U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

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DOT HS 808 654

September 1997

Final Report

The Detection of DWI at BACs Below 0.10

THE DETECTION OF DWI AT BACS BELOW 0.10

FINAL REPORT

Submitted to:
U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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12 September 1997

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 808 654		

4. Title and Subtitle	5. Report Date
The Detection of DWI at BACs Below 0.10	September 1997

7. Author(s)	6. Performing Organization Code
Jack W. Stuster, PhD, CPE	n/a
	8. Performing Organization Report No.
	n/a

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Anacapa Sciences, Inc. P.O. Box 519 Santa Barbara, CA 93102	11. Contract or Grant No. DTNH22-93-C-05187

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Highway Traffic Safety Administration 400 Seventh Street, SW Washington, D.C. 20590	Final Report

15. Supplemental Notes	14. Sponsoring Agency Code
James F. Frank, PhD was the Contracting Officer's Technical Represenative (COTR) for this project.	

16. Abstract

The objective of the research described in this report has been to develop training materials to assist law enforcement officers in the accurate detection of motorists who are driving while impaired (DWI) at the 0.08 BAC level. The project was composed of 13 major project tasks, conducted in two phases. During Phase I, a work plan was developed to guide all subsequent tasks, a comprehensive review of the low BAC literature was performed, interviews were conducted with DWI experts from across the United States, a data base of low BAC arrest reports was assembled, and two field studies were conducted (the ride-along and preliminary field studies). The analysis of archival, interview, arrest report, and field data collected by observers led to the identification of 34 driving cues and 10 post-stop cues for further evaluation.

Five law enforcement agencies participated in the second of the field studies, known as the preliminary field study, by recording the driving and post-stop cues observed for all enforcement stops, regardless of the disposition of the stop; the BACs of all drivers who exhibited objective signs of having consumed alcohol also were recorded. By collecting data about all enforcement stops that were made, it was possible to calculate the proportions of the stops in which specific cues were found in association with various BAC levels. All archival, interview, and field study data were analyzed, and recommendations for draft training materials were developed, as the final Phase I task.

A draft DWI detection guide, training booklet, and training video were developed based on the results of the preliminary field study; the materials included 24 driving and 10 post-stop cues. Law enforcement agencies representing 11 of the 15 states with 0.08 BAC limits for DWI were recruited to participate in the Phase II validation study. Participating officers reviewed the video and printed training materials, then completed a data collection form following every enforcement stop made, regardless of the disposition of the stop; the same form was used as in the preliminary field study, conducted previously. The validation study data were analyzed and a final version of the training materials, and this technical report, were prepared as the final Phase II project tasks.

The results of the preliminary field study largely supported the 20 cues on the original NHTSA (0.10) DWI detection guide at the 0.08 BAC level, but found no cues that reliably predicted BACs below 0.08. The results of the Phase II validation study further confirmed the key cues that were contained in the original NHTSA guide, a few additional driving cues, and the 10 post-stop cues. The driving cues were presented in functional categories in both the printed materials and the training video: Problems Maintaining Proper Lane Position, Speed and Braking Problems, Vigilance Problems, and Judgment Problems.

17. Key Words	18. Distribution Statement
DWI, DUI, detection, alcohol, law enforcement, highway safety	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT 1700.7

EXECUTIVE SUMMARY

This report documents the research activities and presents the results of a study conducted for the National Highway Traffic Safety Administration (NHTSA) to identify driving and other behavioral cues that are associated with blood alcohol concentrations (BACs) below the 0.10 level. The ultimate objective of the research has been to develop training materials to assist law enforcement officers in the accurate detection of motorists who are driving while impaired (DWI).

DESCRIPTION OF THE RESEARCH

The research and development project was composed of 13 major project tasks, conducted in two phases. During Phase I, a work plan was developed to guide all subsequent tasks, a comprehensive review of the low BAC literature was performed, interviews were conducted with DWI experts from across the United States, a data base of low BAC arrest reports was assembled, and two field studies were conducted. The analysis of archival, interview, arrest report, and field data collected by observers led to the identification of 34 driving cues and 10 post-stop cues for further evaluation.

