Vehicle-Borne Drunk Driver Countermeasures

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In many areas of society, the effects of alcohol abuse are subtle and often difficult to quantify. In the area of motor vehicle transportation, however, the effects are highly evident and can be quantified by the number of fatalities, injuries, and the economic losses caused by the misuse of alcohol. While precise figures indicating the extent to which alcohol is the causative agent in accidents are difficult to obtain, it is estimated to be a contributory factor in more than half of the motor vehicle accidents (1, 4). Because of the scope of the problem and the fact that it is an increasing one, General Motors has been exploring potential solutions through an alcohol countermeasures program.

One aspect of this program involves efforts in the area of education where attempts are being made to inform the public of the scope of the alcohol problem through radio announcements, pamphlets, films, and exhibits, as well as to stress personal responsibility in the use of alcohol at all times.

Another aspect of the program represents an engineering approach to the problem; namely, an attempt to develop a vehicle-borne system for detecting driver impairment (3). The different categories of systems that have been considered are firstly, pre-driving tests consisting of breath alcohol analysis and performance testing; and secondly, continuous performance monitoring consisting of psychophysiological parameters and driver performance parameters. Pre-driving tests attempt to identify impairment prior to driving and once it is identified, to inhibit the operation of the vehicle. The detection process can be based on a performance test or on chemical analysis of a breath sample (3, 8). The continuous monitoring techniques attempt to identify impairment while the vehicle is being operated. They are based either on some aspect of driving performance or some measure of psychophysiological condition. Warning systems would be activated upon identification of impairment.

Some of the advantages and disadvantages of each of these approaches are shown in Tables I and II. Pre-driving tests offer the opportunity to safely inhibit operation of the vehicle if impairment is identified. On the other hand, continuous monitoring approaches do not burden the driver with any additional tasks and can be based on longer samples of data. They can also detect impairment whose onset occurs after the vehicle is in operation. The continuous monitoring approaches are at a very early stage of development, however. In the pre-driving test category, breath analysis techniques

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have received wide support because of their correlation with the legal criterion for intoxication, namely, a given percentage of alcohol in the blood. Performance tests, on the other hand, are based on a functional rather than a chemical identification process. Since it is well recognized that the degree of impairment associated with a given BAC level varies widely among individuals, it is reasonable and defensible to attempt to detect impairment with a behavioral rather than a chemical test.

While benefits can be expected from each of these approaches, General Motors has placed most of its effort on pre-driving performance tests because of their relative ease of implementation and promise of more immediate impact. The remainder of this paper will deal with this category of alcohol countermeasures.

**TABLE I  Advantages and Disadvantages of Pre-Driver Tests**

**Breath Tests**

*Advantages*
- Breath sample relatively easy to obtain
- Based on legal definition of alcohol intoxication

*Disadvantages*
- Could be easy to fool unless made more complicated and discriminating
- Limited to alcohol impairment
- Present devices do not lend themselves readily to rapid automatic operation nor to low maintenance schedules

**Performance Tests**

*Advantages*
- Directly sensitive to degradation in psychomotor performance
- Sensitive to degrading effects of factors such as drugs, illness, fatigue, as well as alcohol
- Not easily defeated by mechanical devices
- Can be made durable and tamper resistant

*Disadvantages*
- Require some training to be effective
- May measure performance levels idiosyncratic to each driver
- Short test length may be detrimental to reliability

**REVIEW OF PRE-DRIVING PERFORMANCE TESTS**

*Objectives and Desired Characteristics*

In order for a pre-driving performance test to be effective as an alcohol ignition interlock, it must meet the following objectives:

1. Large discrimination against intoxicated individuals (positive rejection rates).
2. No discrimination against sober individuals capable of driving (false rejection rates).

