Measuring cognitive and psychomotor impairment by alcohol at low blood alcohol concentrations

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The repeal of the Eighteenth Amendment to the United States Constitution decriminalized the consumption of alcohol and resulted in a precipitous increase in per-capita consumption throughout the country. The repeal of Prohibition was also earmarked by a near simultaneous increase in automobile ownership. The combination of alcohol consumption and driving proved to be inevitable and not without serious public safety consequences. By 1939 the first legislation defining drunk driving in terms of Blood Alcohol Concentration (BAC) was enacted in North America. In 1958 an international committee consisting of seven distinguished scientists issued the following statement concerning BAC’s and driving ability:

«As a result of the material presented at this Symposium, it is the opinion of the Committee that a BAC of 0.05% g/dL will definitely impair the driving ability of some individuals and, as the BAC increases, a progressively higher proportion of such individuals are so affected until, at a BAC of 0.10% g/dL, all individuals are definitely impaired.»

One of the scientists from this group of seven, Robert F. Borkenstein, later published the results of his classic investigation of alcohol’s role in automobile accident involvement in Grand Rapids, Michigan. This work consisted of a population of almost 10,000 and clearly demonstrated a positive correlation between BAC’s in excess of 0.05% g/dL and accident involvement. This research was singularly responsible for the establishment of a maximum per se limit of 0.10% g/dL throughout North America.

Subsequent scientific investigations into the interaction of alcohol with skills essential to optimal performance of safety sensitive tasks have demonstrated impairment of specific neurologic functions at levels well below 0.10% g/dL.

In response to such findings, the United States has prohibited alcohol use by transportation workers through the Omnibus Transportation Employee Testing Act of 1991 (P.L. 102-142, Title V). In all jurisdictions, the Act supersedes state and local statutes with the exception of certain criminal laws. Alcohol testing is regulated through the U.S. Department of Transportation and includes employees in commercial transportation. This investigation was designed to determine if the affects of alcohol on psychomotor and cognitive functioning could
be reliably measured at low BAC's on an individual and/or group basis.

**EXPERIMENTAL DESIGN**

**Two session group**
Subjects: A total of forty male and female social drinkers participated in two identical testing sessions. Session two was normally held within three weeks of session one. Participants were unpaid volunteers who were screened by telephone and were excluded from participation: if recent drug use was noted; there was a history of mental illness; a personal history of alcoholism; or a medical problem that contraindicated participation. Each testing session was 4-6 hours and each subject was required to refrain from alcoholic beverages for 24 hours and all solid food for 5 hours prior to testing.

Each subject was randomly assigned to one of four BAC groups and subsequently received a dose of alcohol calculated to elevate the BAC to one of four target concentrations:

- **Group I** - 0.010% to 0.050%
- **Group II** - 0.051% to 0.070%
- **Group III** - 0.071% to 0.090%
- **Group IV** - BAC > 0.090%

Ethanol was administered in the form of distilled beverages with the dose determined by use of the Widmark Formula.4

To minimize the complexity and inherent variability associated with attempts to compare subjects individually, paired data comparisons (each subject serving as his own control) were used to evaluate performance. Furthermore, to negate the obvious impact of the «learning curve», the data comparisons relied on performance from the second testing session only, but participants had no knowledge of this.

**Blood alcohol determinations**
Breath analysis with the Model 5000 Intoxilyzer was combined with whole blood testing through gas chromatography to establish the Blood Alcohol Concentration (BAC) at timely intervals throughout the study. Samples were collected in accord with established forensic procedures and analyzed in duplicate.
Psychomotor and cognitive testing
Two separate microprocessor based tasks were used to measure performance. Psychomotor performance was evaluated by an instrument intended to measure information processing functions known to be important in the safe operation of a vehicle. A second repeat human performance measurement system was configured to measure five separate cognitive functions. Each test measured the speed and accuracy of the subject in executing a predefined response.

