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RESEARCH REPORT

Behavioral monitoring of DUI offenders with the Alcohol Ignition Interlock Recorder

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Abstract

Aims. *To evaluate patterns of blood alcohol concentration (BAC) and driving logged on the ignition interlock recorder and to assess whether this event record is a useful outcome measure for a behavioral intervention.* **Design**. *Descriptive analyses of recorder data and multivariate analysis of the predictors of high BACs associated with a motivational intervention for driving-under-the-influence (DUI) offenders using an interlock.* **Setting**. *Two interlock service centers in Alberta, Canada.* **Participants**. *1309 first-time and multiple DUI offenders who agreed to participate during interlock installation.* **Intervention**. *A human-services (supportive guidance) intervention based on motivational interviewing and pragmatic counseling was delivered to interlock users in Calgary, but not to interlock users in Edmonton, Canada.* **Measurements**. *This report summarizes the patterns and predictors of BAC warnings (0.02–0.039%) (20–39 mg/dl) and failures (≥0.04) (≥40 mg/dl) from more than 3 million in-vehicle breath tests. Data come from three sources: driver records, questionnaires and the interlock.* **Findings**. *From the beginning to the end of the interlock use period, there was a significant linear decline in the proportion of positive BAC driving to total driving. After controlling for prior offenses, demographics and reported drinking levels, offenders in the intervention site (Calgary) were less likely to have recorded fail BACs than were offenders in the control site (Edmonton). The temporal patterns of BAC fails with the interlock mimic the high-risk periods for DUI arrests and alcohol-involved fatal crashes.* **Conclusions**. *The interlock successfully blocks drinking and driving during high-risk periods. Preliminary recorder data suggest the services intervention may be affecting DUI behavior.*

Introduction

The Breath Alcohol Ignition Interlock requires a driver, usually a convicted driving-under-the-influence (DUI) offender, to provide a low alcohol or alcohol-free breath sample before a vehicle's engine can be started. By 1997, an estimated 24 000 interlocks were in active use in the United States and another 1000 in Canada. This paper is the first comprehensive review of vehicle use and blood alcohol content (BAC) data as recorded by the interlock; it is based on more than 3 million breath tests of 1309 alcohol offenders in Alberta, Canada, from 1995 to 1997.

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The first ignition interlock law was the California Farr–Davis Driver Safety Act of 1986. By 1990, there were pilot programs in a few US states and in Alberta, Canada. These early programs, along with the National Highway Traffic Safety Administration (NHTSA) studies (Compton, 1988; Frank, 1988), identified several issues and problems with the first-generation equipment. In 1990, different technical approaches to measurement and uncertainty about interlock capabilities led to problems for state authorities certifying equipment from different manufacturers. Certification standards varied widely from state to state. In 1992, NHTSA published a set of "Model Specifications" (NHTSA, 1992; Voas & Marques, 1992; Marques & Voas, 1993) to help guide the development of both the states' certification of interlock devices and the equipment produced by the interlock manufacturers. These model specifications added emphasis that the purpose of the interlock was for safety enforcement, not the performance of field forensic tests. The new NHTSA guidelines attempted to divert the preoccupation with accuracy and advocated two key features: a rolling retest and a data recorder. The rolling retest required the operator to retest periodically his or her BAC while the vehicle was running. This feature was included to prevent driver circumvention such as getting someone else to blow into the interlock, allowing a vehicle to sit idling for long periods to avoid having to restart and retest, or using stored air samples to blow into the sampling head of the interlock. An early, unpublished evaluation study found these to be among the most frequent classes of violations. All these are effectively defeated by the rolling retest.

The other requirement, the data recorder, is the main topic of this paper. The recorder provides a running record of driver behavior each time the vehicle is used. The typical recorder logs the date and time of each attempt to start the engine and the BAC test result. The warning point for BAC varies with the jurisdiction's requirements. In Alberta, a BAC lower than 0.02% is a pass; 0.02%–0.039% is a warning (but pass); while 0.04% or greater is a failure. In addition to test outcome, the interlock record can be queried to extract duration of a driving episode and the number of retests performed during each episode of driving. Procedural violations, such as failure to comply with a breath test request within the allotted time, are also recorded.

The Alberta interlock program is operated administratively through the Driver Control Board, which has the authority to assign DUI offenders to the interlock program as a condition of license reinstatement. Different Boards operate in the two major cities under the same guidelines. Overall, about 6% of the interlock users are mandated; the majority volunteer in exchange for earlier license reinstatement. Interlock sentences can range from a few months to several years, but the modal required interlock periods have been 7, 12 and 18 months. In this dataset, during the interlock period, the median number of BAC tests taken by each offender exceeds 2000.