*An alcohol ignition interlock is a device designed for installation in an automobile to automatically determine if the driver is intoxicated and to prevent operation of the vehicle when intoxication is detected.*
TABLE II  Advantages and Disadvantages of Continuous Monitoring Systems

**Driver Performance Monitoring**

**Advantages**
- Sensitive to variable of prime interest, driving performance
- Does not burden driver with any additional tasks
- Sensitive to all forms of impairment
- Would catch drivers who become impaired after starting to drive

**Disadvantages**
- Requires more clearly established base line for normal performance than is presently available

**Physiological Monitoring**

**Advantages**
- Based on detection of physiological concomitant of impairment and, therefore, hard to fool
- Sensitive to all forms of impairment
- Would catch impairment whose onset occurs while driving

**Disadvantages**
- Incomplete knowledge of physiological correlates of impairment
- Present laboratory measures have not been reduced to practical application

While most programs to date were conducted primarily with the goal of quantifying individual test sensitivities to BAC by assessing the above rejection rates, the following additional characteristics are desired and must be considered in any comparative analysis: high correlation with driving ability; short duration of test; rapid learning rate; easy integration in vehicle; insensitivity to age, sex, intelligence, and social and educational backgrounds; not easily compromised; low cost.

**Effectiveness Level**

There are two approaches which can be taken in setting the test parameters for most pre-driving behavioral tasks used as alcohol interlocks. One may use a single level of performance (Universal Threshold) as a requirement for the total driving population or use a level determined by the capability of each driver (Individual Threshold) (20). In some cases, the nature of the test determines the criterion which must be used. In those cases where the type of test permits the use of either criterion, greater effectiveness in detecting impaired behavior will be attained by using an Individual Threshold since it reduces the variability between individuals. Implementing this criterion for the entire driving population would be a difficult if not impossible task. However, if alcohol ignition interlocks are court ordered for convicted offenders only, then the procedure of individualizing the performance level for starting a vehicle is feasible.

**The Phystester**

The first significant effort in the application of modern technology to deny the drunk
driver the use of his vehicle was the development of the Phystester by General Motors. While providing the main impetus for the initiation of programs by government and private organizations to counteract the major cause of accidental death, the Phystester program also provided a tremendous amount of heretofore unavailable and much needed information.

**Universal threshold approach.** Although individual performances on the Phystester were significantly correlated with both BAC and performance on a simulated driving task, the alcohol test results using a universal threshold criterion indicated that while the Phystester is capable of discriminating between sober and intoxicated individuals, the debilitating effects of alcohol are not large enough to eliminate more than 50 per cent of the drivers at BACs of 0.1% without also eliminating a large number of sober drivers (12).

In addition to our own tests conducted at the William Beaumont Hospital (12), the Phystester was tested extensively by the Medical College of Wisconsin (MCOW) (9), Cornell Aeronautical Labs (CAL) (18) and Systems Technology, Inc. (STI) (7) with similar results. For example, MCOW rated the effectiveness of the hand-held Phystester (using a five-digit display with 3.5 seconds response time) to be in the 30 per cent range. Better effectiveness was predicted if only the first three trials were used. Effectiveness in this study was defined as:

\[
E = \frac{\left(\% \text{ sober passes}\right)^2 \times \left(\% \text{ drunk failures}\right)}{10,000}
\]

Using this definition, STI results showed a maximum effectiveness of 25 per cent (five-digit 3.5 seconds response time) when BAC was 0.1%. There was no significant change when three trials were used. Cornell results for a representative group of subjects in the 0.15% BAC range showed a maximum effectiveness of 53 per cent, although at this response time (3.0 seconds) the sober failure rate was 4 per cent. With a 3.2 seconds response time, the sober failure rate was reduced to 0.6 per cent, but the effectiveness was then reduced to about 20 per cent. The large variability in performance observed among sober subjects is the main factor limiting effectiveness.

