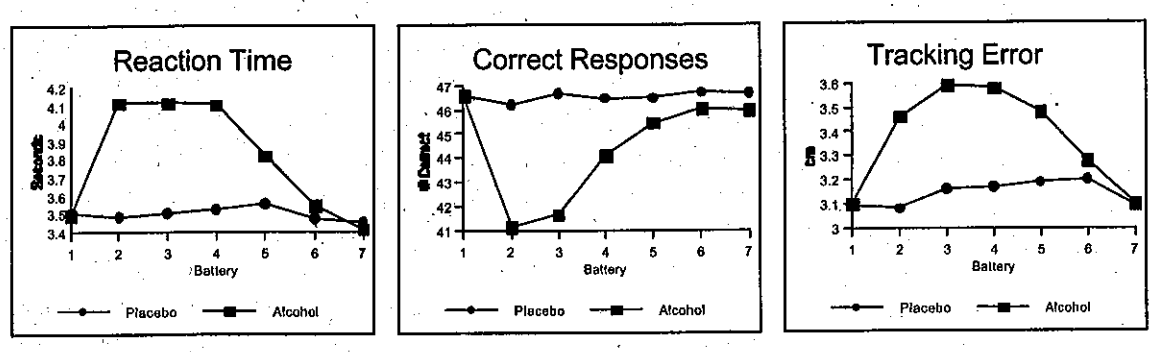
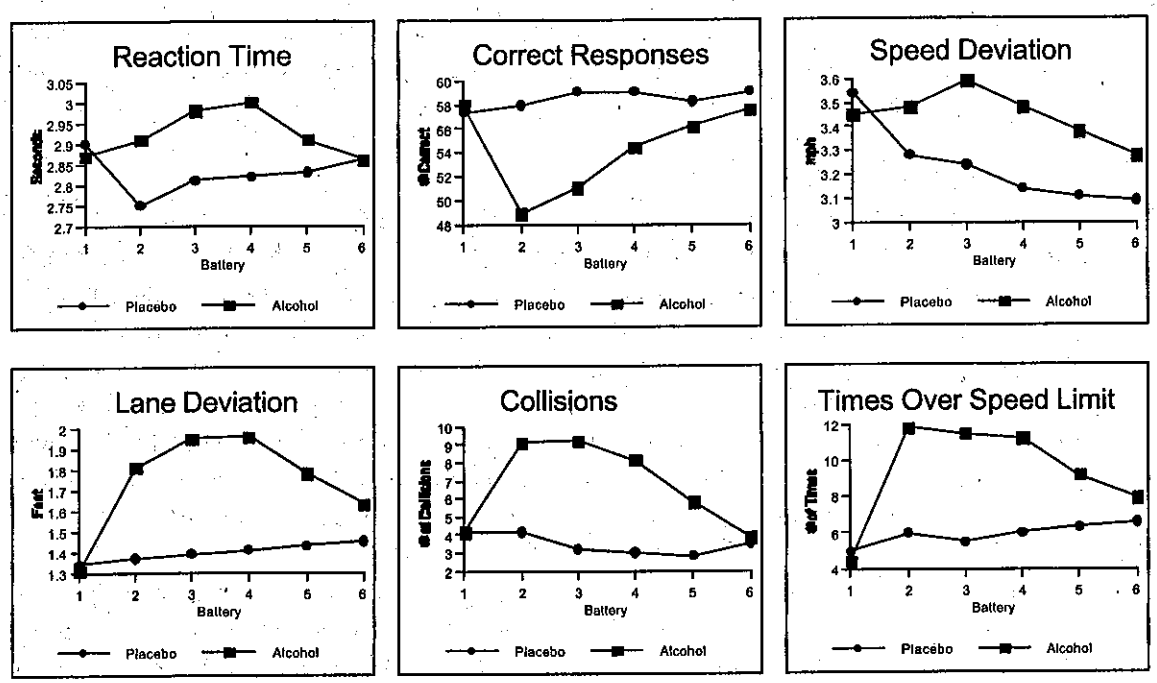


Figure 3

SIM Raw Scores, All Subjects (N=168)



The raw scores, which do not take pre-treatment performance into account, reveal impairment of all DAT and SIM measures at all positive BACs in comparison to performance in the placebo condition. If the curves are mentally adjusted so that the placebo and alcohol curves begin at the same point, it will be seen that the differences in SIM scores are even greater than they appear in the figures. In all comparisons, the adjustment produces greater separation of the alcohol and placebo curves. In order to take into account the variability of the pre-test scores on the two test days, the comprehensive statistical analysis used an impairment score, as described below.

Note in the succeeding tables, that the measure "number of incorrect responses to peripheral signals" for both DAT and SIM appears in two forms. The measure is tabled both as number of errors and as percent errors. The percent measure was generated, because there was a statistical question as to whether the measure, number of errors, would be normally distributed. A log-odds ratio was used for comparing correct responses under alcohol to correct responses under placebo. For counted variables, many statisticians and researchers prefer log-odds ratios to simple difference scores. Log-odds lead to more stable variances than do simple difference scores and often the statistical distribution of log-odds ratios are better approximated by the normal distribution than the distribution of the untransformed variable (see Appendix A for a more detailed description of this approach). As it developed, the results of statistical tests were the same for both number of errors and as percent errors but rather than re-create the tables both are included. Note, however, that in all subsequent discussions, the response error measure is counted only once for DAT and once for SIM.

1. Impairment Scores

An impairment score was created for the statistical analysis of the alcohol effect. An impairment score is defined as the performance score on the alcohol treatment day at a given BAC minus the comparable placebo score minus the differences in the pre-treatment test scores on the two test days. Thus, the impairment score takes into account the time-of-day factor at which testing occurred under the two treatments, and it also takes into account variations in a S's overall performance from day to day.

Ss were tested at BACs from 0.08% to 0.00%. Moderate and heavy drinkers only (n=112) were also tested at 0.10% BAC (Table AP-I-1). Impairment scores were created for each S at each BAC for the nine original single response measures and three composite scores. The advantage of the latter is that they take a larger slice of the performance information into account and, therefore, provide a more stable measure.

Table 2 shows the percent of Ss whose impairment score was poorer under alcohol than under placebo. Table 3 shows the results of the statistical test of the null hypothesis, which states that fifty percent of the Ss would have performed worse under alcohol if alcohol had no effect. To be redundant, the null hypothesis states that there is no difference between active and placebo treatments, and that by chance half the scores

will be poorer on the alcohol treatment day, and half the scores will be poorer on the placebo treatment day.

Table 2

Percent of Subjects Impaired by BAC
(DAT and SIM Impairment Scores)

Measurement	BAC (%)					
	.00	.02	.04	.06	.08	.10
DAT Reaction Time	50	50	63	70	80	90
DAT Number Incorrect (%)	39	37	45	54	58	71
DAT Number Incorrect (#)	41	38	44	54	58	70
DAT Tracking Error	53	60	68	77	79	83
SIM Reaction Time	.	52	58	72	72	78
SIM Number Incorrect (%)	.	52	54	63	72	73
SIM Number Incorrect (#)	.	53	56	65	73	78
SIM Speed Deviation	.	55	55	61	64	66
SIM Lane Deviation	.	70	77	88	90	88
SIM Collisions	.	43	56	65	72	75
SIM Times Over Speed Limit	.	57	65	78	79	86
DAT Performance Index	52	56	67	82	83	91
SIM Performance Index	.	68	71	84	88	96
DAT+SIM Performance Index	.	68	79	88	92	93

The scores in Table 2 were tested for statistical significance with a two-tailed binomial distribution test. If the null hypothesis were true and alcohol and placebo treatments were equal in effects, half the impairment scores would be positive and half would be negative. Examining the binomial distribution for 168 Ss reveals that the probability is less than .05 that as many as 58 percent of the Ss would show a positive impairment score if the null hypothesis were true, or conversely that as few as 42 percent would show a negative impairment score. For 112Ss (the number tested at 0.10% BAC), the probability is less than .05 that as many as 60 percent would have an alcohol score worse than the placebo score. Thus, the null hypothesis is rejected if as many as 58 or 60 percent of the Ss exhibit poorer performance under alcohol.

Table 3 gives the exact probability for tests of the null hypothesis for each response measure at each BAC. Beginning with 0.02% BAC, two of the nine single response measures and two of the three composite measures showed statistically significant poorer performance under alcohol.

Table 3

Tests of the Null Hypothesis
That 50% of the Subjects Were Impaired
p Values

Measurement	BAC (%)					
	.00	.02	.04	.06	.08	.10
DAT Reaction Time	.938	1.000	.001	.001	.001	.001
DAT Number Incorrect (%)	.004	.001	.165	.355	.045	.001
DAT Number Incorrect (#)	.016	.001	.123	.355	.031	.031
DAT Tracking Error	.395	.014	.001	.001	.001	.001
SIM Reaction Time	.	.537	.031	.001	.001	.001
SIM Number Incorrect (%)	.	.643	.280	.001	.001	.001
SIM Number Incorrect (#)	.	.440	.123	.001	.001	.001
SIM Speed Deviation	.	.217	.217	.003	.001	.001
SIM Lane Deviation	.	.001	.001	.001	.001	.001
SIM Collisions	.	.064	.123	.001	.001	.001
SIM Times Over Speed Limit	.	.090	.001	.001	.001	.001
DAT Performance Index	.588	.123	.001	.001	.001	.001
SIM Performance Index	.	.001	.001	.001	.001	.001
DAT+SIM Performance Index	.	.001	.001	.00	.001	.001

At 0.04% BAC, five of the single response measures and all three composite scores show statistically significant alcohol impairment. At 0.06% BAC eight of the nine measures and all composite scores show statistically significant alcohol impairment. At 0.08% and 0.10% BAC all single and composite scores show statistically significant alcohol impairment.

As suggested by the graphs and supported by the statistical analyses, the overwhelming majority of Ss were significantly impaired by alcohol on some important measures beginning at 0.02% BAC, the lowest level tested. The number of Ss who were impaired by alcohol increased as BACs increased. Also, in general the magnitude of the impairment increased with increasing BAC (Figures 2 and 3).

Several of the single response variables showed a slight deviation from the finding of maximum impairment at 0.10% BAC in that the greatest impairment occurred at 0.08% BAC. To investigate this phenomenon, which initially was believed to be due to the light drinkers being first tested at 0.08% BAC, raw scores were examined separately for light, moderate, and heavy drinkers. For all drinking practices groups, greater impairment on some responses occurred at the second post-treatment testing. That is, for moderate and heavy drinkers, there was more impairment on a few of the responses at 0.08% than at 0.10%, and for light drinkers there was more impairment on some variables at 0.06% than at 0.08%.

It should be noted that since the behavioral tests began at the same time for all Ss, the moderate and heavy drinkers were tested at 0.10% at the time of day when light drinkers were tested at 0.08%. It is possible, therefore, that a time-linked factor increased impairment at the second post-treatment test. Perhaps some source of stimulation offset impairment at the first post-treatment test, or possibly a circadian interaction produced a greater decrement at the next test time. The issue cannot be resolved from the data, but the analyses make it clear that it was the order of testing rather than BAC that caused the variation in the magnitude of impairment. For the majority of measures, the expected relationship of greater impairment with higher BAC was found. Figures AP-I-3a to AP-I-10b, which present raw DAT and SIM scores separately for light, moderate and heavy drinkers, illustrate that for most measures the greatest impairment occurred at the highest BACs.

Finally, Ss were tested on DAT only when their BACs returned to 0.00%. Three of the four DAT response measures showed no alcohol effect; the percent of Ss with more impairment after alcohol was roughly equal to the percent of Ss with more impairment after placebo. There was, however, an unusual effect for the remaining measure, number of errors in detecting peripheral signals. In a statistically significant deviation, performance was better than what would be expected. Whether this result reflects some time-linked factor or a rebound effect cannot be determined. Since it was only one of four response measures, it also cannot be predicted that it would occur upon retest.

2. Age, Gender and Drinking Practice Effects

As discussed above, these data indicate that alcohol, even at 0.02% BAC, produces impairment in some important measures in the majority of Ss. This section

considers whether impairment by alcohol varies as a function of age, gender or drinking practices.

The original design for this study would have supported a complete factorial analysis of variance with age, gender and drinking practices as the main effect and with the alcohol treatments nested within each cell of the factorial design. All Ss were to have received sufficient alcohol to achieve a peak 0.11% BAC. As discussed in an earlier section, however, it was determined that many light drinkers probably would experience nausea or more severe effects at that level of alcohol. As a consequence, the peak BAC for light drinkers was set at 0.09%. It was further determined that a standard analysis of variance of main effects, which would sum the effect of a variable across all levels, might obscure small effects which occurred at certain BACs and not at others. It was decided, therefore, to simplify the analysis by examining each alcohol level as a separate factorial design. This analysis also removed the problems of the interactions with the different BACs, which would have required another dimension in the factorial design

The five factorial designs for statistical analysis of the impairment scores at the five BACs from 0.02% to 0.10% are shown in the matrix below. With only heavy and moderate drinkers at 0.10% BAC, the design is a 4 (Age) X 2 (Gender) X2 (Drinking Groups) factorial. With all Ss and three drinking groups at 0.08%, 0.06%, 0.04%, and 0.02%, the design is 4 X 2 X 3.