Several studies, including the companion paper in this issue (Voas *et al.*, pp. 1849–1859), have shown from 50% to near 100% reduction of recidivism (relative to suspension alone) while interlocks are installed. However, the DUI offenses can climb sharply after the interlock is removed. Because of this, one of the features of the Alberta study was to deliver and evaluate a harm-reducing, motivational intervention (Bien, Miller & Tonigan, 1993; Marques & Voas, 1995; Project MATCH, 1997; Marques, Voas & Hodgins, 1998). The program elements were designed to educate and raise awareness among interlock users of the need to plan and to re-evaluate their manner of vehicle use whenever any drinking may be possible. The intervention attempted to move the offenders along a change–readiness dimension (Prochaska, DiClemente & Norcross, 1992) toward greater problem recognition and action. It worked with the offenders while they have an interlock, in part to prepare them for driving more responsibly after it is gone. The interlock service provider in Alberta, Guardian Interlock Systems, operates service centers in Calgary and in Edmonton.

This paper briefly reviews the methodology of the Alberta Interlock Services Intervention Program and describes and evaluates the patterns of findings in the interlock record. The patterns of BAC warnings and failures in the interlock recorder data are reviewed both at the descriptive level, and as an outcome associated with driver characteristics and the intervention variable.

Methods

Subjects included both first and multiple DUI offenders ($n = 1309$) in Alberta, Canada, who completed a required period with the interlock. The sample was as follows: 972 first-time offenders, 206 second-time offenders, 77 third-time offenders, 21 fourth-time offenders, 15 fifth-time offenders, and 18 offenders whose prior offense status was unclear; 55% of the sample was from Edmonton, 45% from Calgary. The proportion of prior offenses by city was, respectively, for Calgary and Edmonton: first: 75%, 76%; second: 16%, 16%; third and higher: 9%, 8%. At the time of this study, Alberta set the "look-back" period for the number of prior offenses at 5 years.

Intakes for these data began in 1994 and continued to 1997; 83% of all possible interlock-assigned offenders agreed to participate in the research program (84% Edmonton, 81% Calgary). Of those enrolled in the study, 6% dropped from Edmonton (the control sample), and 3% dropped from Calgary (the intervention sample). The intervention was confounded with city; however, the alcohol-related traffic offenses and the demographic profiles of these two cities are generally similar (~800 000 population, more than 90% white). In an effort to determine if differences between cities could be attributed to the intervention, 16 covariates were statistically controlled/equated.

On monthly or bimonthly service visits, the interventions occurred during the interlock-service waiting period. Over 1 year, depending on the length of the interlock assignment, there were from seven to 12 occasions when the offenders came in. During these visits, a four-element intervention was tested in Calgary, which was not available at the control site in Edmonton. The elements, while not delivered in a structured format, were as follows:

(1) *Educational support* covered the pragmatics of living with an interlock (helping users to avoid warnings and failures, staying in the program, avoiding the costs of further DUIs).
(2) *Case management support* was to assist in finding and using community resources relevant to various needs (family counseling, job counseling, grief counseling and addiction treatment).
(3) *Motivational enhancement therapy* emulated the NIAAA Project MATCH protocol in order to enhance a sense of responsibility toward self-change and to begin movement along the change–readiness continuum.
(4) *Protective planning support* assisted in planning for activities during the high-risk post-interlock period when the ignition will no longer be locked by high BACs.

Some additional commentary about the intervention and the intervention model have been published previously (Marques & Voas, 1995; Marques *et al.*, 1998).

Instruments

All subjects completed baseline questionnaires. Germane to this report are the Alcohol Use Disorders Identification Test (AUDIT), quantity and frequency of drinking in the 28 days before the interlock and a questionnaire about vehicle use and availability of non-interlock vehicles, including questions about their expectations for the interlock. A general demographics questionnaire obtained information about family income, ethnicity, education, marital status, children, age and gender. In addition, drivers' records from Alberta were obtained for all study participants. The driver records provided information about prior offenses, suspension time and interlock duration.

Recorder data

The interlock recorder data as a total event record was used to study temporal patterns of BAC failures and warnings. The data were aggregated at the person level to examine the relationship between individual characteristics, vehicle use and BACs. Either the offender or others who need to use the vehicle may drive the interlock vehicle, but survey data show more than 99% of the offenders were the majority users of the vehicle (61% were the exclusive users). Non-offender users of the interlock vehicle were spouses or adult children. BAC test data from such sources cannot be identified separately in the record, but it is not likely that these add many warnings or failures since such violations could result in resuspension of the offender (typically the husband or father).