**Individualized threshold approach.** A significant increase in intoxicated failure rates was observed when the response time of the primary task was individualized to each subject so that given three trials a 1 per cent sober failure rate was assured (14). The drunk failure rate obtained from 15 subjects who exceeded 0.10% BAC was 35 per cent. For six subjects who exceeded 0.15% BAC, the failure rate was increased to 41 per cent. These results were obtained for three allowed trials in which to obtain one pass. More sensitivity was noted during the rising BAC phase than during the descending phase. These results are summarized in Table III.

<table>
<thead>
<tr>
<th>BAC (g/100ml)</th>
<th>No. of Subjects</th>
<th>Failure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>.05</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>.10</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>.125</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>.150</td>
<td>6</td>
<td>41</td>
</tr>
</tbody>
</table>

\(^a\)Pass Criterion = 1:3
Other Devices and Tests Evaluated

A review of alternative devices tested by the Department of Transportation’s Transportation Systems Centre (TSC) (15) shows that those listed below are apparently no more effective than the Phystester.

<table>
<thead>
<tr>
<th>Device</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compensatory Tracker (TSC)</td>
<td>23%</td>
</tr>
<tr>
<td>Complex Reaction Time (TSC)</td>
<td>22%</td>
</tr>
<tr>
<td>Quick-Key (Smith)</td>
<td>35%</td>
</tr>
</tbody>
</table>

Other studies were conducted by the Medical College of Wisconsin (9), Ohio State University (17), and the Cornell Aeronautical Laboratories (18) to evaluate both applicable devices and sensitive behavioral mechanisms upon which a device could be based. All the tests measure sensory, cognitive, or motor behavior.

Analyses of these approaches and of the results obtained to date led us to the conclusion that the most promising tasks would be ones that require: a) high concentration; b) simultaneous information processing; and c) rate perception.

Consequently, General Motors developed a second generation alcohol ignition interlock based on the critical task concept (10). This task forces high workloads on the driver, since it is inherently unstable without the subject in the loop. By varying the controlled element properties, the driver’s time delay or rate perception capabilities can be tested. In both a laboratory test environment and under simulated field test conditions, this second-generation development has proved more effective than any other experimental interlock system tested or developed to date by General Motors and is discussed in the following section.

THE CRITICAL TRACKING TASK (CTT) AS AN ALCOHOL INTERLOCK SYSTEM

Task Description

The task requires the operator to stabilize the output of a dynamically unstable system whose level of instability (or degree of difficulty) increases with time. The error is displayed visually to the operator whose task is to cancel the error by manipulating a control. When the level of difficulty reaches a point where the operator can no longer compensate for the error, the test is terminated.

The test is easy at first. Gradually it becomes more difficult, resembling somewhat the steering of a car on a slippery surface, such as ice, while the speed of the car gradually increases (without the driver’s control). It involves controlling an unstable system which gradually becomes more unstable. In the analogy of driving a car on ice, it is obvious that as speed increases, the system becomes more unstable and its control becomes more demanding. If the speed is increased indefinitely, control will eventually be lost. The performance index or score is the speed at which control is lost. The higher this critical level of instability (the higher the critical speed), the higher the score.

Figure 1 illustrates what takes place when the driver performs the task. At initiation of the test, the output of the controlled element \( y_c \) starts to diverge from the reference, since the system is unstable. The operator \( y_p \), sensing the error,
controls the output by means of steering wheel corrections. As the test proceeds, the “autopacer” changes the dynamic characteristics of the controlled element, making them more unstable.

Interesting correlations between performance on the CTT and neuromuscular time delays have been established in man/machine related research (10). In particular, it was discovered that the constraint of the task on the operator’s dynamic behavior provides for accurate estimations of the operator’s effective time delay \(^3\). This observation could indicate that performance on the task is not solely a measure of motor responses but may also involve higher neural functions since the effective time delay is influenced by central processing delays, neuromuscular delays, and the subject’s ability to anticipate the consequences of his own responses. It was anticipated, therefore, that performance on the task would show significant degradation when conducted by a person in an unfit or intoxicated state. A well-validated background of applications and statistical data exists for the Critical Tracking Task. Applications have included both acute and chronic drug studies (2, 16) and investigations of the effects of environmental stress on human performance (5, 19).