BAC	DESIGN
0.10%	Age (4) X Gender (2) X Moderate and Heavy Drinkers (2)
0.08% 0.06% 0.04% 0.02%	Age (4) X Gender (2) X Light, Moderate and Heavy Drinkers (3)

Table 4 summarizes the mean impairment score for each response variable within age, gender, and drinking practice. These data, which are across all BACs, are not the basis of the statistical significance tests. They merely provide an overview of the variability in impairment by alcohol with the three groupings. The scores are in the original response measure dimension, adjusted for baseline; for example, reaction time is in seconds. The figures in Appendix II show the original impairment scores at each BAC for each of the single response variables by each of the categories within age, gender, and drinking practices. The figures in Appendix III show the impairment scores at each BAC for the three DAT, SIM, and DAT+SIM composite scores.

Table 4

Impairment Scores (Means),
by Age, Gender, and Drinking Practice

Measurement	Subject Groups									
	Age				Drinking			Gender		All
	19-20	21-24	25-50	51-69	Light	Mod	Heavy	Female	Male	
DAT Reaction Time	0.50	0.37	0.53	0.33	0.43	0.30	0.36	0.34	0.53	0.43
DAT Number Incorrect (%)	1.65	1.72	1.43	0.76	1.94	0.73	1.16	1.05	1.73	1.39
DAT Number Incorrect (#)	0.41	0.41	0.57	0.25	0.54	0.29	0.29	0.24	0.58	0.41
DAT Tracking Error	0.42	0.37	0.29	0.21	0.22	0.35	0.28	0.40	0.25	0.32
SIM Reaction Time	0.30	0.26	0.24	0.06	0.21	0.14	0.21	0.22	0.22	0.22
SIM Number Incorrect (%)	6.66	5.03	4.71	1.04	4.42	1.61	5.47	4.05	4.67	4.36
SIM Number Incorrect (#)	0.72	0.64	0.57	0.08	0.58	0.20	0.55	0.50	0.50	0.50
SIM Speed Deviation	0.33	0.81	0.42	0.22	0.42	0.21	0.66	0.73	0.16	0.44
SIM Lane Deviation	0.35	0.55	0.46	0.56	0.46	0.53	0.40	0.48	0.48	0.48
SIM Collisions	2.73	3.74	3.15	6.50	3.67	4.06	3.46	4.16	3.90	4.03
SIM Times Over Speed Limit	3.68	6.30	4.89	4.81	4.80	4.14	4.81	4.88	4.96	4.92
DAT Performance Index	0.47	0.38	0.42	0.28	0.31	0.33	0.32	0.38	0.39	0.39
SIM Performance Index	0.51	0.61	0.52	0.46	0.51	0.47	0.48	0.53	0.53	0.53
DAT+SIM Performance Index	0.54	0.54	0.50	0.40	0.46	0.43	0.43	0.49	0.50	0.50

Table AP-I-6 presents the mean scores for each classification within each of the three main grouping factors. The scores have been standardized; that is, they have been transformed in terms of standard errors of the mean so that they have a common metric. In addition, the probability level appearing after each mean value indicates whether the mean impairment score within that category, when divided by the standard error of the mean of that category, is statistically significant. The tabled probability values are defined as follows: zero = probability less than .10, 1 = probability less than .05, 2 = probability less than .01, and 3 = probability less than .001.

Finally, Table AP-I-7 gives the test results for the mean effects of age, gender and drinking practices and their interactions. At each BAC, for each of the three main effects

and four interaction terms, there were 48 statistical tests. Composite measures were excluded. Thus, there are nine single measure (6 from SIM, 3 from DAT) for five BACs plus three DAT measures at zero BAC for a total of 48 tests.

Table 5 summarizes the number of tests that were significant at the .05 level for each factor and the interactions. Six tests are significant for age, four for gender, five for drinking practices, two for the age X gender interaction, and five for the age X drinking practices interaction.

Table 5

Number of Significant Tests,
by Factor and Interaction

Effect	Tests (Total Number)	Tests p• .05 (Number)
Age	48	6
Gender	48	4
Drinking Practice	48	5
Age X Gender	48	2
Age X Drinking Practice	48	5
Gender X Drinking Practice	48	0
Age X Gender Drinking Practice	48	0

Thus, of 336 statistical tests performed to evaluate differential alcohol effects as a function of age. gender, or drinking practices, only 22 reached the .05 significance level. Given random performance variability, some statistical tests will be significant by chance even if there were no true underlying performance differences as a function of the experimental variable. An experiment-wide judgement of the number of findings expected to be significant at the .05 level by chance is difficult, because in the repeated measures design the same Ss were used in all tests. An approximation, however, assuming independence of statistical tests and using Fisher's exact test, indicates that six positive significant tests out of 48 are required to reach at least a .05 level. Five significant tests only reach a .18 probability level.

Only the age variable approaches overall significance. Even within the age variable, however, six significant test among four response variables at three BACs occurred in no consistent pattern. It is concluded, therefore, that within the limits of the

population represented by the study sample, there is no significant evidence that either age, gender, or drinking practice produces a differential response to the impairing effects of alcohol.

As noted earlier, no Ss were younger than 19 years of age nor over 70, nor did the sample include alcohol abstainers, heavy alcohol abusers, or alcoholics. Thus, the conclusions are limited by the sample, but the characteristics of the sample likely represent the characteristics of 80 - 90 percent of the driving public who will take a drink.

To re-state the finding, for the population represented by the study sample, which demonstrated impairment in driving skills beginning at 0.02% BAC, differences in age, gender, and drinking practices provide no mitigation of impairment. Had the experiment used many more Ss to greatly increase the power of the statistical tests, some of the small differences might have reached statistical significance. From a social point of view, that would be irrelevant to the study findings, because the actual differences would remain small in comparison to the overall effects of alcohol.

The tables and figures in the appendix support these conclusions. In a non-significant trend, the oldest drivers' response to alcohol appeared dissimilar to the response of the other three groups. There was, however, no consistent direction since the oldest drivers were least impaired on four measures and most impaired on two measures. Males and females split the measures on which they were more impaired with no evidence of any gender superiority. Among drinking practice groups, light drinkers showed a tendency toward more impairment, but it was small and non-significant. Moderate and heavy drinkers were indistinguishable in degree of impairment. Even if these trends had been statistically significant, they were so small as to be socially irrelevant.

V. DISCUSSION AND CONCLUSIONS

The results obtained in this laboratory study demonstrate that major driving-related skills were impaired by BACs as low as 0.02% on some important measures for a majority of Ss who were a broadly representative sample of the driving population. The results also indicate that as BACs rise, the percentage of individuals exhibiting impairment, as well as the magnitude of the impairment, grows. Thus, there is great consistency in the relationship between the degree of impairment and BAC. Throughout the range of 0.02% - 0.10% BAC there is evidence of significant alcohol-related impairment. These findings are consistent with the findings from epidemiological crash data, which have been analyzed with contemporary statistical methods (Allsop, 1966; Hurst, 1973; Zador et al., 2000). Additionally, Ss in the study were examined only on a declining BAC curve, and the results, therefore, underestimate the magnitude of impairment expected to occur during alcohol consumption and absorption when BAC is rising.

Logic suggests that the impairment found at low BACs should be paralleled by crash and fatality data. The relationship, however, may be obscured in on-the-road data by uncontrolled variables, which can be controlled in an experiment. The laboratory data, therefore, yield conclusions about causal relationships, which frequently cannot be detected in epidemiological data.

This study further examined the issue of the universality of the conclusion that impairment exists for many behaviors at BACs as low as 0.02%. The study employed a diverse sample of the driving population as Ss and found no substantial differences between the S groups either in the BACs at which impairment appeared or the magnitude of the impairment. Within the statistical power of the study and within the breadth of diversity of the Ss, there is only random variation in the degree of impairment.

Data from epidemiological studies have suggested that age, gender, and drinking practices do differentially affect impairment. As noted earlier, however, the presence of other co-variates associated with each of these three variables may interfere with examination of the relationship of alcohol and traffic collisions and fatalities. For example, an examination of alcohol effects on traffic deaths as a function of driver age is confounded by the fact that the collision force that would moderately injure a young driver can fatally injure an older driver. Although multivariate statistical analysis can control for some of the co-variates, data from controlled laboratory experiments are better able to clarify the underlying relationship of impairment by alcohol.

Although there were essentially no significant differences in alcohol impairment between age groups, male and female Ss, or light, moderate, and heavy drinkers, it is important to note the restricted range of S characteristics. No Ss were18 years or younger, the age group that showed the greatest increase in crash rates at low to moderate BACs in the Grand Rapids data. The effects of age and lack of driving experience are confounded in the epidemiological data, and due to the legal restrictions on giving alcohol to youth, these laboratory data permit no conclusion about the relationship.

Conclusions based on the laboratory data are further limited by the lack of Ss ages 70 years and above. Although not statistically significant, the Grand Rapids data suggested an increased impairment by alcohol for these older individuals. Finally, and perhaps most importantly, as demonstrated by an ethanol clearance rate of 0.0183% per hour for heavy drinkers, the study did not examine alcohol impairment in *very* heavy drinkers, that is, alcoholics or alcohol abusers. These individuals were excluded out of ethical concern about administering alcohol to problem drinkers.

The major conclusion of this study is that a majority of the driving population is impaired in some important measures at BACs as low as 0.02% BAC. Although research at BACs below 0.03% has been limited, the scientific literature contains no evidence of a threshold BAC below which impairment does not occur. Nor do the data from this study provide any evidence that the driving skills of a particular category of drivers will not be impaired by alcohol.

Scientific data provide clear evidence that important driving skills are impaired at very low BACs. It falls to society as a whole, and legislative representatives in particular, to assess the costs of and the remedies for alcohol-impaired driving.

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Appendix A

Description of Calculation of Individual Difference Scores

Individual difference scores for variables representing counts were calculated using logistic- transformed test results for corresponding batteries under alcohol and placebo. The count variables were DAT and SIM correct answer counts, and SIM collisions and speed exceedances.

AD_CORR/(50-AD_CORR) is the odds for correct response under alcohol, and
PD_CORR/(50-PD_CORR) is the odds for correct response under placebo, so that

LOG (OR) =
LOG((0.5+AD_CORR)/(0.5+50-AD_CORR)) - LOG((0.5+PD_CORR)/(0.5+50-PD_CORR))

is the log odds ratio for comparing correct responses under alcohol to correct responses under placebo. Note, log(OR) > 0 if the odds for a correct response under alcohol exceeds the corresponding odds under placebo, and log(OR) < 0 in the opposite case. Log(OR) = 0 if the alcohol has no effect on correct response frequency.

For counted variables, statisticians, and various researchers, tend to prefer log-odds ratios to simple difference scores because of its interpretation: log odds is approximately equal to percent difference in correct answers minus percent difference in incorrect answers. In contrast, a simple difference score of say 7 may represent a huge difference between 1 and 8 or a relatively small difference between 24 and 31.

Also, log-odds lead to more stable variances than do simple difference scores and, often the statistical distribution of log-odds ratios are better approximated by the normal distribution than the distribution of the untransformed variable. Finally, when linear regression is used to
predict, or to estimate, a simple difference score, the estimated value will, on occasion fall, outside the legitimate range (say, one may end up with a negative probability!). Difference estimates based on logistic regression can not yield such meaningless numbers.

The log-odds ratios for the other three count variables were defined in the same spirit as:

LOG((1/6+AS_COR)/(1/6+ 72-AS_COR)) - LOG((1/6+PS_COR)/(1/6+ 72-PS_COR))

LOG((1/6+AS_COLL)/(1/6+ 79-AS_COLL)) - LOG((1/6+PS_COLL)/(1/6+79-PS_COLL))

LOG((1/6+AS_SPEX)/(1/6+ 58-AS_SPEX)) - LOG((1/6+TPCB9)/(1/6+ 58-AS_SPEX)).

Note. The authors followed customary practice of adding 0.5 to avoid zero-counts.

Appendix I

Table AP-I-1

Testing Schedules

Testing Schedules for *Light* Drinkers
Alcohol and Placebo Sessions

		BAC (%)						
Session	Test	Pre-dose	Post-dose					
		1	2	3	4	5	6	7
Alcohol Session	SIM	0.00%		0.08%	0.06%	0.04%	0.02%	
	DAT	0.00%		0.08%	0.06%	0.04%	0.02%	0.00%
Placebo Session (*)	SIM	0.00%		0.00%	0.00%	0.00%	0.00%	
	DAT	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%

Testing Schedules for *Moderate and Heavy* Drinkers
Alcohol and Placebo Sessions

		BAC (%)						
Session	Test	Pre-dose	Post-dose					
		1	2	3	4	5	6	7
Alcohol Session	SIM	0.00%	0.10%	0.08%	0.06%	0.04%	0.02%	
	DAT	0.00%	0.10%	0.08%	0.06%	0.04%	0.02%	0.00%
Placebo Session (*)	SIM	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
	DAT	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

(*) = batteries began at time intervals equivalent to a 0.02% BAC decrease calculated with metabolism rate of 0.017% per hour.