In Alberta, the interlock was assigned to both first-time and repeat offenders. Repeat (or multiple) offenders were usually assigned to the interlock for longer periods. The majority of the offenders in this study were first offenders, but even first offenders can represent a significant public risk. Based on roadside surveys, the average person has driven drunk hundreds of times without a first arrest (Beitel, Sharp & Glauz, 1975; Voas & Hause, 1987). First-time offenders were defined operationally in this study as having had no prior convictions in Alberta during the 5 years before the index offense. When looking back beyond the 5-year history, 50% of this sample had prior DUI convictions in Alberta alone.

Data handling and statistical methods

Data are presented at the event level, the person level, and person–week level. Because this is the first comprehensive report on the alcohol interlock data recorder, the results section includes some general descriptive information about the topography of interlock BAC violations as events. Warning and/or failed BACs have been represented as counts of events or as a proportion of all breath tests taken.

To aggregate the data at the person level, the frequency of violations required adjustment to reflect the amount of vehicle use by an individual in order to prevent more frequent vehicle users from unduly influencing the conclusions. The person-level data were adjusted in two ways: (1) by the number of vehicle trips taken (e.g. one BAC test per driving episode or engine start), and (2) by the number of BAC tests taken (e.g. there are usually multiple retests within each trip or engine start). The "trips" data may be a better representation of the true proportion of violation occurrences. This is because an initial failure would not be followed by programmed retests since the engine would not have started.

Modeling learning: aggregating at person–week level. Since the interlock record follows a timeline, it was possible to ask if there was evidence of learning or changed patterns of drinking and driving while on the interlock. The first examination of the data showed the pattern of change over time in warnings and failures to be similar across subjects (regardless of sentence length) with a steep initial decline and a smoothing over the course of the sentence. These had the form of a curvilinear learning function that was *relative* to each subject's total sentence length, and not a function of absolute time (weeks) with an interlock. That is, the same general pattern recurred among those assigned to 7 months, 12 months and 18 months on the interlock. To model the shape of the distribution while retaining the majority of the statistical power of the sample, the full interlock sentence was converted to 100% for each individual regardless of sentence length.

In modeling, weekly data for each subject were expressed in terms of "relative time", such that either the 13th week of a 26-week sentence or the 36th week of a 72-week sentence both represented that subject's 50% completion in terms of relative time. Subjects with shorter or longer sentences than the median each had the representation of his or her absolute period stretched or condensed to relative time. A weighting system within each driver's data was used to prevent the less stable rates from weeks of low-volume driving from having a disproportionate impact on that subject's curve.

This learning function was modeled with relative time represented as a quadratic variable, i.e. $a + b_1(time) + b_2(time^2)$. This model was analyzed using weighted GLS regression, in which variables were selected via backward elimination (using probability $= 0.05$). Other factors assessed in the model were total length of sentence, site and interactions of site by relative time. There was one parameter each for the linear component and the squared (leveling-off) component. Warnings and failures as a proportion of all tests taken were then tested by a variety of regression models to search for the best fit of the data points. Figure 1 shows the calculated best fit regression line with plotted data points along the time base representing 0–100% of the time the interlock was in service. The "learning curves" were constructed by aggregating each subject's data on a weekly basis (i.e. one case per week per subject). The dependent measure was the proportion of all tests per week that resulted in a positive BAC greater than or equal to 0.02% (e.g. warnings and failures). Each subject–week was weighted by the ratio of the number of tests that week divided by the average number of tests in a week by that subject. Each subject's cases, over the entire interlock sentence, averaged out to a weight of one. To display the mean rates (the diamond-shaped data points in Fig. 1), weekly data for each subject were aggregated into increments of 5% of each subject's total