Results - two session group
Data Analysis: To minimize person to person variation, paired data was used in this analysis which compared performance before and after alcohol ingestion. After careful review of all results obtained in both testing batteries, two responses were considered of the five tests in each battery:

1. Change in Response Time w/ Alcohol v. Response Time Sober.
2. Change in Percentage of Correct w/ Alcohol v. Percentage of Correct Sober.

All attempts to establish a correlation between BAC level and the various test responses using individual data points proved unsuccessful. Correlation coefficients of 0.25 to 0.35 indicated factors individually, or in combination with alcohol, affected performance.

To minimize the individual response variation, the data was grouped into four (4) cells based on the BAC:

- Group I - 0.010% to 0.050%
- Group II - 0.051% to 0.070%
- Group III - 0.071% to 0.099%
- Group IV - BAC > 0.099%

Measurements with grouped data provided more promising results and gave correlations as high as 0.98 for certain responses. This indicated positive correlations based on the average response.

The following responses appeared to be reasonable estimators of the grouped data:

1. Code Substitution (Change in Average Response Time)
2. Grammatic Reasoning (Change in the Percentage Correct)
3. Letter Comparison (Change in Average Response Time)
4. Psychomotor Evaluation (Change in Error Response)

One session group
Subsequent to the evaluation of all data from the Two Session Group, a second group of 32 volunteers was selected. All conditions for participation were identical to the Two Session Group. After selection, the group was sub-divided into groups based on BAC and performed the same tasks with and without alcohol.
Results - one session group

Those aspects of testing that proved to be the most reasonable estimators of the grouped data from the Two Session Group, were used exclusively to evaluate the One Session Group. Since these are repeat performance tasks, the highest sober score was compared to the highest drinking score on an individual basis and then grouped according to BAC as previously described.

In order to standardize test results, scores were converted to Z-Scores and plotted against the BAC on an individual and group basis. Individual data comparing BAC performance based on Z-scores showed considerable intra-subject variation and correspondingly low correlation coefficients. However, grouped Z-score data comparisons based on BAC ranges did demonstrate a trend towards performance deterioration as a function of BAC’s above 0.05%.

Of the four tasks considered, the following three appear to be alcohol sensitive and reasonable estimators of deterioration by alcohol. The tests are ranked in order of sensitivity to alcohol:

1. Psychomotor Evaluation (Change in Error Response)
2. Letter Comparison (Change in Average Response Time)
3. Grammatic Reasoning (Change in Percentage Correct)

DISCUSSION

Research on driving clearly demonstrates that the probability of crash involvement increases as the BAC increases above 0.05%. At a BAC above 0.10%, the relative probability of collision was found to be several times that for 0.00%. There is no apparent increase in relative crash probability at BAC’s below 0.05%. However, the risk of crashing begins to increase exponentially at BAC’s above 0.08%. Can this obvious deterioration linked to alcohol’s affect on driving skills be reliably measured in a controlled, non-driving context?

The thrust of this study was to evaluate specific, repeat, performance, cognitive and psychomotor tasks with and without alcohol. Those tasks which appeared to be the most sensitive to alcohol as a function of the BAC were isolated from a group of forty volunteers, who were tested on two occasions. These tasks were subsequently used to evaluate a second group of 32 volunteers who participated in identical testing, but only in one session.

To minimize person to person variation, paired data comparisons were used in this analysis which compared performance before and after alcohol ingestion. Correlations between BAC and the various test responses using individual data points proved unsuccessful. When the individual results were grouped according to BAC, the correlations proved to be more promising in both groups. It was also clear that certain tests (e.g. strict reaction measurement) were of no value, since «blood ethanol concentrations below 100 mg per 100 mL have very
little effect on reaction time.»⁶ Furthermore, deterioration by alcohol on psychomotor and cognitive functioning could not be reliably measured below 0.05%. By evaluating the performance data as a group based on BAC, a trend similar to what has been reported from epidemiologic studies on crash risk was evident. The same could not be said of individual data analyses based on BAC where no central trend could be discerned. This is probably due to the significant differences in individual abilities combined with factors such as age, alcohol, tolerance, intelligence and an assortment of other considerations.

REFERENCES


BIBLIOGRAPHY