Table AP-I-2

Subject Characteristics (Means)
by Age, Gender, and Drinking Practice

		No.	Age (yr-mo)	Height (in)	Weight (lbs)
Gender	Males	84	34-11	69.7	172.4
	Females	84	33-2	64.5	139.2
Age	19-20 yrs	42	19-8	67.0	143.8
	21-24 yrs	42	22-5	67.2	154.0
	25-50 yrs	42	32-8	67.1	158.0
	51-69 yrs	42	61-7	67.2	167.4
Drinking Practice	Light	56	33-8	66.8	154.0
	Moderate	56	34-11	66.8	155.8
	Heavy	56	33-7	67.8	157.6

Table AP-I-3

Tests of the Null Hypothesis
No Significant Sequence Effects
p Values

Measurement	BAC (%)						Overall
	.00	.02	.04	.06	.08	.10	
DAT Reaction Time	0.441	0.953	0.945	0.312	0.614	0.160	0.377
DAT Number Incorrect (%)	0.452	0.489	0.867	0.887	0.894	0.543	0.894
DAT Number Incorrect (#)	0.029	0.077	0.692	0.782	0.819	0.893	0.182
DAT Tracking Error	0.592	0.328	0.879	0.605	374.000	0.020	0.264
SIM Reaction Time	.	0.503	0.646	0.963	0.670	0.970	0.970
SIM Number Incorrect (%)	.	0.415	0.379	0.310	0.893	0.900	0.803
SIM Number Incorrect (#)	.	0.176	0.079	0.043	378.000	0.317	0.399
SIM Speed Deviation	.	0.243	0.890	0.791	0.812	0.085	0.301
SIM Lane Deviation	.	0.513	0.438	0.555	0.153	0.254	0.775
SIM Collisions	.	0.361	0.106	0.053	0.908	0.901	0.159
SIM Times Over Speed Limit	.	0.969	0.803	0.706	0.834	0.093	0.515
DAT Performance Index	0.305	0.474	0.868	0.758	0.788	0.568	0.782
SIM Performance Index	.	0.264	0.267	0.511	0.395	0.796	0.858
DAT+SIM Performance Index	.	0.843	0.453	0.564	0.745	0.838	0.935

Figure AP-I-1a

DAT Test Score Change From Baseline by Battery on Day 1 and on Day 2

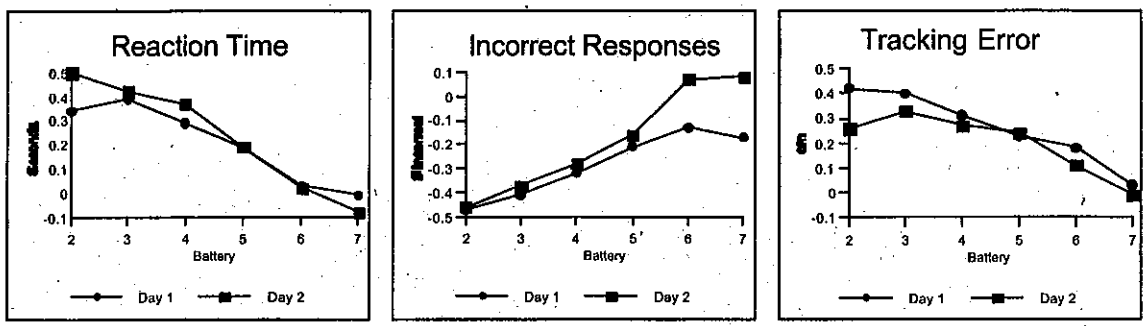


Figure AP-I-1b

SIM Test Score Change From Baseline by Battery on Day 1 and on Day 2

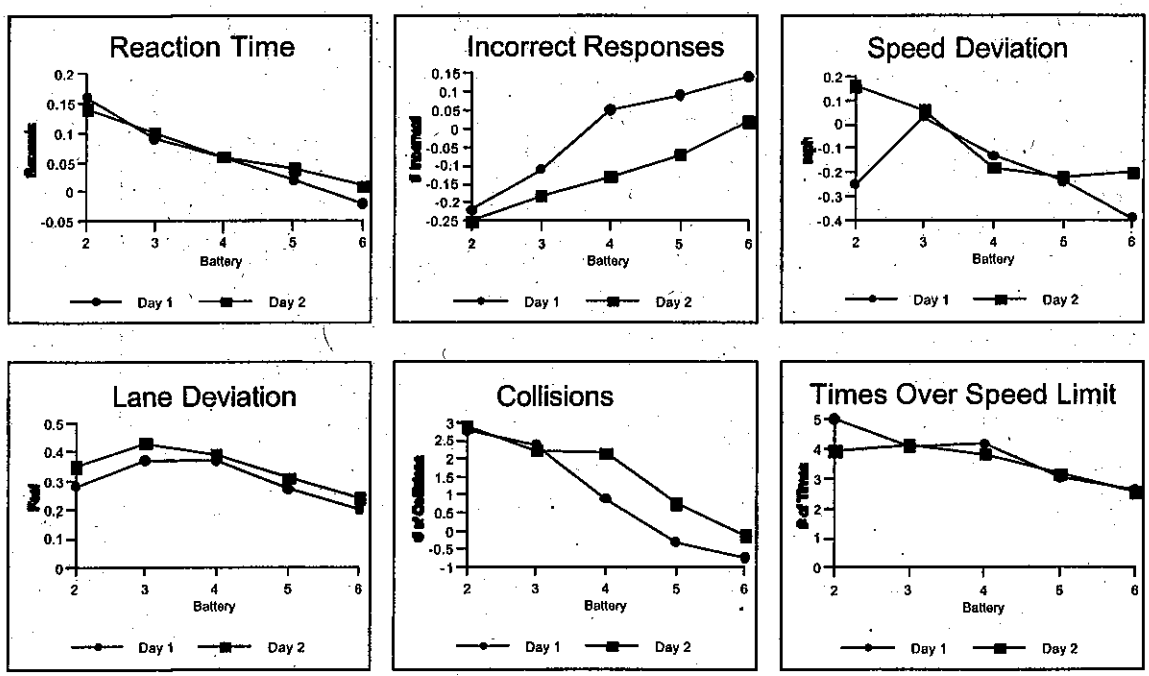


Table AP-I-4

Performance Change from Day 1 to Day 2
p Values, t Tests and F Tests

	Day 2- Day 1		Battery X Day
	Estimate	$p > t$	$p > F$
DAT Reaction Time	-0.020	0.537	0.371
DAT Number Incorrect (%)	0.050	0.683	0.701
DAT Tracking Error	0.060	0.004	0.550
SIM Reaction Time	0.020	0.100	0.982
SIM Number Incorrect (%)	-0.030	0.005	0.903
SIM Speed Deviation	0.100	0.050	0.442
SIM Lane Deviation	-0.010	0.485	0.795
SIM Collisions	0.540	0.027	0.372
SIM Times Over Speed Limit	-0.190	0.431	0.854

Table AP-I-5

DAT and SIM Subjects (Number) Tested at Each BAC

Measurement	BAC (%)						
	.00	.10	.08	.06	.04	.02	.00
DAT Reaction Time	168	104	160	167	168	167	166
DAT Number Incorrect (%)	168	104	160	167	168	167	166
DAT Number Incorrect (#)	168	104	160	167	168	167	166
DAT Tracking Error	168	104	160	167	168	167	166
SIM Reaction Time	168	104	160	166	167	167	.
SIM Number Incorrect (%)	168	104	160	166	167	167	.
SIM Number Incorrect (#)	168	104	160	166	167	167	.
SIM Speed Deviation	168	104	160	166	167	167	.
SIM Lane Deviation	168	104	160	166	167	167	.
SIM Collisions	168	104	160	166	167	167	.
SIM Times Over Speed Limit	168	104	160	166	167	167	.
DAT Performance Index	168	104	160	167	168	167	166
SIM Performance Index	168	104	160	166	167	167	.
DAT+SIM Performance Index	168	104	160	166	167	167	.

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
DAT Reaction Time	Age	19-20	-0.103	.	0.105	.	0.343	1	0.578	3	0.934	3	1.095	3
		21-24	-0.103	.	0.055	.	0.099	.	0.669	3	0.649	3	0.791	3
		25-50	0.211	.	0.242	.	0.486	2	0.569	3	0.632	3	1.136	3
		51-69	-0.013	.	0.086	.	0.220	0	0.319	1	0.445	2	1.131	3
	Drinking Practice	Light	-0.078	.	0.082	.	0.334	1	0.796	3	0.740	3	.	.
		Mod	-0.032	.	0.106	.	0.131	0	0.449	3	0.632	3	1.077	3
		Heavy	0.105	.	0.177	.	0.396	2	0.357	2	0.623	3	0.999	3
	Gender	Male	-0.016	.	0.193	0	0.394	3	0.657	3	0.763	3	1.212	3
		Female	0.012	.	0.051	.	0.180	0	0.411	3	0.567	3	0.864	3
DAT Number Incorrect (%)	Age	19-20	0.049	.	0.106	.	0.277	0	0.360	1	0.729	3	0.464	1
		21-24	0.134	.	0.218	.	0.210	.	0.665	3	0.536	3	0.251	.
		25-50	0.169	.	0.106	.	0.299	0	0.216	.	0.410	2	0.892	3
		51-69	-0.205	.	-0.045	.	0.144	.	0.220	.	0.225	.	0.706	3
	Drinking Practice	Light	0.094	.	0.168	.	0.361	2	0.650	3	0.593	3	.	.
		Mod	-0.050	.	0.005	.	0.054	.	0.274	1	0.330	1	0.491	3
		Heavy	0.067	.	0.116	.	0.282	1	0.171	.	0.502	3	0.666	3
	Gender	Male	0.047	.	0.168	.	0.385	3	0.435	3	0.501	3	0.734	3
		Female	0.027	.	0.025	.	0.080	.	0.295	2	0.449	3	0.423	2
DAT Number Incorrect (#)	Age	19-20	-0.091	.	0.064	.	0.240	.	0.361	1	0.607	3	0.540	2
		21-24	0.002	.	0.066	.	0.025	.	0.627	3	0.587	3	0.327	0
		25-50	0.116	.	0.077	.	0.485	2	0.363	1	0.574	3	0.938	3
		51-69	-0.090	.	0.025	.	0.138	.	0.281	0	0.331	1	0.378	1

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
	Drinking Practice	Light	0.020	.	0.126	.	0.329	1	0.669	3	0.610	3	.	.
		Mod	-0.034	.	-0.030	.	0.116	.	0.377	2	0.478	3	0.500	3
		Heavy	-0.032	.	0.080	.	0.221	0	0.177	.	0.485	3	0.592	3

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
	Gender	Male	0.040	.	0.123	.	0.421	3	0.562	3	0.595	3	0.733	3
		Female	-0.071	.	-0.006	.	0.023	.	0.254	1	0.454	3	0.359	2
DAT Tracking Error	Age	19-20	-0.030	.	0.092	.	0.448	2	0.417	2	0.946	3	1.226	3
		21-24	0.113	.	0.200	.	0.354	1	0.464	2	0.841	3	0.631	3
		25-50	-0.012	.	0.136	.	0.335	1	0.415	2	0.517	3	0.663	3
		51-69	0.090	.	-0.044	.	0.345	1	0.364	1	0.253	0	0.525	2
	Drinking Practice	Light	-0.130	.	-0.029	.	0.320	1	0.413	2	0.632	3	.	.
		Mod	0.197	.	0.143	.	0.514	3	0.528	3	0.562	3	0.715	3
		Heavy	0.054	.	0.175	.	0.277	1	0.304	1	0.724	3	0.807	3
	Gender	Male	-0.053	.	0.012	.	0.327	2	0.335	2	0.574	3	0.572	3
		Female	0.134	.	0.181	.	0.414	3	0.494	3	0.705	3	0.951	3
SIM Reaction Time	Age	19-20	.	.	0.354	1	0.349	1	0.764	3	0.824	3	0.623	2
		21-24	.	.	0.179	.	0.357	1	0.627	3	0.582	3	0.827	3
		25-50	.	.	0.233	.	0.268	0	0.364	1	0.614	3	0.973	3
		51-69	.	.	-0.227	.	0.089	.	0.080	0	0.247	.	0.413	1
	Drinking Practice	Light	.	.	0.047	.	0.394	2	0.532	3	0.622	3	.	.
		Mod	.	.	0.051	.	0.083	.	0.418	2	0.525	3	0.767	3
		Heavy	.	.	0.307	1	0.320	1	0.427	2	0.554	3	0.651	3
	Gender	Male	.	.	0.103	.	0.222	1	0.513	3	0.594	3	0.692	3
		Female	.	.	0.167	.	0.310	2	0.405	3	0.540	3	0.726	3
SIM Number Incorrect (%)	Age	19-20	.	.	0.429	2	0.376	1	0.763	3	0.707	3	0.476	1
		21-24	.	.	0.163	.	0.220	.	0.560	3	0.535	3	0.678	3

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
		25-50	.	.	0.176	.	0.228	.	0.188	.	0.648	3	0.856	3
		51-69	.	.	-0.229	.	0.040	.	0.021	.	0.324	1	0.331	0

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
	Drinking Practice	Light	.	.	0.004	.	0.334	1	0.491	3	0.650	3	.	.
		Mod	.	.	-0.073	.	-0.047	.	0.241	0	0.401	2	0.494	3
		Heavy	.	.	0.474	3	0.362	2	0.417	2	0.608	3	0.677	3
	Gender	Male	.	.	0.135	.	0.173	.	0.394	3	0.648	3	0.664	3
		Female	.	.	0.134	.	0.259	1	0.372	3	0.459	3	0.507	3
SIM Number Incorrect (#)	Age	19-20	.	.	0.393	1	0.318	1	0.829	3	0.703	3	0.759	3
		21-24	.	.	0.307	1	0.225	.	0.665	3	0.616	3	0.953	3
		25-50	.	.	0.232	.	0.390	2	0.242	.	0.712	3	0.909	3
		51-69	.	.	-0.131	.	0.022	.	0.011	.	0.246	.	0.202	.
	Drinking Practice	Light	.	.	0.136	.	0.416	2	0.552	3	0.790	3	.	.
		Mod	.	.	0.002	.	-0.025	.	0.239	0	0.420	2	0.618	3
		Heavy	.	.	0.464	3	0.326	1	0.519	3	0.497	3	0.793	3
	Gender	Male	.	.	0.185	0	0.153	.	0.468	3	0.617	3	0.730	3
		Female	.	.	0.216	1	0.325	2	0.406	3	0.521	3	0.681	3
SIM Speed Deviation	Age	19-20	.	.	0.071	.	0.129	.	0.218	.	0.198	.	0.168	.
		21-24	.	.	0.382	1	0.274	0	0.470	2	0.270	0	0.536	2
		25-50	.	.	-0.010	.	0.166	.	0.147	.	0.518	2	0.155	.
		51-69	.	.	0.205	.	0.143	.	0.181	.	0.111	.	-0.122	.
	Drinking Practice	Light	.	.	0.021	.	0.139	.	0.265	0	0.407	2	.	.
		Mod	.	.	0.115	.	0.070	.	0.225	0	0.024	.	0.100	.
		Heavy	.	.	0.350	2	0.325	1	0.272	1	0.392	2	0.268	1