Five law enforcement agencies participated in the second of the field studies, known as the preliminary field study, by recording the driving and post-stop cues observed for all enforcement stops, regardless of the disposition of the stop; the BACs of all drivers who exhibited objective signs of having consumed alcohol also were recorded. By collecting data about all enforcement stops that were made, it was possible to calculate the proportions of the stops in which specific cues were found in association with various BAC levels. All archival, interview, and field study data were analyzed, and recommendations for draft training materials were developed, as the final Phase I task.

A draft DWI detection guide, training booklet, and training video were developed based on the results of the preliminary field study; the materials included 24 driving and 10 post-stop cues. Law enforcement agencies representing 11 of the 15 states with 0.08 BAC limits for DWI were recruited to participate in the Phase II validation study. Participating officers reviewed the video and printed training materials, then completed a data collection form following every enforcement stop made, regardless of the disposition of the stop; the same form was used as in the preliminary field study, conducted previously. The validation study data were analyzed and a final version of the training materials, and this technical report, were prepared as the final Phase II project tasks.

Data were collected during more than 12,000 enforcement stops during this research project. The stops were made by several hundred participating officers, representing more than 50 law enforcement agencies from across the United States.

RESULTS

The results of the preliminary field study largely supported the 20 cues at the 0.08 BAC level that were presented on the original NHTSA DWI detection guide, which was developed in 1980 for the 0.10 BAC level. However, no cues were found that reliably predicted BACs below 0.08; that is, the cues that are key predictors of DWI at the 0.08 BAC level failed to emerge with useful probabilities at BAC levels below 0.08. The results of the Phase II validation study further confirmed the key cues that were contained in the original NHTSA guide, a few additional driving cues, and the 10 post-stop cues. The DWI driving cues were presented in functional categories in both the printed materials and the training video: Problems Maintaining Proper Lane Position, Speed and Braking Problems, Vigilance Problems, and Judgment Problems.

Slight modifications were made to the training materials, based on the results of the Phase II validation study. The final version of the DWI detection guide is reproduced below.

DWI DETECTION GUIDE

Weaving plus any other cue: p = at least .65
Any two cues: p = at least .50

PROBLEMS MAINTAINING PROPER LANE POSITION

- Weaving
- Weaving across lane lines **p=.50-.75**
- Straddling a lane line
- Swerving
- Turning with a wide radius
- Drifting
- Almost striking a vehicle or other object

SPEED AND BRAKING PROBLEMS p=.45-.70

- Stopping problems (too far, too short, or too jerky)
- Accelerating or decelerating for no apparent reason
- Varying speed
- Slow speed (10+ mph under limit)

VIGILANCE PROBLEMS p=.55-.65

- Driving in opposing lanes or wrong way on one-way
- Slow response to traffic signals
- Slow or failure to respond to officer's signals
- Stopping in lane for no apparent reason
- Driving without headlights at night*
- Failure to signal or signal inconsistent with action*

JUDGMENT PROBLEMS p=.35-.90

- Following too closely
- Improper or unsafe lane change
- Illegal or improper turn (too fast, jerky, sharp. etc.)
- Driving on other than the designated roadway
- Stopping inappropriately in response to officer
- Inappropriate or unusual behavior (throwing, arguing, etc.)
- Appearing to be impaired

POST STOP CUES p≥ .85

- Difficulty with motor vehicle controls
- Difficulty exiting the vehicle
- Fumbling with driver's license or registration
- Repeating questions or comments
- Swaying, unsteady, or balance problems
- Leaning on the vehicle or other object
- Slurred speech
- Slow to respond to officer/officer must repeat
- Provides incorrect information, changes answers
- Odor of alcoholic beverage from the driver

* p≥ .50 when combined with any other cue:
- Driving without headlights at night
- Failure to signal or signal inconsistent with action

The probability of detecting DWI by random traffic enforcement stops at night has been found to be about three percent (.03).

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Many individuals and organizations contributed to the research that is described in this report. Anacapa Sciences, Inc., and the National Highway Traffic Safety Administration (NHTSA) greatly appreciate the cooperation of all those who participated in the study. Many of those individuals and organizations are acknowledged in Appendix A of this report, but hundreds of additional law enforcement personnel, too numerous to name, also participated, primarily during the preliminary and validation field studies. All of the individuals and organizations who participated in the study contributed to the development of these DWI detection training materials.

INTRODUCTION

This report documents the research activities and presents the results of a study conducted for the National Highway Traffic Safety Administration (NHTSA) to identify driving and other behavioral cues associated with blood alcohol concentrations (BACs) below the 0.10 level. The ultimate objective of the research has been to develop training materials to assist law enforcement officers in the accurate detection of motorists who are driving while impaired (DWI).