**Figure 1**  
Block Diagram Representation of CTT.

The motivation and roots of the development of this task originate in the fields of handling qualities and engineering psychology. Notable among this research is the investigation of manual control of a statically unstable, inverted pendulum using visual and/or motion cues (21), and the review of several concepts of “self-paced” tracking tasks by Kelly (13). Perhaps the most pertinent related work is that by Chernikoff and Birmingham (6), wherein a parameter governing the dynamic response of the system to be controlled is varied, and its limiting value is used to measure some aspect of the operator’s tracking skill.

**Task Mechanization**

Evidence that the level of task difficulty at which control can no longer be maintained differs significantly in the normal and intoxicated states was first obtained in a laboratory test environment using an oscilloscope to display the system error and an isometric force stick as the control manipulator (20). The results from the study suggested that the CTT had the potential for being an effective pre-driving test for impairment if it could be mechanized effectively in the vehicle.

\(^3\)The reciprocal of \(\lambda_{ct}\) (the value of \(\lambda\) at which control is lost) corresponds to the subject’s effective time delay.
Subsequently, a vehicle configuration of the CTT was developed. For vehicle use, the steering wheel and a meter were substituted for the force stick and the oscilloscope used in the initial evaluation. Although the basic concept of the task remained unchanged, differences in the dynamic characteristics of the Driver/CTT system were apparent. While the laboratory unit required only small movements of the fingers and wrist, the vehicle unit required larger motions of the hands and arms. Consequently, large neuromuscular lags and hardware lags were introduced into the task. Because of these fundamental differences, it was inappropriate to assume that the level of effectiveness obtained from the laboratory evaluation would be the same for the vehicle system.

AN EXPERIMENTAL PROGRAM USING THE CCT

Objectives

Because of the differences in task dynamics between the laboratory and vehicle units as well as the type of training procedure used in the laboratory evaluation, the goals of the program were to establish the level of effectiveness of the vehicle CTT using more realistic training conditions, in both frequency of use and environment, by providing subjects with cars equipped with the CTT units, and to compare the level of effectiveness obtained with that found in the laboratory evaluation.

In the laboratory evaluation of the Critical Tracking Task, the training procedure consisted of two practice sessions separated by a two-week interval. A total of 30 practice trials were taken on the first day and 20 trials on the second day followed by 10 test trials in the intoxicated state.

A second area of interest was whether differences in task performances exist related to subject differences in age, sex and education.

The performance criterion used in determining the percentage of intoxicated failures in the laboratory evaluation was based on a single level of performance which was applied to the total subject population (Universal Threshold). To permit comparisons in this report with the data obtained from the laboratory evaluation, the same data format and criterion are used. Other analyses of the data using the individual criterion (Individual Threshold) are presented to determine if significant improvements in effectiveness can be attained using this procedure.

Method

Subjects. Seventy-one subjects (45 males and 26 females) ranging in age from 18 to 51 years participated in the study. The subjects were primarily a cross-section of the employees of a local hospital where the study was conducted.

An attempt was made to select subjects so that a wide range of occupations, educational levels, and ages would be represented in the subject population. The screening and selection of the participants were made by medical personnel at the hospital based on a review of the subjects' medical history. Volunteers with medical problems which would be aggravated by the ingestion of alcohol or those under medication which was incompatible with alcohol were not permitted to participate in the program.

Training/testing. The evaluation program was conducted in cooperation with the
hospital staff and used its facilities for the training and testing of subjects. An area in the administrative section of the hospital was provided for the program and was arranged to convey an informal, relaxed atmosphere. Subjects were permitted to read newspapers and magazines or otherwise occupy themselves during the waiting periods in the training and test sessions.