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
	Gender	Male	.	.	-0.017	.	-0.005	.	0.143	.	0.218	0	0.032	.
		Female	.	.	0.341	2	0.362	3	0.365	2	0.331	2	0.336	1

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
SIM Lane Deviation	Age	19-20	.	.	0.228	.	0.414	2	0.690	3	0.682	3	0.586	2
		21-24	.	.	0.539	3	0.725	3	1.049	3	0.907	3	0.944	3
		25-50	.	.	0.507	2	0.560	3	0.613	3	0.981	3	0.830	3
		51-69	.	.	0.544	3	0.794	3	0.779	3	1.016	3	1.197	3
	Drinking Practice	Light	.	.	0.508	3	0.826	3	0.837	3	0.621	3	.	.
		Mod	.	.	0.505	3	0.639	3	0.902	3	1.107	3	0.927	3
		Heavy	.	.	0.351	1	0.405	2	0.610	3	0.960	3	0.852	3
	Gender	Male	.	.	0.492	3	0.661	3	0.802	3	0.904	3	0.754	3
		Female	.	.	0.417	3	0.585	3	0.764	3	0.889	3	1.025	3
SIM Collisions	Age	19-20	.	.	0.036	.	0.233	.	0.402	2	0.462	2	0.315	0
		21-24	.	.	0.120	.	0.338	1	0.532	3	0.489	2	0.608	2
		25-50	.	.	-0.062	.	0.142	.	0.315	1	0.649	3	0.707	3
		51-69	.	.	0.130	.	0.692	3	0.898	3	0.871	3	0.997	3
	Drinking Practice	Light	.	.	0.025	.	0.324	1	0.694	3	0.486	3	.	.
		Mod	.	.	0.139	.	0.379	2	0.487	3	0.718	3	0.565	3
		Heavy	.	.	0.005	.	0.350	2	0.430	2	0.649	3	0.749	3
	Gender	Male	.	.	-0.029	.	0.324	2	0.501	3	0.629	3	0.725	3
		Female	.	.	0.142	.	0.378	3	0.572	3	0.607	3	0.589	3
SIM Times Over Speed Limit	Age	19-20	.	.	0.274	0	0.332	1	0.442	2	0.607	3	0.561	2
		21-24	.	.	0.261	0	0.619	3	0.845	3	1.015	3	1.034	3
		25-50	.	.	0.147	.	0.361	1	0.522	2	0.841	3	1.199	3
		51-69	.	.	0.455	2	0.465	2	0.639	3	0.635	3	0.710	3

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
	Drinking Practice	Light	.	.	0.324	1	0.454	3	0.653	3	0.787	3	.	.
		Mod	.	.	0.226	0	0.380	2	0.599	3	0.692	3	0.935	3
		Heavy	.	.	0.303	1	0.499	3	0.585	3	0.845	3	0.817	3

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
	Gender	Male	.	.	0.317	2	0.463	3	0.685	3	0.769	3	0.714	3
		Female	.	.	0.252	1	0.425	3	0.539	3	0.780	3	1.038	3
DAT Performance Index	Age	19-20	-0.066	.	0.099	.	0.395	2	0.497	3	0.940	3	1.161	3
		21-24	0.005	.	0.128	.	0.226	0	0.566	3	0.745	3	0.711	3
		25-50	0.100	.	0.189	.	0.410	3	0.492	3	0.575	3	0.899	3
		51-69	0.038	.	0.021	.	0.282	1	0.342	2	0.349	2	0.828	3
	Drinking Practice	Light	-0.104	.	0.027	.	0.327	2	0.604	3	0.686	3	.	.
		Mod	0.083	.	0.124	.	0.322	2	0.488	3	0.597	3	0.896	3
		Heavy	0.079	.	0.176	0	0.337	2	0.330	2	0.674	3	0.903	3
	Gender	Male	-0.035	.	0.102	.	0.360	3	0.496	3	0.668	3	0.892	3
		Female	0.073	.	0.116	.	0.297	3	0.452	3	0.636	3	0.908	3
SIM Performance Index	Age	19-20	.	.	0.276	2	0.359	3	0.663	3	0.699	3	0.553	3
		21-24	.	.	0.300	2	0.491	3	0.774	3	0.723	3	0.848	3
		25-50	.	.	0.276	2	0.357	3	0.440	3	0.769	3	0.908	3
		51-69	.	.	0.145	.	0.428	3	0.460	3	0.624	3	0.763	3
	Drinking Practice	Light	.	.	0.224	1	0.530	3	0.660	3	0.628	3	.	.
		Mod	.	.	0.218	1	0.320	3	0.587	3	0.745	3	0.786	3
		Heavy	.	.	0.306	3	0.376	3	0.505	3	0.739	3	0.750	3
	Gender	Male	.	.	0.245	3	0.401	3	0.614	3	0.727	3	0.716	3
		Female	.	.	0.253	3	0.416	3	0.554	3	0.681	3	0.821	3
DAT+SIM Performance Index	Age	19-20	.	.	0.188	1	0.377	3	0.580	3	0.820	3	0.857	3
		21-24	.	.	0.214	1	0.359	3	0.670	3	0.734	3	0.780	3

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
		25-50	.	.	0.232	2	0.384	3	0.466	3	0.672	3	0.904	3
		51-69	.	.	0.083	.	0.355	3	0.401	3	0.487	3	0.795	3

Table AP-I-6

Scores (Standardized) and p Values by BAC
for Age, Gender, and Drinking Practice

Variable	Effect	Level	BAC (%)											
			.00		.02		.04		.06		.08		.10	
			Mean	p	Mean	p	Mean	p	Mean	p	Mean	p	Mean	p
	Drinking Practice	Light	.	.	0.125	0	0.429	3	0.632	3	0.657	3	.	.
		Mod	.	.	0.171	1	0.321	3	0.538	3	0.671	3	0.841	3
		Heavy	.	.	0.241	2	0.356	3	0.418	3	0.706	3	0.827	3
	Gender	Male	.	.	0.174	2	0.381	3	0.555	3	0.698	3	0.804	3
		Female	.	.	0.185	2	0.357	3	0.503	3	0.659	3	0.864	3

p values:

. = not significant
0 = 0.05<p<0.10
1 = 0.05
2 = 0.01
3 = 0.001
4 = 0.0001

Table AP-I-7

Significance Test Results
Main Effects and Interactions for Age, Gender, and Drinking Practice

Effect	Variable	BAC (%)					
		.00	.02	.04	.06	.08	.10
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
Age (A)	DAT Reaction Time	0.42	0.83	0.32	0.41	0.15	0.52
	DAT Number Incorrect (%)	0.30	0.70	0.89	0.12	0.12	0.09
	DAT Number Incorrect (#)	0.73	1.00	0.16	0.39	0.54	0.08
	DAT Tracking Error	0.89	0.74	0.95	0.97	0.01	0.03
	SIM Reaction Time	.	0.04	0.57	0.01	0.06	0.16
	SIM Number Incorrect (%)	.	0.02	0.47	0.00	0.30	0.22
	SIM Number Incorrect (#)	.	0.09	0.34	0.00	0.10	0.02
	SIM Speed Deviation	.	0.29	0.90	0.45	0.31	0.11
	SIM Lane Deviation	.	0.43	0.31	0.23	0.41	0.15
	SIM Collisions	.	0.80	0.06	0.04	0.22	0.09
	SIM Times Over Speed Limit	.	0.57	0.54	0.30	0.22	0.06
	DAT Performance Index	0.71	0.79	0.65	0.59	0.00	0.14
	SIM Performance Index	.	0.69	0.77	0.09	0.83	0.19
	DAT+SIM Performance Index	.	0.62	1.00	0.18	0.08	0.85

Table AP-I-7

Significance Test Results
Main Effects and Interactions for Age, Gender, and Drinking Practice

Effect	Variable	BAC (%)					
		.00	.02	.04	.06	.08	.10
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
Gender (G)	DAT Reaction Time	0.85	0.35	0.17	0.11	0.20	0.07
	DAT Number Incorrect (%)	0.89	0.36	0.05	0.35	0.73	0.10
	DAT Number Incorrect (#)	0.46	0.40	0.01	0.04	0.35	0.04
	DAT Tracking Error	0.23	0.29	0.58	0.29	0.38	0.04
	SIM Reaction Time	.	0.67	0.57	0.46	0.72	0.86
	SIM Number Incorrect (%)	.	1.00	0.56	0.88	0.21	0.41
	SIM Number Incorrect (#)	.	0.84	0.25	0.68	0.52	0.79
	SIM Speed Deviation	.	0.02	0.02	0.16	0.48	0.11
	SIM Lane Deviation	.	0.64	0.63	0.81	0.92	0.16
	SIM Collisions	.	0.26	0.72	0.64	0.89	0.47
	SIM Times Over Speed Limit	.	0.68	0.80	0.35	0.94	0.08
	DAT Performance Index	0.29	0.91	0.60	0.71	0.78	0.91
	SIM Performance Index	.	0.94	0.88	0.59	0.68	0.39
	DAT+SIM Performance Index	.	0.90	0.80	0.58	0.68	0.59

Table AP-I-7

Significance Test Results
Main Effects and Interactions for Age, Gender, and Drinking Practice

Effect	Variable	BAC (%)					
		.00	.02	.04	.06	.08	.10
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
Drinking Practice (D)	DAT Reaction Time	0.60	0.87	0.34	0.05	0.78	0.68
	DAT Number Incorrect (%)	0.72	0.68	0.24	0.03	0.35	0.36
	DAT Number Incorrect (#)	0.95	0.70	0.50	0.03	0.73	0.62
	DAT Tracking Error	0.22	0.53	0.43	0.48	0.68	0.61
	SIM Reaction Time	.	0.27	0.22	0.78	0.86	0.53
	SIM Number Incorrect (%)	.	0.01	0.05	0.36	0.36	0.33
	SIM Number Incorrect (#)	.	0.05	0.04	0.16	0.11	0.34
	SIM Speed Deviation	.	0.20	0.37	0.97	0.09	0.37
	SIM Lane Deviation	.	0.65	0.09	0.29	0.03	0.69
	SIM Collisions	.	0.74	0.96	0.34	0.46	0.33
	SIM Times Over Speed Limit	.	0.86	0.81	0.93	0.72	0.51
	DAT Performance Index	0.23	0.58	0.99	0.17	0.79	0.96
	SIM Performance Index	.	0.73	0.24	0.51	0.63	0.77
	DAT+SIM Performance Index	.	0.55	0.63	0.17	0.91	0.90
A x G	DAT Reaction Time	0.17	0.08	0.02	0.22	0.52	0.37
	DAT Number Incorrect (%)	0.15	0.99	0.34	0.29	0.63	0.79
	DAT Number Incorrect (#)	0.02	0.69	0.02	0.10	0.09	0.19
	DAT Tracking Error	0.38	0.44	0.54	0.10	0.46	0.31
	SIM Reaction Time	.	0.36	0.17	0.78	0.50	0.07
	SIM Number Incorrect (%)	.	0.84	0.73	0.88	0.74	0.14
	SIM Number Incorrect (#)	.	0.99	0.08	0.50	0.53	0.29
	SIM Speed Deviation	.	0.85	0.31	0.79	0.82	0.45
	SIM Lane Deviation	.	0.60	0.24	0.98	0.48	0.67
	SIM Collisions	.	0.17	0.38	0.50	0.47	0.14
	SIM Times Over Speed Limit	.	0.06	0.16	0.38	0.40	0.01
	DAT Performance Index	0.39	0.35	0.04	0.23	0.70	0.72

Table AP-I-7

Significance Test Results
Main Effects and Interactions for Age, Gender, and Drinking Practice

Effect	Variable	BAC (%)					
		.00	.02	.04	.06	.08	.10
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
	SIM Performance Index	.	0.43	0.17	0.84	0.52	0.04
	DAT+SIM Performance Index	.	0.20	0.15	0.53	0.62	0.16

Table AP-I-7

Significance Test Results
Main Effects and Interactions for Age, Gender, and Drinking Practice