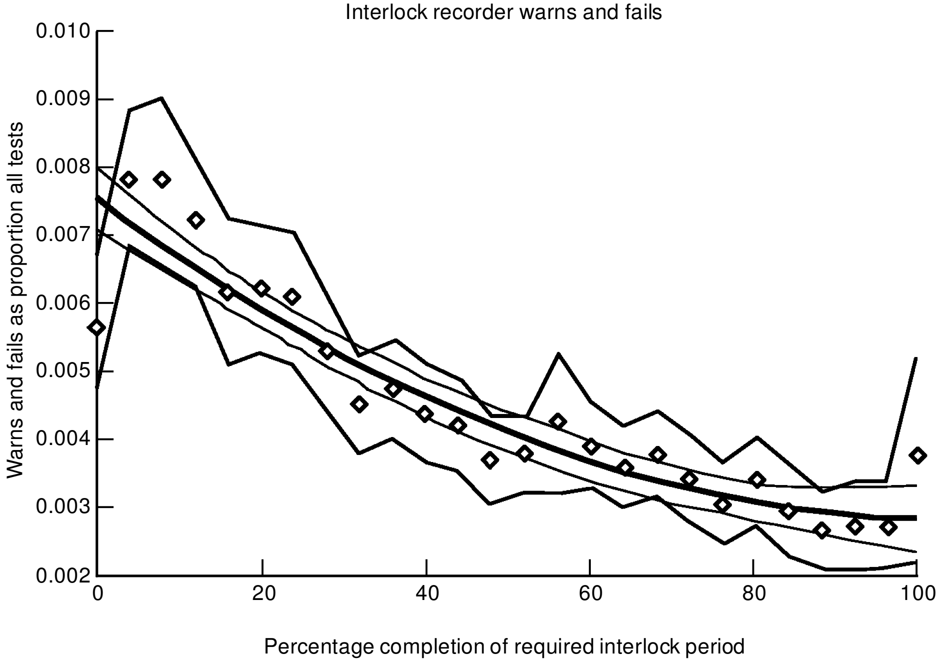

Figure 1. *Time line distribution of the relative proportion of tests that are warnings and failures as a function of the percentage of required interlock time completed. Regression line is shown ± 95% confidence interval. Weighted data points each represent test results during 5% of the interlock time (± 2 standard errors)*

sentence length. Therefore, each point represents anywhere from 1 week of data (for those on the interlock for 5 months) to 5 weeks of data (for those on the interlock for 2 years). In graphing mean rates across all subjects for these 5% intervals, each subject's 5% increments were weighted equally, so that subjects with longer exposure—more weeks per 5%—would not be disproportionately represented. Mean data points in Fig. 1 are shown (± 2 standard errors represented by the ragged interval around those means).

Transformations. At the person level, two transformations were made to the data to normalize and to facilitate data handling. Because the events of greatest interest occur at relatively low frequency (fewer than 1% of all BAC tests were a warning or a failure), a constant was multiplied to each case so that numbers were in a more manageable format. In addition, to eliminate skew, the natural log transformation was used to normalize the distributions.

Analyses. The BAC failures (failures by tests and failures by trips) were set as a dependent measure in a multiple analysis of variance (MANOVA). The question of interest was to determine if the subjects in the intervention site showed more evidence of learning and/or recorded fewer failures than did the subjects in the control site. City was set as one factor, along with other possible predictive measures. These other factors and covariates were tested in an interactive process to identify those that contribute variance in explaining fail BACs. When neither the main effect nor the second order interaction of a variable with the city factor was found to have a chance probability greater than about 0.3, it was eliminated. If either a main effect or an interaction with city was less than 0.3, it was retained in subsequent MANOVAs until the most predictive final set of variables was identified. Variables tested included city (e.g. intervention), dummy-coded age categories (< 21, 21–34, 35–49, 60 +), gender, race, education, income, married or living with someone versus living alone, children or none, prior DUIs, assigned time on interlock, quantity and frequency of drinking in past 28 days, expectation that the interlock will change behavior, full-time employment, whether the vehicle was used for work, initial AUDIT score and length of suspension before interlock.

Results

With 1309 offenders completing the program, the interlock was in the average vehicle for 8.2 months. First offenders on average were assigned to 7.8 ±1.4 months on interlock; multiple offenders received a mean 14.1 ± 9.0. The average vehicle was used on 80% of the days (198 of 248) that the interlock was installed. On days when the vehicle was used, the interlock required 12.8 ±5.6 total BAC tests plus retests. On average, there were 6.5 ± 3.8 engine starts during each day the vehicle was used, suggesting that the average trip required one subsequent test after starting the engine. There were no differences in the amount of vehicle use by city.

Learning to not drive after drinking

The data were structured to determine if there was evidence of learning to change drinking-and-driving tendencies while on the interlock. The BAC warnings and failures of interlock users who were assigned to at least 5 months are shown as combined performance data. The data suggest the proportion of warning and failure BACs does decline over time on the interlock. The *X*-axis of Fig. 1 shows the weekly BAC data rescaled as a percentage of the completed time on the interlock. Fitted curves for regression and 95% confidence intervals portray the proportion of all tests taken (*Y*-axis) that were warnings and failed results (i.e. all BAC tests ≥02) against the percentage of interlock time completed.