The training and testing schedule required a period of 11 days for each subject. On the first day the subject was familiarized with the CTT and given 25 training trials on a simulator instrumented with the device. Following the training, the subject was assigned a vehicle instrumented with the CTT which functioned as an ignition interlock system. Ten trials were given on the vehicle to ensure that the subject could meet the level of task difficulty required for starting the vehicle. The subject was instructed to use the vehicle as his own for the next 10 days and whenever operating the task to continue each time until control could no longer be maintained.

On the 11th day, the subject returned for the test session. A Breathalyzer was given upon arrival and was followed by five trials in the vehicle and five trials on the simulator. Four drinks were next administered evenly spaced in an 80-minute period. Forty minutes after completing the fourth drink the subject was given a Breathalyzer test and taken to the vehicle. Five trials were given on the vehicle unit. The subject was then returned to the test room and received five trials on the simulator followed by a second Breathalyzer test.

**CTT Parameters.** Identical task parameters were used on the simulator and vehicles during the evaluation program. These parameters are:

1) $\lambda_{1c}$ = initial level of stability
2) $\lambda$ = rate of change in stability
3) $\lambda_T$ = threshold level required for starting vehicle

The settings of these task variables on the simulator and vehicles were checked during each training and test session.

**Alcohol Administration.** The alcohol given to the subject during the drinking phase was 100 proof vodka and was mixed with either orange or tomato juice. The total volume of vodka administered was calculated on the subject’s weight and a summary of the amount and frequency of his drinking. Based on the summary, the subject was categorized as one of the following and scheduled to receive the corresponding volume of vodka indicated:

<table>
<thead>
<tr>
<th>Category</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Drinker</td>
<td>2.2 ml/kg body weight</td>
</tr>
<tr>
<td>Average Drinker</td>
<td>2.75 ml/kg body weight</td>
</tr>
<tr>
<td>Above Average Drinker</td>
<td>3.3 ml/kg body weight</td>
</tr>
</tbody>
</table>

The alcohol was administered by a physician and adjustments were made as necessary during the drinking period in the amount of vodka administered to compensate for nausea reported by the subject, excessive behavioral impairment or the lack of signs of intoxication.

The Breathalyzer measurements were taken by a trained operator, and the instrument was checked for calibration at the end of each session.
Results

Table IV presents the failure rate obtained at increasing levels of $\lambda$ (task difficulty) and trial criteria for the unimpaired state (0% BAC) and at increasing levels of impairment ($\geq 0.09\%$ to $\geq 0.15\%$ BAC). As shown, under 1 Pass out of 3 Trial requirements, no failures occur at 0% BAC up to a level of difficulty of $\lambda_T = 4.2$. The corresponding failure rate for the impaired states ranges from 76.5% for BACs $\geq 0.09\%$ to 83.4% for BACs $\geq 0.15\%$.

Table V presents the comparable data obtained on the laboratory CTT unit used in the previous evaluation.

<table>
<thead>
<tr>
<th>Universal Criterion</th>
<th>Passes Required</th>
<th>Trials Allowed</th>
<th>Blood Alcohol Concentration (g/100ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>4.1</td>
<td>1</td>
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<td>3</td>
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<td>7.0</td>
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<td></td>
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<td>3</td>
<td>0.0</td>
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<tr>
<td>4.2</td>
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<td>1</td>
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<td>1</td>
<td>38.0</td>
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<td>1</td>
<td>3</td>
<td>11.0</td>
</tr>
<tr>
<td>Number of Subjects</td>
<td>71</td>
<td>67</td>
<td>63</td>
</tr>
</tbody>
</table>

Again, no failures occur at 0% BAC up to a $\lambda$ level of 4.2. However, the corresponding failure rate for BACs $\geq 0.10\%$ is approximately 30 per cent lower than that found with the vehicle units. Additional comparisons at increasing levels of BAC show consistently lower failure rates for the laboratory results up to the $\geq 0.15\%$ level. Here the failure rate is 100 per cent for the four subjects at that level. The failure rate at the BAC level $\geq 0.15\%$ in the present study was 83.4 per cent for the 12 subjects who reached that level.