STATEMENT OF THE PROBLEM

Nearly 1.4 million people have died in traffic crashes in the United States since 1966, the year of the National Traffic and Motor Vehicle Safety Act (which led to the creation of NHTSA in 1970). During the late 1960s and early 1970s more than 50,000 people lost their lives each year on our nation's public roads. Traffic safety has improved considerably since that time: the annual death toll has declined to about 40,000, even though the numbers of drivers, vehicles, and miles driven have all greatly increased. The dramatic improvements in traffic safety are reflected in the change in fatality rate per 100 million vehicle miles traveled: The fatality rate fell from 5.5 in 1966 to 1.7 in 1995 (FARS--Fatal Analysis Reporting System--95), a 69 percent improvement. Figure 1 illustrates this important trend. When miles traveled are considered, the likelihood of being killed in traffic in 1966 was more than three times what it is today.

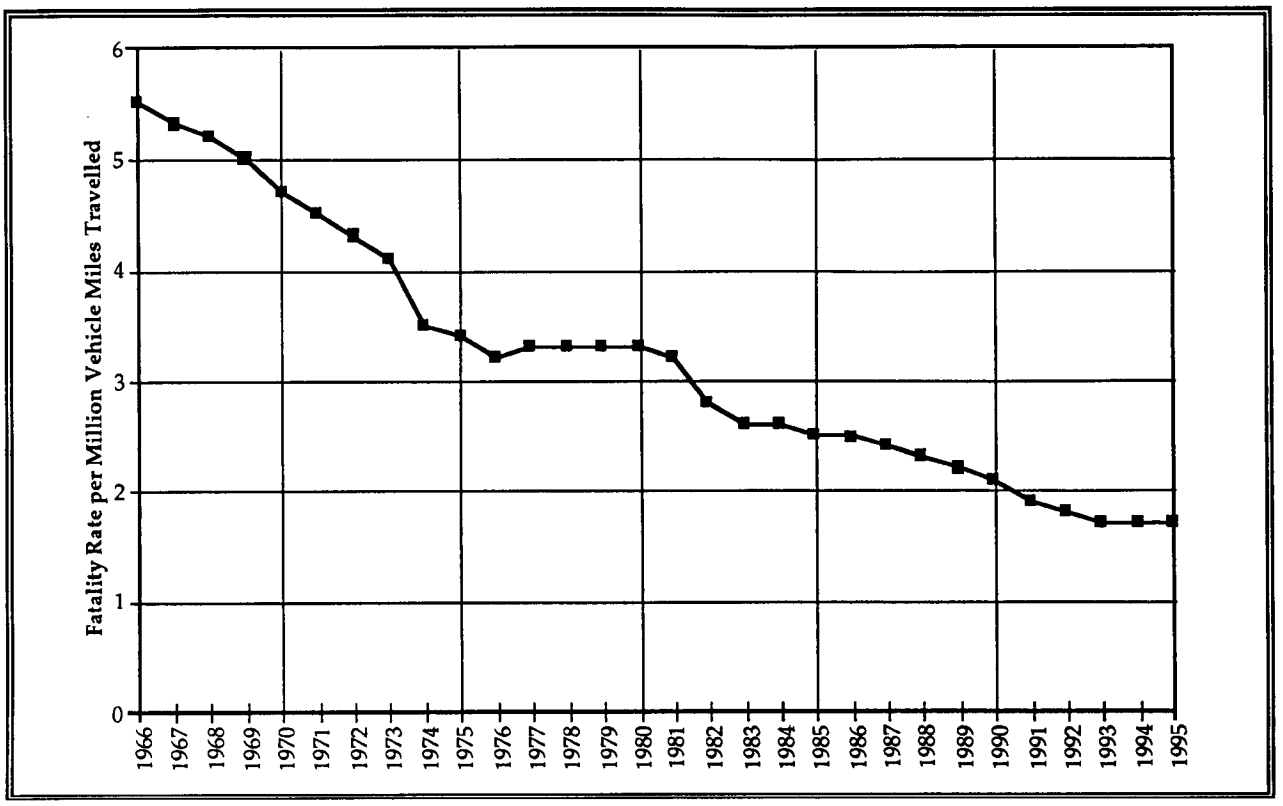

Figure 1. Fatality rates per million miles travelled in the U.S.