Relative time in the curvilinear function is represented as a quadratic variable [i.e. $a + b_1(time) + b_2(time^2)$] and the model was analyzed using weighted GLS regression, with variables selected via backward elimination (using probability = 0.05). Other factors assessed in the model included total length of sentence, the intervention variable of city difference (Calgary or Edmonton) and interactions of site by relative time (one parameter each for the linear component and the squared, or leveling-off, component). There was a city difference with Calgary, the intervention site, showing fewer warnings and failures ($t = 0.9$, $p < 0.003$).

The most significant factor in the model was length of time on the interlock ($t = 13.8$, partial correlation = 0.066), which was expected since those assigned to longer interlock periods were usually the more serious offenders with more DUI history. This factor was significant only as a predictor of the *overall* level of the subject's total learning curve from beginning to end but was not a factor in the steepness of decline or the rate of leveling-off. Also, the variation between subjects in overall rates of warning and failed BACs (e.g. level of each subject's learning curve across time) was more than double the amount of variation explained by within-subject change over time (based upon the partial correlations of factors included in the model).

The curve in Fig. 1 suggests that as experience with the interlock progresses, the offenders learn to accommodate to the interlock and presumably do so with an overall halving of the proportion of warnings and failures from the beginning to the end of the interlock time. Also, those in Calgary have fewer warnings and failures proportional to total breath tests.

It was also found that the total amount of driving (e.g. engine running time) was 9.8 median hours per week or 12.3 ± 10.2 (mean ± SD hours) with the interlock vehicle. There was a great deal of inter-subject variability in driving time. Those with interlocks installed for 12 or more months dropped in total driving time by about 20% from the beginning to the end of the interlock period. For the majority of subjects, however, the driving time did not change from the beginning to the end of their interlock time. When driving did decrease, there is no way of knowing if this finding reflects use of non-interlock vehicles (e.g. drinking-and-driving or other purposes) or a genuine behavior change in which planning and ride-sharing, for example, became a more active part of the behavioral repertoire of the offender.

MANOVA – predictors of failed BACs

The effect of the services intervention delivered in Calgary was assessed in a MANOVA in which failed BAC test results (failures by tests and failures by trips) were set as the dependent vector. Predictor variables were tested by the method described previously. Seventeen initial variables and 16 second-order interactions between the variable and the city were reduced to eight significant predictors, none of which were interactions. The most predictive factor was the main effect of the city. Calgary, site of the intervention, had fewer fails than Edmonton ($F = 19.79$, $df = 1083$, $p = 0.000$, $\eta^2 = 0.035$). The model predicted that those who benefited from the four-element intervention program in Calgary would be less likely to record warning and failure levels of BAC.

Self-reported drinking quantity (drinks per day) and the number of drinking days were the second and third strongest predictors of fail BACs ($F = 12.60$ and 8.07, respectively, $df = 1083$ and $\eta^2 = 0.023$ and 0.015, respectively). Additional predictors of recording more failures were living alone ($F = 6.84$), expecting the interlock to play a strong role in changing one's behavior ($F = 4.89$), more prior DUIs ($F = 5.82$), female gender ($F = 7.62$) and a longer time assigned to be on the interlock ($F = 3.39$). All these other additional main effects were significant but with η^2 ranging from only 0.012 to 0.006.

In addition to the intervention site predicting fewer failures, the Calgary sample with the services intervention also had significantly fewer procedural violations (failure to test within the allotted time) than the interlock group in Edmonton.

General topography of BAC warnings and failures at the event level

Since the interlock was expected to reduce drunk driving, it was of interest to see when the warning or the failure BAC test results occurred most commonly. The pattern of warnings and failures by the months of the year, days of the week and hours of the day were examined. By months, the proportion of warnings and failures were symmetrical around a June peak when warnings and failed violations represented 0.55% of all tests taken. In January, warnings and failures were 0.32% of all tests taken. The drop from June is mainly symmetrical with a slight rise in December, possibly reflecting holiday parties.

A familiar pattern is found when examining warnings and failures by the day of the week. In this case, Saturday and Sunday represent the days with the highest proportion of warnings and failures with a gradual upswing beginning after a Tuesday low. Sunday tests (beginning at midnight Saturday) are highest, with warnings or failures totaling 0.65% of all tests taken. Figure 2 shows these data divided into three intervals: the BAC warnings (0.02–0.039), the low end of the failure range (0.04–0.079) and the upper end of the failure range (0.08+). The ordinate is scaled as a percentage of all breath tests. The data represent a sampling base of 3 010 736 breath tests of the 1309 offenders.