The resulting failure rates obtained using the Individual Threshold criterion are compared against those obtained using the Universal Threshold criterion ($\lambda = 4.2$ with a 1 Pass out of 3 Trial required) in Figure 2.

To determine an individual threshold, the highest and lowest score of the five Pre-Drink trials were discarded and the mean of the remaining three scores was computed for each subject. The first three trials following the drinking period were then compared to this value to compile the failure rates.
TABLE V Failure Rate Obtained at Increasing Levels of Task Difficulty (Laboratory CTT System)

<table>
<thead>
<tr>
<th>UNIVERSAL THRESHOLD (λr)</th>
<th>CRITERION BLOOD ALCOHOL CONCENTRATION (g/100ml)</th>
<th>Passes Req'd</th>
<th>Trials Al­lowed</th>
<th>0</th>
<th>≥.10</th>
<th>.12</th>
<th>.13</th>
<th>.14</th>
<th>.15</th>
</tr>
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<tbody>
<tr>
<td>4.0</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>62.5</td>
<td>66.7</td>
<td>75.0</td>
<td>81.8</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>3</td>
<td>1.5</td>
<td>55.0</td>
<td>62.5</td>
<td>75.0</td>
<td>81.8</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>50.0</td>
<td>54.2</td>
<td>62.5</td>
<td>72.7</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>42.5</td>
<td>50.0</td>
<td>56.3</td>
<td>63.6</td>
<td>100</td>
</tr>
<tr>
<td>4.2</td>
<td></td>
<td>1</td>
<td>1</td>
<td>13.4</td>
<td>72.5</td>
<td>75.0</td>
<td>81.3</td>
<td>81.8</td>
<td>100</td>
</tr>
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<td></td>
<td></td>
<td>2</td>
<td>3</td>
<td>4.5</td>
<td>65.0</td>
<td>70.8</td>
<td>81.3</td>
<td>90.0</td>
<td>100</td>
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<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3.0</td>
<td>60.0</td>
<td>66.7</td>
<td>75.0</td>
<td>81.8</td>
<td>100</td>
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<tr>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>47.5</td>
<td>58.3</td>
<td>68.8</td>
<td>72.7</td>
<td>100</td>
</tr>
<tr>
<td>4.4</td>
<td></td>
<td>1</td>
<td>1</td>
<td>16.4</td>
<td>75.0</td>
<td>79.2</td>
<td>87.5</td>
<td>90.9</td>
<td>100</td>
</tr>
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<td></td>
<td></td>
<td>2</td>
<td>3</td>
<td>11.9</td>
<td>67.5</td>
<td>75.0</td>
<td>87.5</td>
<td>90.9</td>
<td>100</td>
</tr>
<tr>
<td></td>
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<td>2</td>
<td>7.5</td>
<td>65.0</td>
<td>75.0</td>
<td>87.5</td>
<td>90.9</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
<td>3.0</td>
<td>62.5</td>
<td>70.8</td>
<td>87.5</td>
<td>90.9</td>
<td>100</td>
</tr>
<tr>
<td>Number of Subjects</td>
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<td>67</td>
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<td>24</td>
<td>16</td>
<td>11</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 Universal Threshold and Individual Threshold Failure Rates of All Subjects.
As shown, the failure rates for the Individualized Thresholds range from 82.4 per cent for BACs $\geq 0.09\%$ to 91.7 per cent for BACs $\geq 0.15\%$. Compared to the failure rates using the Universal Threshold, slightly greater effectiveness is found using the Individual Threshold criterion.