Effect	Variable	BAC (%)					
		.00	.02	.04	.06	.08	.10
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
A x D	DAT Reaction Time	0.11	0.15	0.77	0.73	0.29	0.70
	DAT Number Incorrect (%)	0.22	0.09	0.13	0.26	0.04	0.90
	DAT Number Incorrect (#)	0.09	0.03	0.09	0.55	0.03	0.43
	DAT Tracking Error	0.19	0.47	0.74	0.02	0.37	0.16
	SIM Reaction Time	.	0.18	0.21	0.02	0.07	0.27
	SIM Number Incorrect (%)	.	0.42	0.19	0.01	0.06	0.65
	SIM Number Incorrect (#)	.	0.34	0.13	0.16	0.22	0.49
	SIM Speed Deviation	.	0.34	0.30	0.22	0.86	0.30
	SIM Lane Deviation	.	0.39	0.96	0.55	0.17	0.94
	SIM Collisions	.	0.41	0.86	0.67	0.35	0.54
	SIM Times Over Speed Limit	.	0.45	0.01	0.90	0.46	0.87
	DAT Performance Index	0.02	0.23	0.95	0.20	0.23	0.65
	SIM Performance Index	.	0.33	0.27	0.11	0.08	0.62
	DAT+SIM Performance Index	.	0.69	0.78	0.11	0.16	0.76
G x D	DAT Reaction Time	0.43	0.24	0.88	0.94	0.72	0.93
	DAT Number Incorrect (%)	0.98	0.97	0.59	0.94	0.55	0.91
	DAT Number Incorrect (#)	0.91	0.75	0.76	0.84	0.87	0.91
	DAT Tracking Error	0.36	1.00	0.99	0.88	1.00	0.45
	SIM Reaction Time	.	0.84	0.63	0.33	0.21	0.38
	SIM Number Incorrect (%)	.	0.61	0.36	0.80	0.41	0.45
	SIM Number Incorrect (#)	.	0.95	0.47	0.67	0.15	0.31
	SIM Speed Deviation	.	0.51	0.60	0.81	0.97	0.69
	SIM Lane Deviation	.	0.64	0.68	0.85	0.34	0.19
	SIM Collisions	.	0.52	0.20	0.35	0.52	0.62
	SIM Times Over Speed Limit	.	0.35	0.81	0.40	0.46	0.59
	DAT Performance Index	0.64	0.58	0.97	0.90	0.86	0.67

Table AP-I-7

Significance Test Results
Main Effects and Interactions for Age, Gender, and Drinking Practice

Effect	Variable	BAC (%)					
		.00	.02	.04	.06	.08	.10
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
	SIM Performance Index	.	0.88	0.75	0.51	0.69	0.90
	DAT+SIM Performance Index	.	0.65	0.95	0.82	0.84	0.84

Table AP-I-7

Significance Test Results
Main Effects and Interactions for Age, Gender, and Drinking Practice

Effect	Variable	BAC (%)					
		.00	.02	.04	.06	.08	.10
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
A x G x D	DAT Reaction Time	0.54	0.14	0.76	0.51	0.08	0.40
	DAT Number Incorrect (%)	0.09	0.54	0.74	0.41	0.32	0.33
	DAT Number Incorrect (#)	0.13	0.38	0.91	0.60	0.66	0.26
	DAT Tracking Error	0.38	0.99	0.25	0.41	0.24	0.31
	SIM Reaction Time	.	0.24	0.25	0.27	0.21	0.48
	SIM Number Incorrect (%)	.	0.34	0.09	0.28	0.33	0.89
	SIM Number Incorrect (#)	.	0.89	0.67	0.63	0.29	0.44
	SIM Speed Deviation	.	0.70	0.21	0.79	0.95	0.65
	SIM Lane Deviation	.	0.77	0.62	0.85	0.55	0.33
	SIM Collisions	.	0.11	0.19	0.50	0.61	0.75
	SIM Times Over Speed Limit	.	0.80	0.91	0.70	0.95	0.75
	DAT Performance Index	0.63	0.76	0.54	0.98	0.30	0.37
	SIM Performance Index	.	0.21	0.18	0.34	0.30	0.35
	DAT+SIM Performance Index	.	0.42	0.30	0.74	0.38	0.35

Figure AP-I-2a
DAT Raw Scores, Ages 19-20 (N=42)

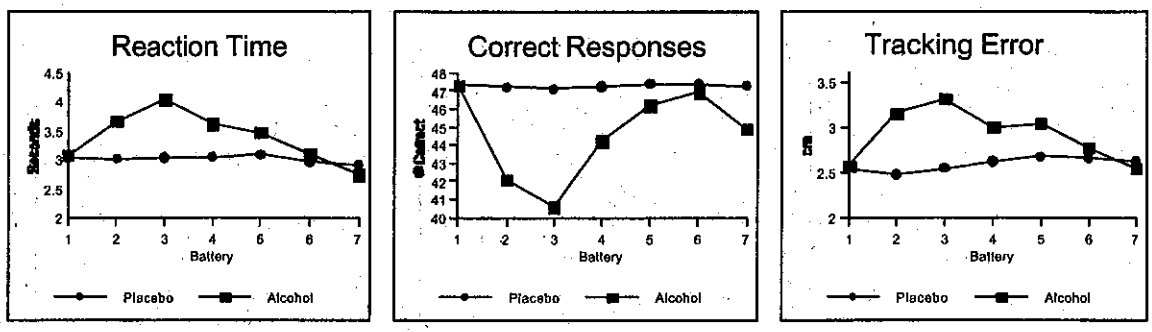


Figure AP-I-2b
SIM Raw Scores, Ages 19-20 (N=42)

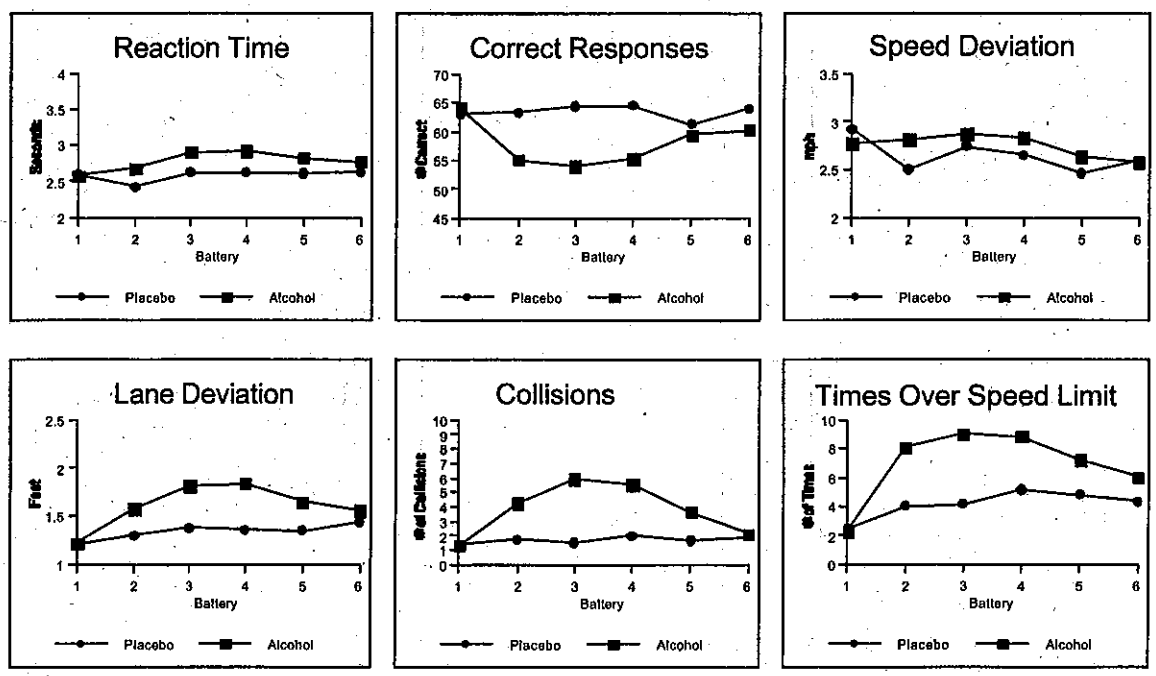


Figure AP-I-3a
DAT Raw Scores, Ages 21-24 (N=42)

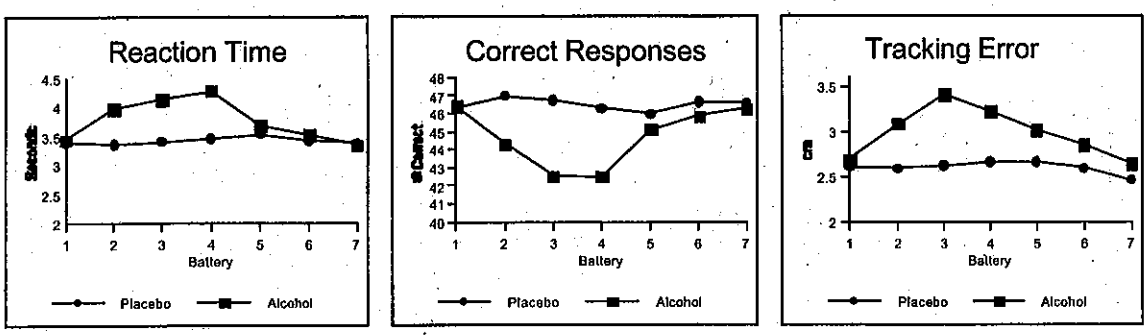


Figure AP-I-3b
SIM Raw Scores, Ages 21-24 (N=42)

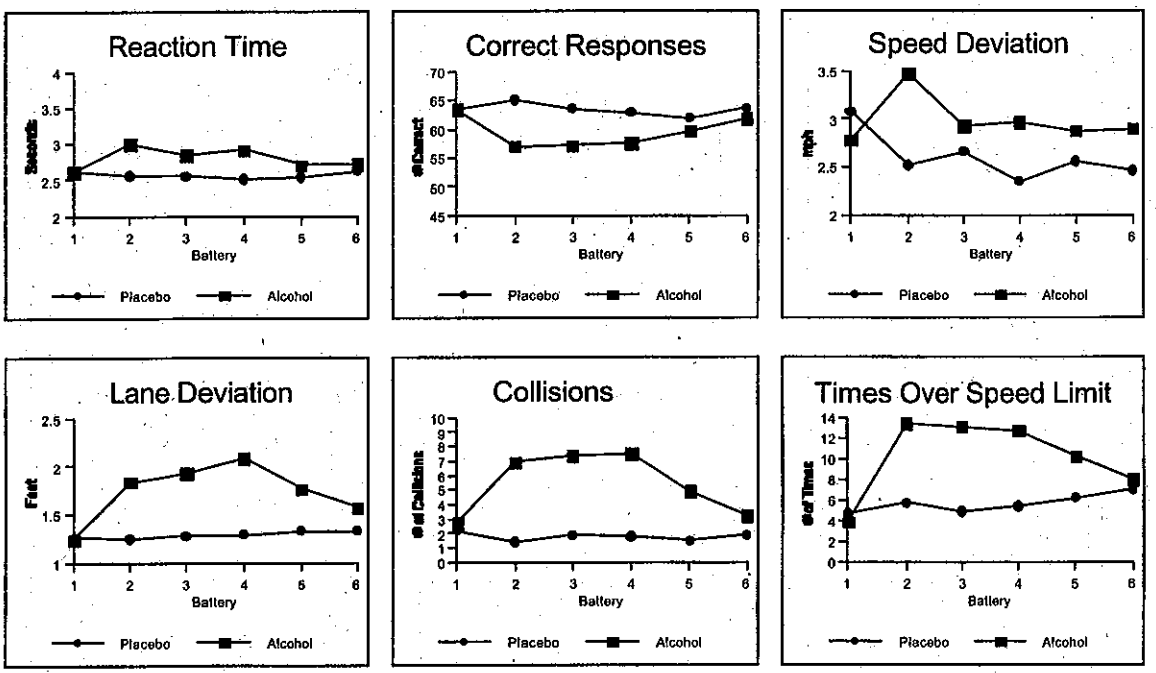


Figure AP-I-4a
DAT Raw Scores, Ages 25-50 (N=42)

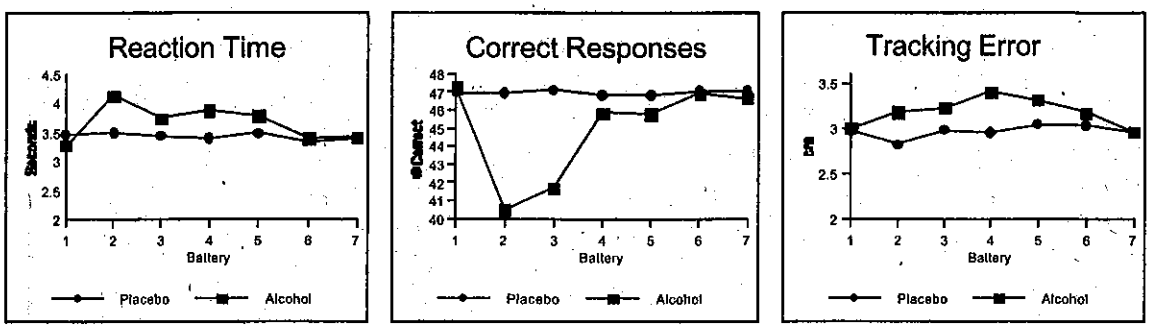


Figure AP-I-4b
SIM Raw Scores, Ages 25-50 (N=42)