Figure 3 shows the pattern in the BAC failures by time of day. This chart shows both the relative percentage of failures by hour ($Y2$ axis, striped bars) and the count or actual number of failures by hour ($Y1$ axis, solid bars). In this figure, only failed BACs are represented (e.g. no warnings), and these failed BACs are split into two ranges—greater than and less than 0.08%. The relative percentage of failures by hour, much like the percentage of failures by day of the week, reflect the summary patterns found in 20 years of FARS (Fatality Analysis Reporting System) data (Greenfeld, 1998). The hours of highest proportional driving risk (that are being blocked by the interlock) peak at 2 a.m. The figure shows only failures; however, if warnings were included, the relative percentage at these hours is 1.2% of all tests taken during those hours.

The greatest *number* of attempts to start the vehicle with failure level BACs occurred between 7 a.m. and 8 a.m. This finding often served a useful purpose for services intervention staff during discussion periods. From the morning peak, the number of failures declined slowly during the day to the lowest frequency count between 4 a.m. and 5 a.m. Within 3 hours of the low, the highest frequencies occurred as the day got under way.

Discussion

These interlock data, with a median of over 2000 breath tests per driver, provide a detailed record of drinking-and-driving behavior among 1309 drivers convicted of DUI offenses. The data reported here represent the first stage of analysis in a two-stage model to investigate whether a human services intervention provided to interlock-using DUI offenders can lower their long-term risk of DUI recidivism. The model for the larger study assumes that having a higher proportion of interlock BAC warning and failure

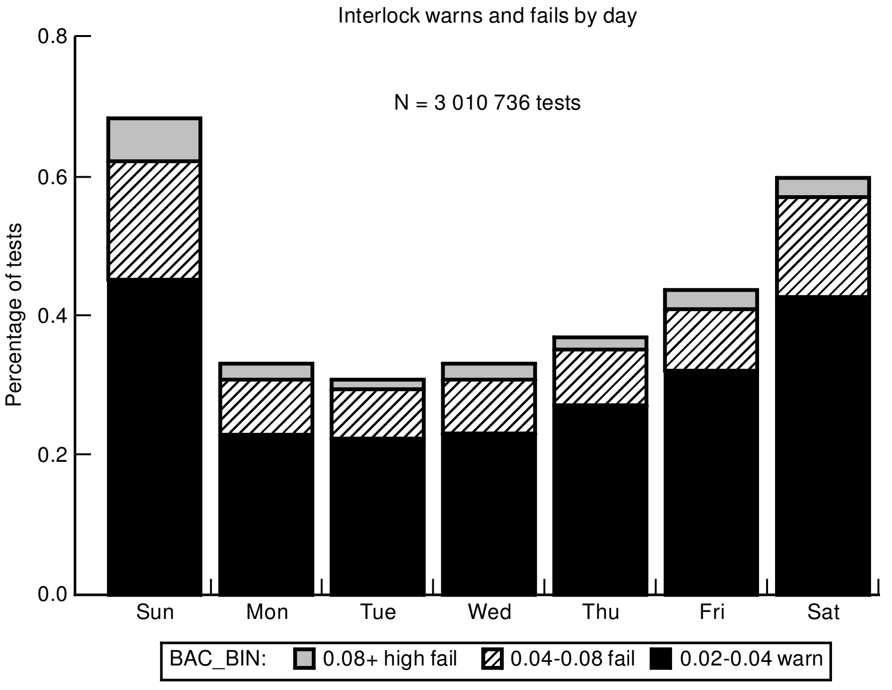

Figure 2. *Stacked distribution of interlock BAC warning (bottom), low faiure (mid), and high failure (top) test results by day of week. Ordinate is scaled as relative percentage of all tests taken in each day.*

events will be predictive of later DUI recidivism, but that those offenders receiving the services intervention in Calgary will have a lower rate of recidivism relative to Edmonton. In the short term, however, the model anticipated that the DUI outcome would be preceded by a lower proportion of interlock warnings and failures among those receiving the intervention (Calgary) relative to those not receiving it (Edmonton). While too few recidivism events have occurred to test the second stage of the model, the results reported here suggest that the first stage has occurred as predicted. Interlock offenders in Calgary are less likely to have procedural violations or record failure-level BACs, even after controlling for demographic, drinking and driver record covariates.

In addition, the descriptive data serve to characterize the timing of BAC warning and failure violations by those drivers who are known to present a higher risk to the driving public. The finding that weekends are proportionally a much higher period of risk will surprise no one. Even on the highest risk days, the rates of failed and warning BACs together are usually below 1% of all tests taken; however, to some extent, these low rates may underscore the extent of behavior change imposed by the interlock. Also, finding that failure violations occur with the highest frequency from 7 a.m. to 8 a.m. makes sense, considering that this is when most vehicles are first started for the day.