**Age differences.** Figure 3 shows the failure rates of those under 30 years and those over 30 years of age for the Universal Criterion analysis. In general, the under 30 year age group shows lower failure rates under the various BAC levels.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig3.png}
\caption{Universal Threshold Failure Rates of the Over 30 Years and Under 30 Years Age Groups.}
\end{figure}

A similar pattern is shown in Figure 4 which shows the failure rates of the two groups using the Individual Threshold criterion.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig4.png}
\caption{Individual Threshold Failure Rates of the Over 30 Years and Under 30 Years Age Groups.}
\end{figure}
Lower failure rates are again shown for the under 30 year group at every BAC level.

*Male and female task performances.* Figure 5 shows the sober and intoxicated failure rates for the male and female subjects, using the Universal Threshold. For low BAC levels, the data show a slightly lower failure rate for the male subjects. Meaningful comparisons at the higher BAC levels (>0.13%) are impossible due to the low number of female subjects who reached that level (N = 2).

![Figure 5](image)

**Figure 5**  *Universal Threshold Failure Rates of the Male and Female Groups.*

A comparison of failure rates of the two groups for the Individual Threshold analysis is shown in Figure 6. Here the overall performance of the two groups is similar.

![Figure 6](image)

**Figure 6**  *Individual Threshold Failure Rates for the Male and Female Groups.*
**Performance differences and educational levels.** Figure 7 shows the sober and intoxicated failure rates for College Graduates and High School Graduates using the Universal Threshold criterion. Lower failure rates under the various levels of BAC for the College Graduate group can be attributed to the fact that the average level of skill acquired on the task was greater than that of the High School group. The average score on the five pre-drink trials for the College Graduate group was $\lambda = 4.8$ while for the High School Graduate group the average pre-drink score was $\lambda = 4.3$.

![Figure 7](image)

**Figure 7** *Universal Threshold Failure Rates of High School Graduates and College Graduates.*

Failure rates of the two groups using the Individual Threshold criterion are presented in Figure 8. As shown, the overall failure rates are more similar due to the fact that the Individual Threshold criterion takes into account differences in levels of skill acquired on the task.

**BAC group performance differences.** Figure 9 presents the mean decrement in performance between the five pre-drink and five post-drink scores as related to the BAC level reached by the subjects in the test session.

As shown, all BAC groups deteriorated in performance with the decrement ranging from 0.70 for the group whose BAC was 0.10% to 1.5 for the 0.15% BAC. In addition, no subject's average performance on the five post-drink trials was greater than his pre-drink average score.

**Effect of drinking habits.** In order to expedite the collection of data on as many subjects as possible, the experimental design did not allow for comparisons between subjects with different drinking habits at similar BAC levels. Studies performed for General Motors by Systems Technology, Inc., with a laboratory unit do provide limited information on this effect, however.

There was significant difference between the scores obtained by the "moderate" versus "heavy" drinkers in each BAC interval, with the moderate drinkers performing
more poorly than the heavy drinkers. This result is presented in Figure 10. The number of moderate and heavy subjects in each BAC interval is not equal because not all moderate drinkers were able to exceed 0.10% BAC and less than half of the heavy drinkers exceeded 0.15% BAC.

In addition to the testing of the vehicle-borne CTT units by General Motors, a CTT simulator on loan to the Department of Transportation has undergone testing in competition with other candidate systems. Blood alcohol concentrations up to and exceeding 0.18% were used, thus requiring the selection of subjects who could be expected to attain such elevated levels. From the STI findings on the effects of drinking habits on performance, one would expect less performance decrement to occur with this group of subjects at a given BAC than the typically moderate drinking habits of the general driving population.
subjects tested by General Motors. This was indeed the case, for in the 0.15-0.18% range, levels of discrimination comparable to what we observed for BAC ≥ 0.10 were obtained. While some of the other devices (Reaction Analyzer, Complex Coordinator, Divided Attention) were comparable to the CTT regarding discrimination, they could not compare on features such as short task duration, simplicity, and ease of implementation.