An emphasis on DWI enforcement since 1980 has been a factor in the significant improvement in traffic safety, as represented by declining fatal and alcohol-involved crash rates. Previous NHTSA-sponsored research contributed substantially to the improved condition, in part, by providing patrol officers with useful and scientifically valid information and training materials concerning the behaviors that are most predictive of impairment. In particular, NHTSA sponsored research that led to the development of a DWI detection guide that listed 20 driving cues and the probabilities that a driver exhibiting a cue would have a BAC of at least 0.10 (Harris et al., 1980). A later NHTSA study led to the development of a motorcycle DWI detection guide (Stuster, 1993). NHTSA's DWI training materials, based on the results of these studies, have influenced the current generation of law enforcement officers in the U.S. by providing a systematic and defensible approach to DWI detection.

Clearly, continued enforcement of DWI laws will be a key to further improvements in measures of traffic safety. But are the behavioral cues and the associated probabilties that were developed nearly 20 years ago still valid? More important, 13 states have implemented 0.08 limits for DWI since the original cue guide was developed, and more states are likely to follow. Are there behaviors that can be used by officers to accurately identify motorists who are driving while impaired at BAC levels below 0.10? Answers to these questions are the objectives of the research described in this report.

BACKGROUND

The field detection of DWI by law enforcement officers is a problem of subtlety and complexity. As a consequence of observing and interpreting one or more operator behaviors, a patrol officer typically assesses the likelihood that a driver is DWI or otherwise impaired. This assessment then is combined with other information to reach an enforcement decision--to stop the vehicle or to continue with the patrol. Either decision might be incorrect. A decision to stop might result in the apprehension of a sober motorist (a false detection); a decision to permit the motorist to continue on his or her way might result in an undetected DWI--perhaps even a traffic collision that could have been prevented by police intervention.

An *ideal* cue always would lead to a correct decision. When an ideal cue is present, the probability of DWI detection is 1 (a certainty); when the cue is not present, the probability of DWI detection is 0 (also a certainty). Conversely, when nighttime drivers are tested randomly for blood alcohol content (BAC), the probability of detection (BAC $\geq$.08) might only be about .04, while the probability of false detection would be .96. Between the certainty of the hypothetical ideal cue and the probabilities of random detection, an officer's decision to apprehend involves the observation and interpretation of visual cues and other information, and the subsequent trade-off between the value of a correct detection and the cost of a false detection. Although the factors involved in the trade-off and the post-detection apprehension process are outside the scope of the current study, they establish requirements and criteria for DWI detection. In short, the detection process should employ visual cues that occur

frequently with DWI at the lower statutory limits, are most capable of discriminating between DWI and sober operation, are simple to understand, and are easy to use by patrol officers.

Operation of a motor vehicle is a multi-dimensional task; the operator must divide his or her attention between maintaining proper lane position and speed, while monitoring the environment for other vehicles' movements, traffic lights, and signs. When operator attention is divided, reaction time degrades as BAC is increased. Alcohol slows the central processing of visual information; the operator's eyes fixate for longer periods as BAC increases, apparently reducing the stimuli perceived per unit of time. This ultimately results in the "gazing" effect characteristic of higher BACs (Moskowitz, et al., 1976; Moskowitz, 1973), and contributes to performance degradation. This physiological process is translated into several observable driving cues. Other driving cues result from alcohol's effect on judgment and decision-making capabilities.

It was considered to be essential to the current research to develop a comprehensive inventory of cues that have been used by officers to detect DWI motorists at lower BAC limits. It was assumed that a comprehensive list would help to ensure that the subtleties and subjectivities of field detection of DWI at lower BACs are identified, understood, and rephrased for later quantitative analysis. The current study would, in this way, build upon the method employed during the original NHTSA DWI detection study to develop a set of scientifically valid behavioral cues that could be used by law enforcement officers for many years to come.

ORGANIZATION OF THIS REPORT

The research documented in this report was conducted in two phases between 1993 and 1997. Research tasks included conducting a large number of personal interviews with DWI experts, performing a comprehensive literature review, and developing and analyzing a data base of 1,000 low BAC arrest reports. Those preliminary tasks were followed by three separate field studies in which hundreds of law enforcement personnel from across the U.S. participated: 1) Ride-along field study, 2) Preliminary field study, and 3) Validation study. During these field studies, data were collected for more than 12,000 traffic enforcement stops. The project also included the development of printed training materials and a training video.