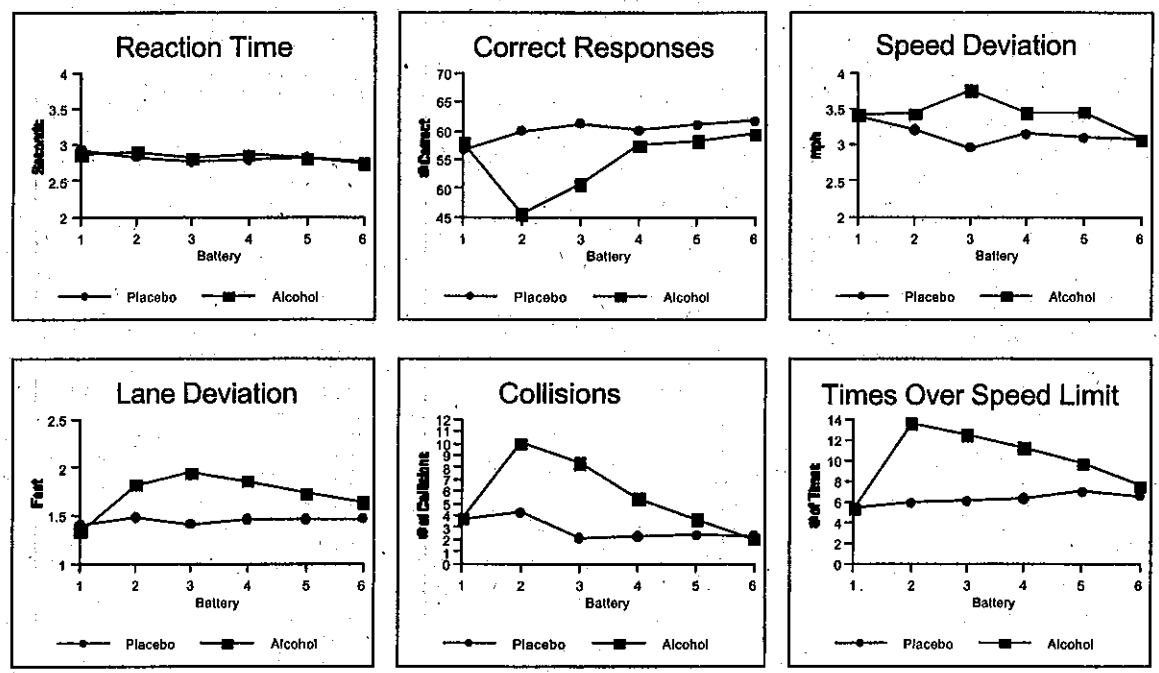


Figure AP-I-5a
DAT Raw Scores, Ages 51-69 (N=42)

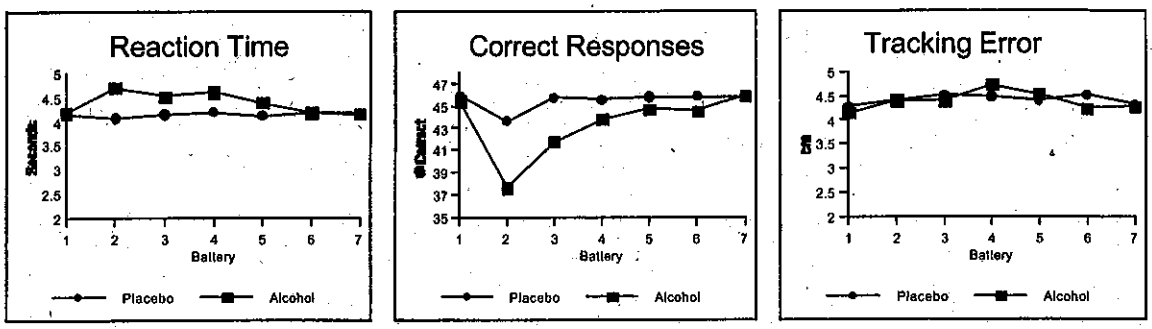


Figure AP-I-5b
SIM Raw Scores, Ages 51-69 (N=42)

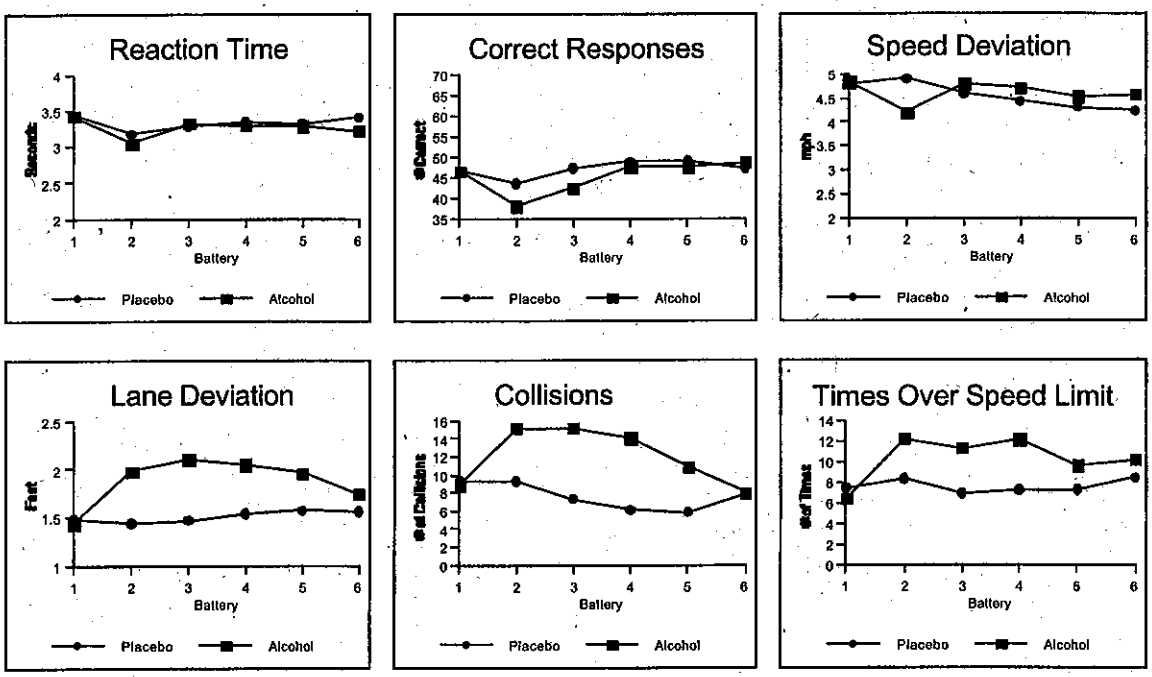


Figure AP-I-6a
DAT Raw Scores, Males (N=84)

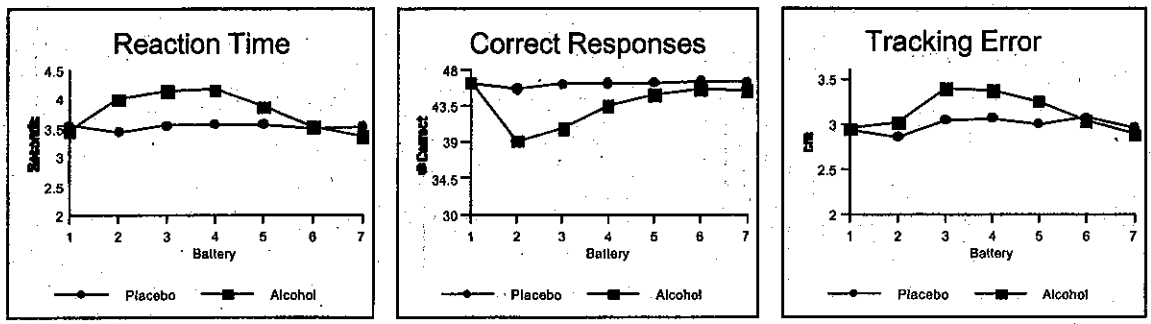


Figure AP-I-6b
SIM Raw Scores, Males (N=84)

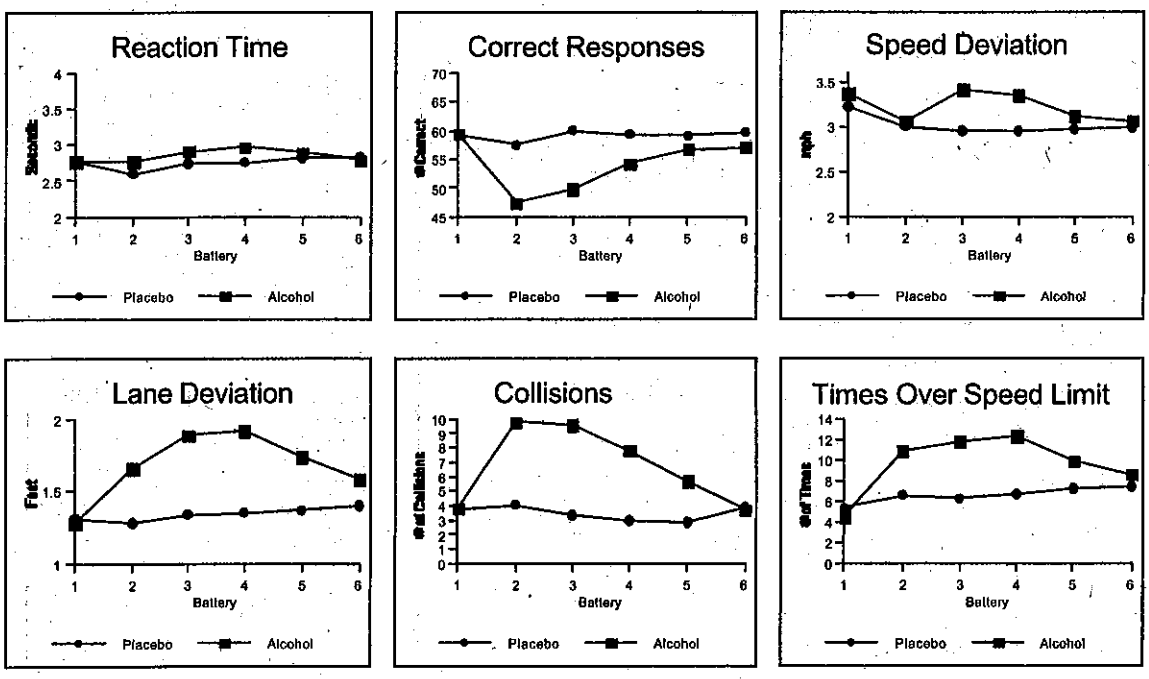


Figure AP-I-7a
DAT Raw Scores, Females (N=84)

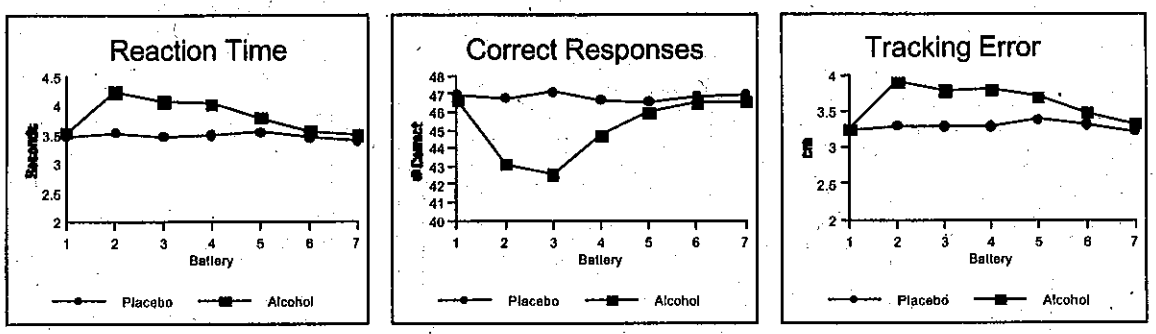


Figure AP-I-7b
SIM Raw Scores, Females (N=84)

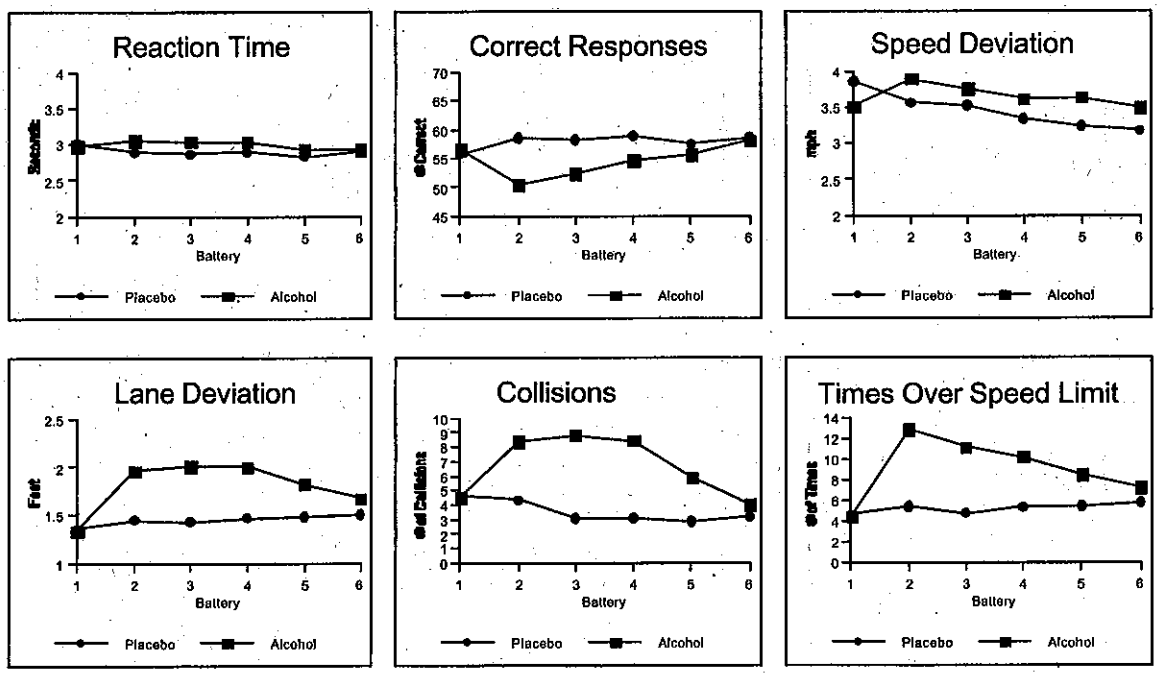


Figure AP-I-8a
DAT Raw Scores, Light Drinkers (N=56)