There are four possible explanations for this finding, two due to non-beverage alcohol and two due to beverage alcohol. Some of this effect may be due to mouth alcohol from morning mouthwash or certain foods. It is true that mouthwash is more commonly used in the morning than at other times of the day. Mouthwash used within a few minutes of getting into the vehicle could cause a warning or a failure violation. Typically, however, any mouth alcohol evaporates fully within 5 to 10 minutes. There is a small amount of alcohol in many foods, but this cannot as easily be explained as a morning-only phenomenon since people eat throughout the day. Alternatively, two possible sources of beverage alcohol may also explain this finding.

Some proportion of the interlock users may have a degree of alcohol dependence that leads

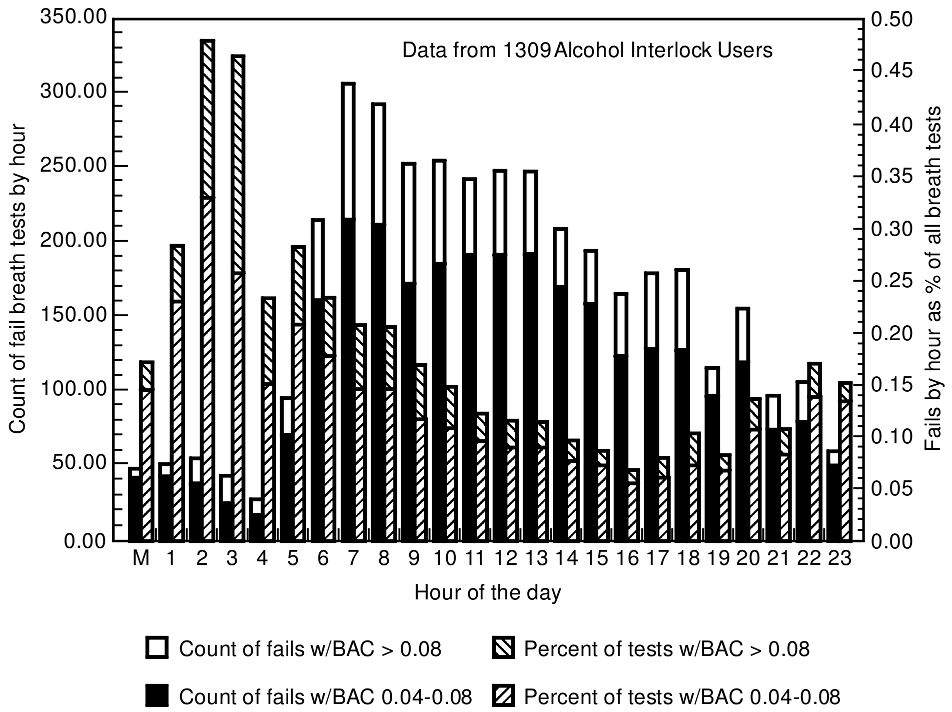

Figure 3. *Dual Y-axis chart showing actual frequency counts per hour and relative percentage of failed tests per hour. The Y1-axis on left references the dark solid bars (number of low failures with BAC 0 .04–0.08) and the light solid bars (number of high failures with BAC > 0.08). The Y2-axis on the right references ▨ (percentage of low failures each hour with BAC 0.04–0.08) and ▧ (percentage of high failures each hour with BAC ≥ 0.08).*

some to have a morning drink. One or more drinks could either prevent a start due to high BAC or due to mouth alcohol. Another explanation, the most likely, is that unmetabolized alcohol from the previous night of drinking has not yet cleared by the time the driver leaves for work in the morning. Convention suggests that an average person metabolizes slightly less than one drink per hour, somewhat more for heavier drinkers with greater tolerance. The average person with a BAC of 0.17 (the average BAC of arrested drunk drivers) who stops drinking just before a midnight bedtime would still not be capable of getting a pass result from the interlock 6 or 7 hours later. Comments from interlock customers who have expressed surprise and annoyance to the case managers suggest that this is a likely explanation. The user initially assumes that the equipment is malfunctioning. This serves as some illustration of how the interlock helps to educate individuals with drinking problems and why there may be value to having case managers present at the interlock centers to help make sense of these experiences and to make use of these "teachable moments".