![Figure 10](Comparison of Performance Between Moderate and Heavy Drinkers Using the Laboratory System.)

**DISCUSSION**

As the data indicate, although the upper level at which the 0% sober failure rate is the same (λ = 4.2 for a 1 Pass out of 3 Trial criterion) in both the laboratory evaluation and the present study, greater discrimination in detecting impairment was obtained with the vehicle CTT units. This difference was probably due in part to the differences in task dynamics but more importantly to the difference in training procedures.

In the laboratory, evaluation training was massed into a two-day period with a 50 trial total. In contrast, training in the present evaluation extended over an 11-day period. This distributed type of training with a large number of trials taken typically reduces variability in performance both among and within subjects, as well as raising the average level of peak performance. Theoretically, lower peak performances should be seen with the vehicle-borne unit because of the delays introduced by the steering wheel and meter mechanisms. The same Universal Threshold (λ = 4.2) resulted from both the laboratory and vehicle units, however, indicating that the training was not equivalent. It is highly probable that had this same training procedure been used in the laboratory evaluation, the level of effectiveness at the various BACs would have been higher.
The slightly greater overall effectiveness shown by using the Individual Threshold criterion was due primarily to the change in failure rates of the College Graduate group. No other groups showed such a large difference in failure rates between the Universal and Individual Threshold analyses. This would indicate that the average performance level of the other groups was probably around the $\lambda = 4.2$ value.

Somewhat surprising was the difference between the under 30 year and over 30 year age groups. If anything, it was expected that, in general, the older subjects with more experience with alcohol, would have learned to compensate for its effects more than the younger group. As indicated above, the subjects were instructed to continue the task each time until control was lost. Because the task is a challenging one, this procedure permitted well-motivated subjects to attempt to maintain control at progressively higher levels of difficulty. As a result, they became quite skilled on the task. Although their performance deteriorated following drinking, it did not decline to the levels of less skilled subjects. One would expect that if exposure to high levels of task difficulty had been prevented by automatically terminating the task when the level of difficulty reached a set value, performance differences among subjects would have been less variable and the overall failure rates using a Universal Threshold would have been higher. Since it is likely that, if implemented, the task would be limited rather than open-ended, the effects of using this procedure during training should be evaluated. If it is successful, significantly higher failure rates in the intoxicated states using a Universal Threshold may result.

Another issue which has not been addressed in the evaluations to date is the rate of failures which may occur at BACs lower than those which legally define impairment or intoxication. While the threshold value at which no sober failures occur is an important consideration, if a significant percentage of failures begin to occur at BACs which are relatively low, the Universal Threshold value may have to be lowered. This, in turn, would reduce the overall effectiveness of using a Universal Threshold criterion.

The performance criterion presently used to determine whether impairment exists depends on whether or not the operator can maintain control up to a required level of task difficulty. In the present configuration, the time required for each trial is relatively short and more than one opportunity is allowed to meet the criterion. A disadvantage of this approach is that it is possible for the operator in an impaired state to "gather himself together" for a single trial and maintain control to the required level.

Test criteria which are based on performance on more than one trial might also be considered. In the present study, the analysis of difference scores between the pre- and post-drink performance showed a deterioration in performance with every subject. While this type of criterion would incur a larger test time penalty, a greater effectiveness in discrimination may be gained. If ignition interlocks are directed at convicted offenders, then the added time required may not be an important consideration.

At the present time, no further testing with the CTT is planned by General Motors since it is felt that significant improvements in its present performance can only be attained at a sacrifice in other desirable characteristics, such as short task duration and ease of implementation. Units are on loan to other organizations, however, where they will be undergoing further evaluation. New approaches that show potential for even greater effectiveness will continue to be evaluated in the future.

REFERENCES

1. Allsop, R. E., Alcohol and Road Accidents. A Discussion of the Grand Rapids Study, Road...