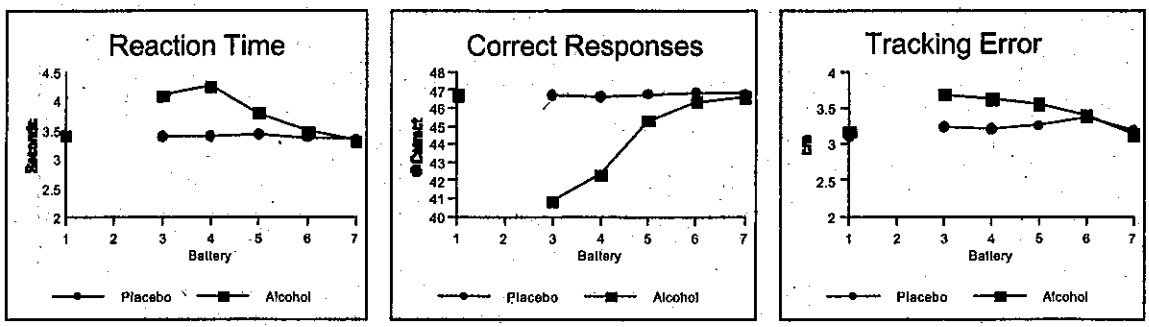


Figure AP-I-8b
SIM Raw Scores, Light Drinkers (N=56)

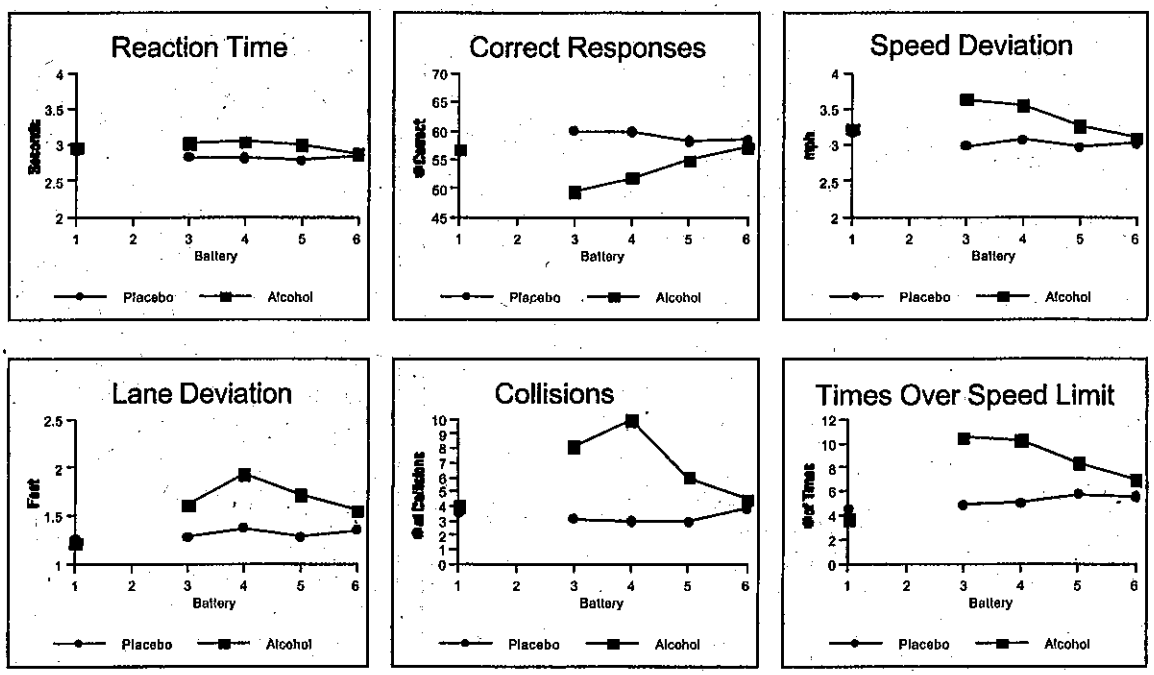


Figure AP-I-9a

DAT Raw Scores, Moderate Drinkers (N=56)

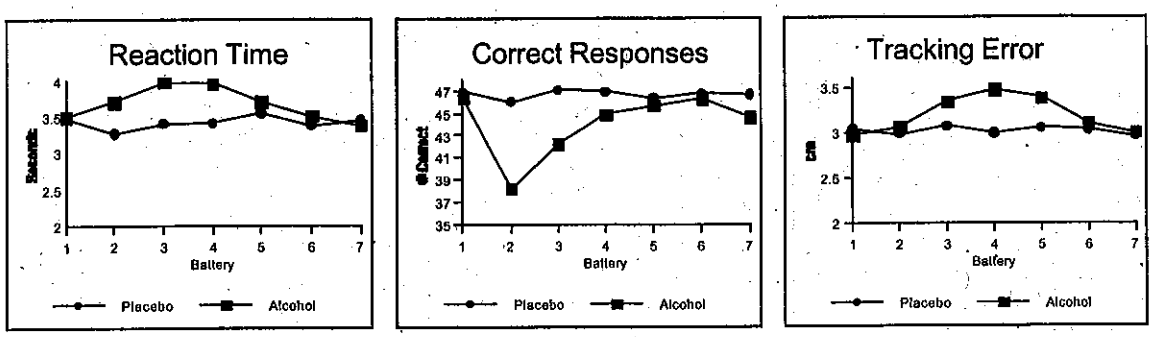


Figure AP-I-9b

SIM Raw Scores, Moderate Drinkers (N=56)

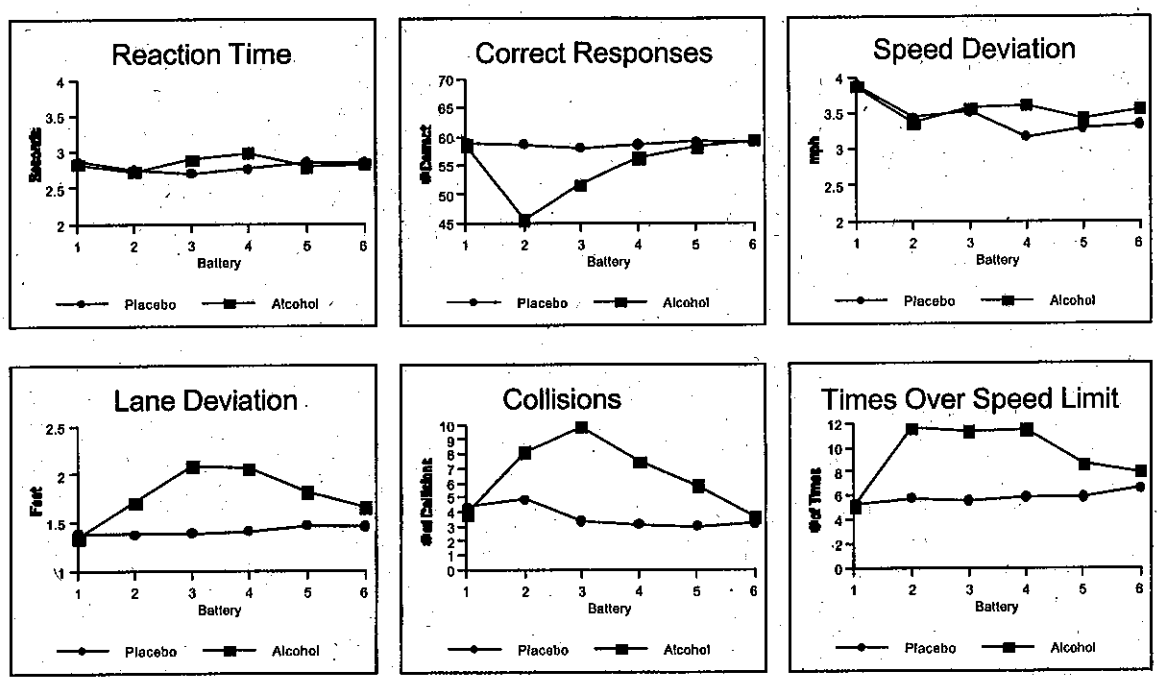


Figure AP-I-10a
DAT Raw Scores, Heavy Drinkers (N=56)

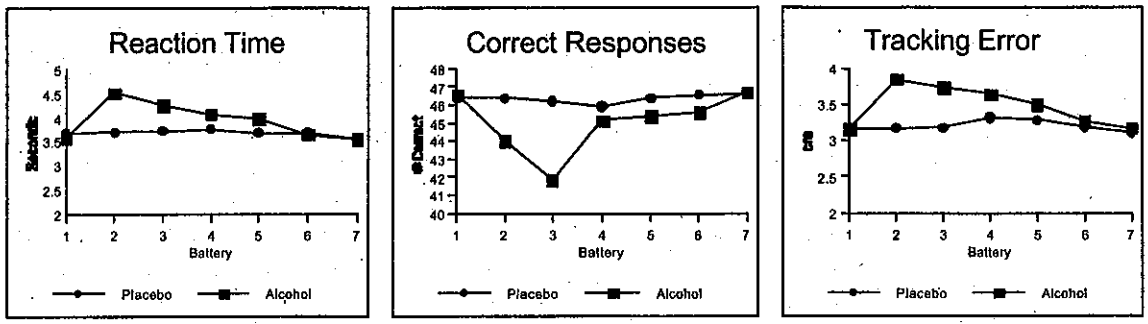
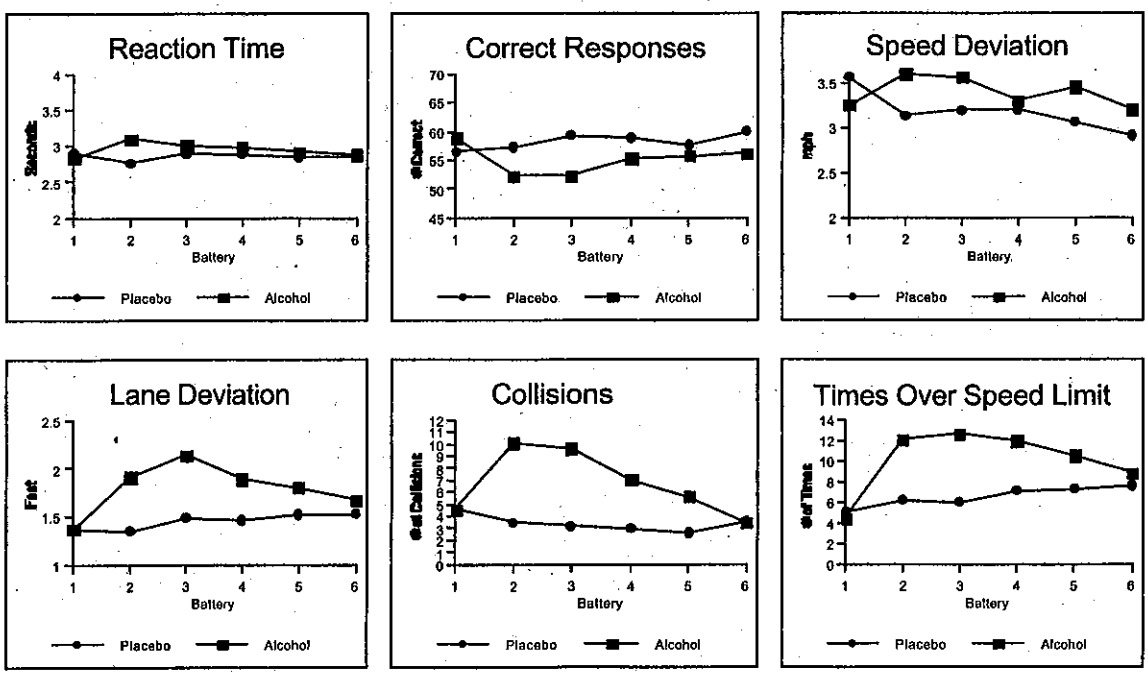


Figure AP-I-10b
SIM Raw Scores, Heavy Drinkers (N=56)



Appendix II

Graphs of Impairment Scores for DAT and SIM by Age, Gender, and Drinking Practice