The large number of research tasks, with each one affecting subsequent tasks, suggests a chronological presentation as most appropriate. For this reason, descriptions of project activities and the results of the many research tasks performed during the study are presented in separate sections corresponding to the two major project phases. Organizing the report chronologically will permit readers to follow the sequence of steps that led to the development of NHTSA's new DWI detection guide and the associated training booklet and video.

PHASE I

The purpose of Phase I of the project was to conduct a series of preliminary research tasks, including two field studies, that would lead to recommendations to guide the development of a new DWI detection guide and training program. The training materials then would be developed and evaluated during Phase II. Phase I comprised the seven major project tasks illustrated in Figure 2, and described in the following pages.

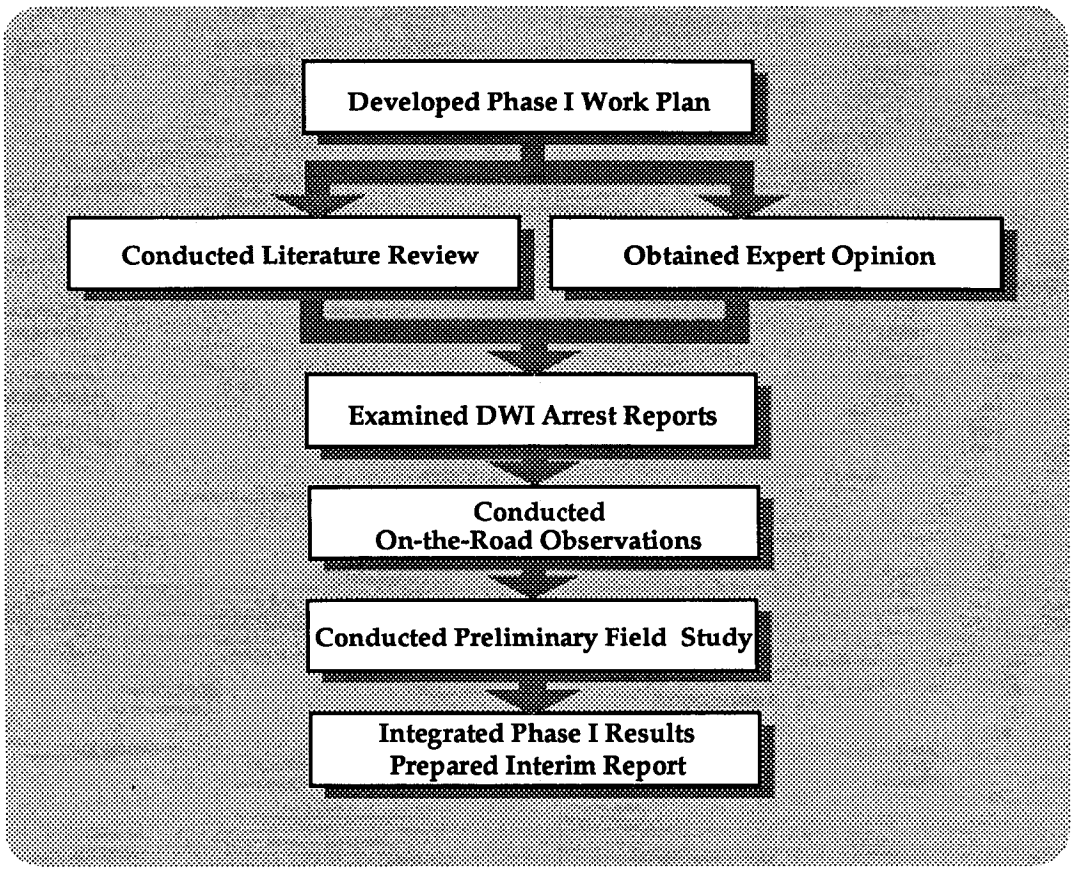

Figure 2. Phase I project tasks.