The site or city was a significant predictor of failed BACs, with Calgary offenders recording fewer than Edmonton and also showing fewer procedural violations. After examining the main and interactive effects of 16 additional subject variables, none displaced the city as an explanation nor interacted with city in a way that suggested an explanation other than the intervention difference between the two cities. This could reflect a simple difference in the proclivity to do more drinking and driving for some reason other than those examined in the MANOVA. However, considerable effort was directed in Calgary to inform and support its offenders into adopting life-style changes that reduce harm through separation of their drinking and driving behaviors. There may be variables, which were not measured in the study nor represented in the model, that explain the difference better. However, the consistent finding that the city variable, even while controlling for multiple covariates, significantly explained a small proportion of the failed tests supports the hypothesis of the intervention model. The favored interpretation, albeit still tentative, is that the human services adjunctive activities are successfully educating both the lighter and heavier drinking offenders to use the interlock more responsibly.

The general topography of warnings and failures is very similar to the known high-risk driving times for alcohol-involved crashes: weekends and the hours between 10 p.m. and 2 a.m. This stands as evidence that to some extent the interlock is accomplishing its intended purpose. However, since there are still only a small percentage of alcohol offenders actually using an interlock, and those that do are generally well-employed and capable of remaining DUI-free for an extended period, the interlock cannot be expected to have a societal-level impact in the near future. There are some clear unknowns. None the less, it is interesting to consider whether such a societal-level impact could be found if the devices were more widely used.

From the recidivism evidence in driving records, we know that following interlock removal the rate of re-offending will accelerate and offenders will revert to drinking-and-driving patterns similar to those of non-interlock control samples. It may be that the prudent policy decision for jurisdictions that place individuals on an interlock will be to require the interlock for extended periods when objective evidence can be found suggesting that an individual falls into the difficult-to-change population. The evidence here suggests that an examination of prior offenses and current drinking can form the beginning of a basis for drawing those inferences. The learning curves show that, in the aggregate, the interlock offenders will adjust their behavior over time and will record fewer warnings and failures. It may be that the solution to the post-interlock recidivism problem will be found in more careful selection of which offenders are given a POST-interlock experience.

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References

Beitel, G. A., Sharp, M. C. & Glauz, W. D. (1975) Probability of arrest while driving under the influence of alcohol, *Journal of Studies on Alcohol*, 36, 109–115.

Bien, T. H., Miller, W. R. & Tonigan, J. S. (1993) Brief interventions for alcohol problems. A review, *Addiction*, 88, 315–336.

Compton, R. P. (1988) *Potential for Application of Ignition Interlock Devices toPprohibit Operation of Motor Vehicles by Intoxicated Individuals*, technical report no. DOT HS 807 281 (Washington, DC, National Highway Traffic Safety Administration (NHTSA)).

Frank, J. (1988) *Further Laboratory Testing of In-vehicle Alcohol Test Devices*, technical report no. DOT HS 807 333 (Washington, DC, National Highway Traffic Safety Administration (NHTSA)).

Greenfeld, L. A. (1998) *Alcohol and Crime: an analysis of national data on the prevalence of alcohol involvement in crime*, technical report no. NCJ 168632 (Washington, DC, US Department of Justice, Office of Justice Programs).

Marques, P. R. & Voas, R. B. (1993) Setting performance priorities for breath alcohol ignition interlock devices, *Journal of Traffic Medicine*, 21, 127–132.

Marques, P. R. & Voas, R. B. (1995) Case-managed alcohol interlock programs: a bridge between the criminal and health systems, *Journal of Traffic Medicine*, 23, 75–85.

Marques, P. R., Voas, R. B. & Hodgins, D. (1998) Vehicle interlock programs: protecting the community against the drunk driver, *Journal of Prevention and Intervention in the Community*, 17, 33–46.

National Highway Traffic Safety Administration (NHTSA) (1992) Model specifications for breath alcohol ignition interlock devices (BAIIDs), 57 *Federal Register*, 67, 11772–11787.

Prochaska, J. O., DiClemente, C. C. & Norcross, J. C. (1992) In search of how people change: applications to the addictive behaviors, *American Psychologist*, 47, 1102–1114.

Project MATCH Research Group (1997) Matching alcoholism treatments to client heterogeneity: Project MATCH posttreatment drinking outcomes, *Journal of Studies on Alcohol*, 58, 7–29.

Voas, R. B. & Hause, J. M. (1987) Deterring the drinking driver: the Stockholm experience, *Accident Analysis & Prevention*, 19, 81–90.

Voas, R. B. & Marques, P. R. (1992). *Alcohol Ignition Interlock Service Support*, technical report no. DOT HS 807–923 (Washington, DC, National Highway Traffic Safety Administration).

Voas, R. B., Marques, P. R., Tippetts, A. S. & Bierness, D. J. (1999) The Alberta Interlock Program: the evaluation of a province-wide program on DUI recidivism, *Addiction*, 94, 1849–1859.