Figure AP-II-1a
DAT Impairment Scores by Age

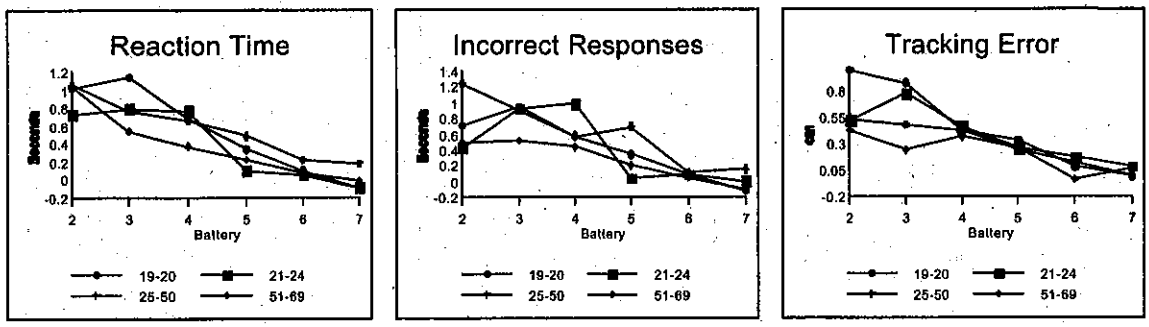


Figure AP-II-1b
SIM Impairment Scores by Age

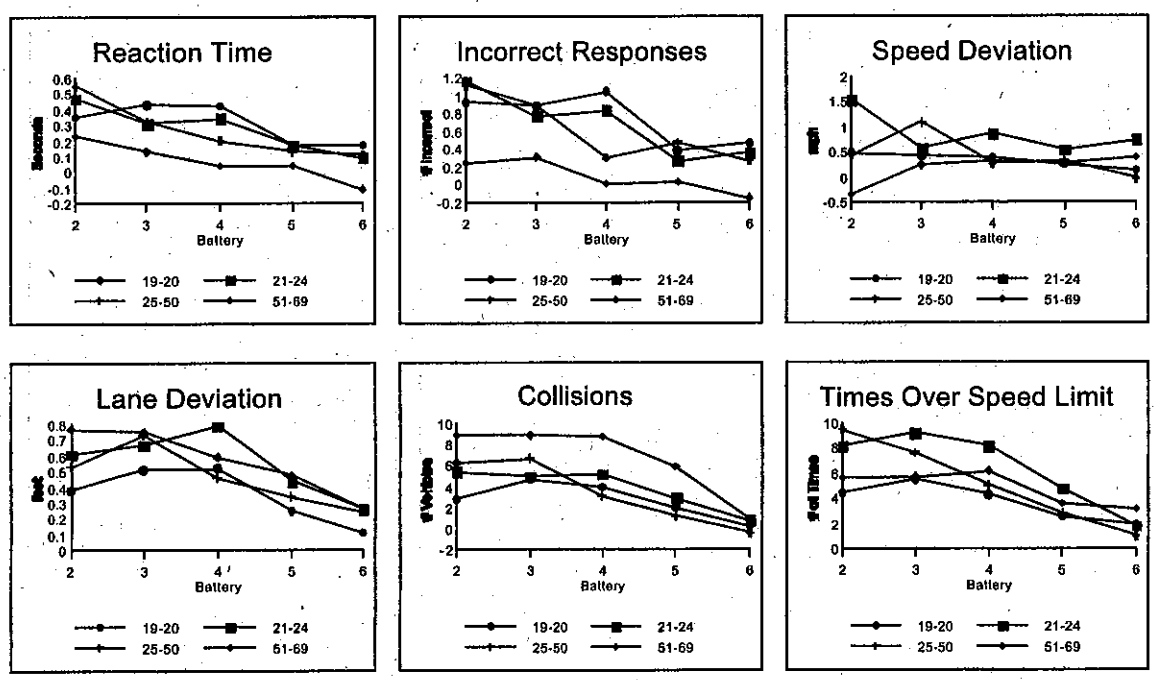


Figure AP-II-2a
DAT Impairment Scores by Gender

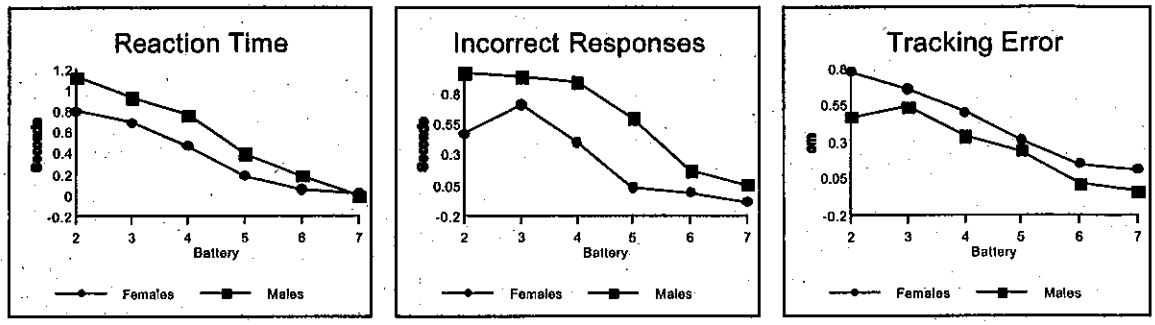


Figure AP-II-2b
SIM Impairment Scores by Gender

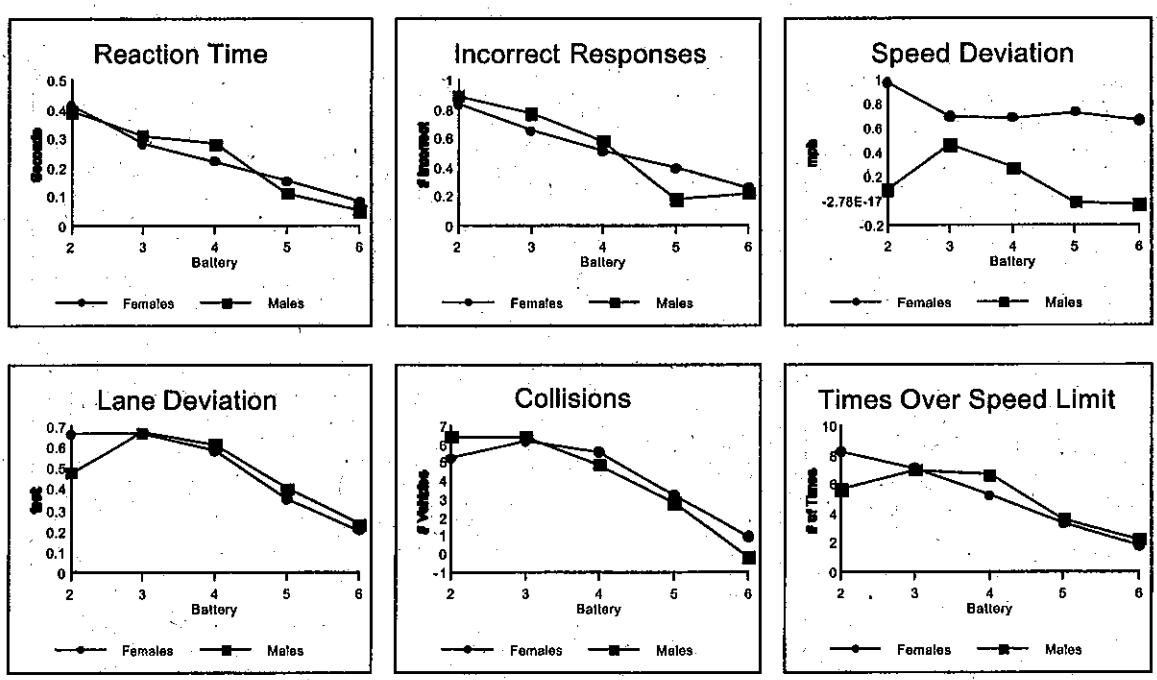


Figure AP-II-3a

DAT Impairment Scores by Drinking Practice

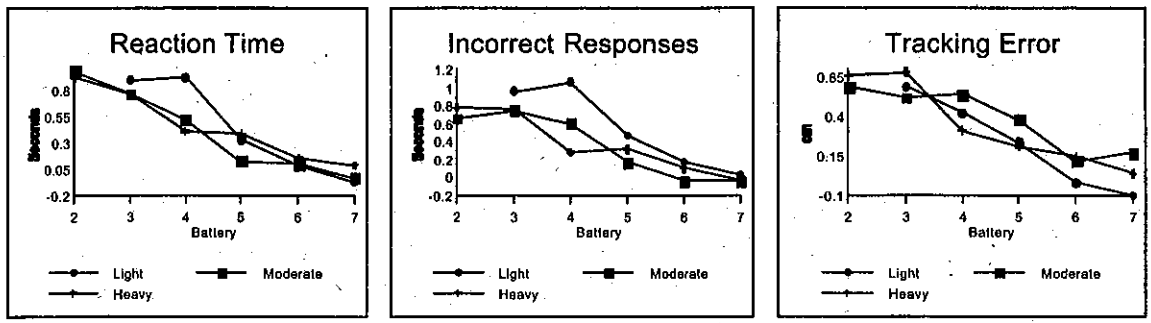
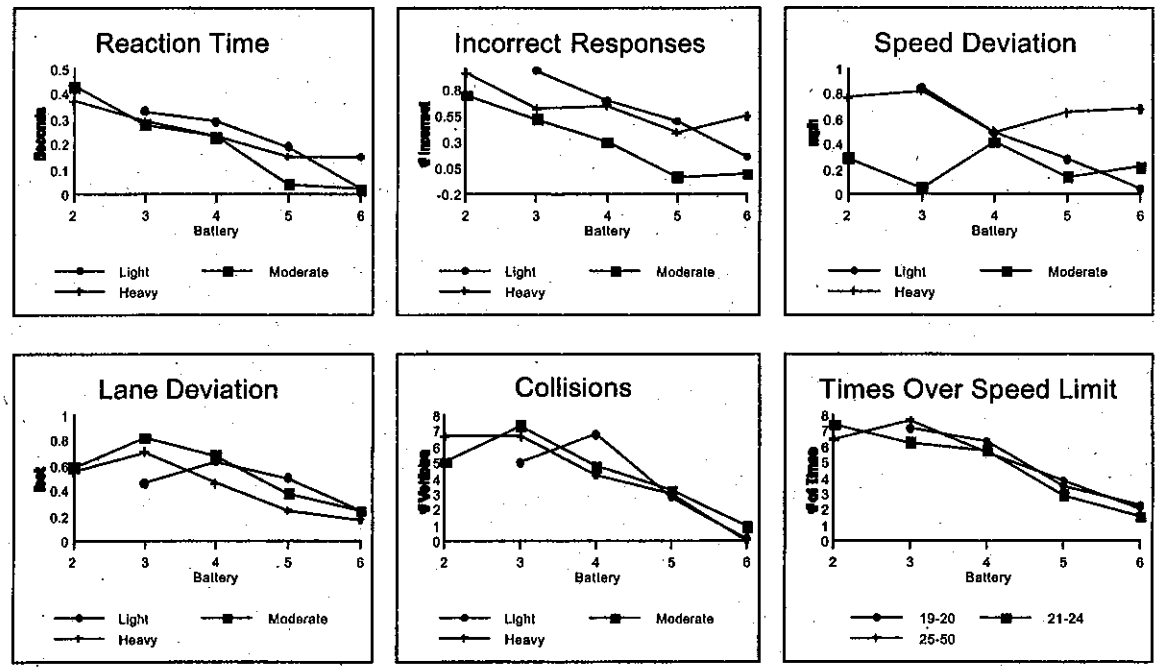


Figure AP-II-3b

SIM Impairment Scores by Drinking Practice



Appendix III

Graphs of Impairment Scores for DAT- and SIM-Based Performance Indices by Age, Gender, and Drinking Practice

Figure AP-III-1
DAT-Based Performance Index, Impairment Scores by
Age, Gender, and Drinking Practice

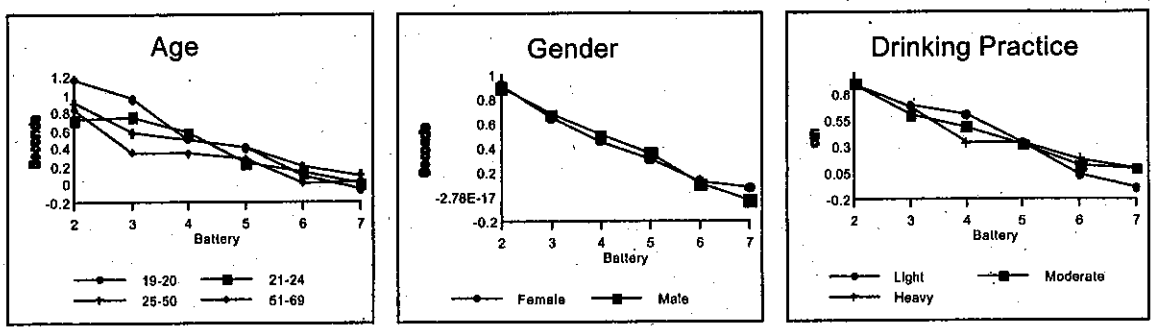


Figure AP-III-2
SIM-Based Performance Index, Impairment Scores by
Age, Gender, and Drinking Practice

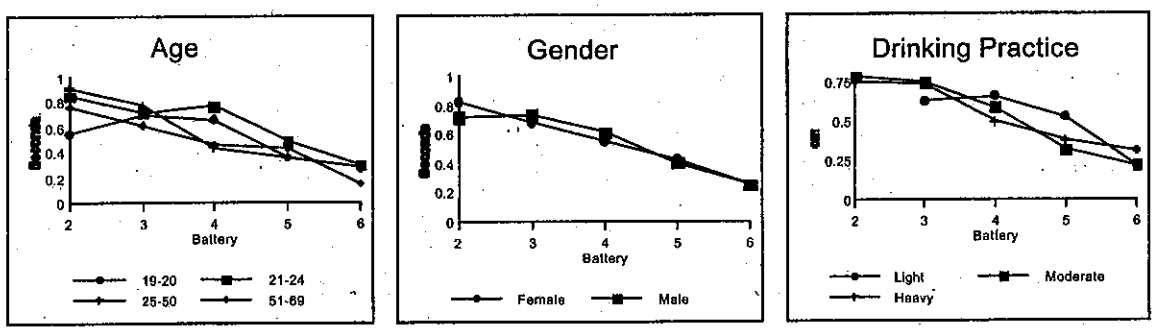


Figure AP-III-3
DAT+SIM-Based Performance Index, Impairment Scores by
Age, Gender, and Drinking Practice