TASK 1: DEVELOPED PHASE I WORK PLAN

The project began with the development of a Work Plan to guide the conduct of all Phase I research activities and subsequent analyses. The primary purposes of the Work Plan were to, 1) establish all data collection objectives, and to the extent possible, specify protocols, and procedures; 2) develop site-selection criteria for participating in the several tasks that would require law enforcement cooperation; 3) identify critical research issues and special NHTSA concerns; and, 4) develop the data evaluation plan. In short, the purpose of the Work Plan was to serve as a road map to guide the project team throughout Phase I of the study.

TASK 2: REVIEWED LOW BAC LITERATURE

A literature review was performed to determine if additional methods or cues had been developed or data collected concerning DWI cues since the original Anacapa research on this subject. The focus of the inquiry was on behaviors associated with lower BACs (i.e., 0.08, 0.04, and 0.02), but attempts also were made to identify any additional or "new" cues that might have emerged at any BAC level.

The project team reviewed all previous DWI research that Anacapa Sciences has conducted, and performed a comprehensive search of the highway safety literature to identify and review materials relevant to behavioral indicators of impairment at low BACs. Review of journals and other library sources was augmented by systematic searches of computerized databases. The NHTSA Literature Review, *Effects of Low Doses of Alcohol on Driving-related Skills: A Review of the Evidence,* by Moskowitz and Robinson (1988) served as a starting point for the performance of this project subtask. Moskowitz and Robbins included 177 publications in their analytical review and found evidence that several key driving abilities are impaired at relatively low BAC levels. The abilities that appeared from the Moskowitz and Robinson review to be the most likely to be affected by lower BAC levels were complex reaction time, tracking, divided attention, and information processing.

Information gathered during the literature search was compiled, evaluated, and submitted to NHTSA for review. The results of the literature review are presented as Appendix B to this report.

TASK 3: OBTAINED EXPERT OPINION

A series of open-ended interviews was conducted with law enforcement officers experienced in the detection of DWI motorists. The purpose of the interviews was to identify the full range of behavioral cues and procedures that are used to detect driving while impaired. Again, the focus of interviews was on behaviors associated with a 0.08 BAC level, but expert opinions about cues relevant to all BAC levels were requested and recorded. Interviews were conducted with a large sample of officers from across the United States to ensure coverage of jurisdictions that encompass all driving conditions (i.e., surface streets, interstate highways, freeways, urban and rural environments). Also, when selecting experts to be interviewed, an emphasis was placed on those states that have experience enforcing BAC limits 0.10, to ensure capturing law enforcement experience at those levels.

It is important to note that NHTSA directed Anacapa Sciences to include behaviors in this review that might be exhibited by an impaired driver *following* an enforcement stop (i.e., behaviors that are not necessarily driving behaviors, but might be indicative of the BAC levels in question). Neither of the previous NHTSA DWI detection guides included post-stop cues.

Anacapa Sciences, Inc., was assisted in the performance of the personal interviews by the Police Executive Research Forum (PERF) and Dunlap and Associates. Interviews were guided by a protocol, but open-ended responses were encouraged. A

list of the expert law enforcement personnel who were interviewed is presented in Appendix A.

Nearly 200 separate behaviors were reported by the law enforcement experts to have been found in association with BAC levels below 0.10. Some officers also provided information about behaviors that are characteristic of young drinking drivers under 21. The interview data were prepared in tabular form, with the driver behaviors listed by BAC level; multiple reports of a cue were indicated by check marks. The results of the interviews with expert patrol officers are presented in Appendix C.

TASK 4: EXAMINED DWI ARREST REPORTS

The primary purpose for conducting archival research among police arrest records was to develop quantitative data concerning the use of visual cues that are used by officers to identify DWI motorists (as recorded in the narrative section of the reports). A further objective was to collect data that might suggest relationships between specific cues or cue types and BAC levels.

A list of candidate law enforcement agencies was prepared and submitted to the NHTSA Contracting Officer's Technical Representative (COTR) for approval; again, the focus was on jurisdictions that enforce lower BAC limits. Upon NHTSA approval, requests were made of the law enforcement agencies for copies of the narrative sections of DWI arrest reports, with an emphasis on BACs below 0.10. Nine law enforcement agencies participated in this project task by providing access to these records, or copies of the actual reports. The agencies listed in Table 1 contributed a total of nearly 1,000 low-BAC arrest reports.

TABLE 1
LAW ENFORCEMENT AGENCIES THAT CONTRIBUTED
TO THE LOW BAC DWI ARREST REPORT DATA BASE

Agency
California Highway Patrol
Los Angeles (CA) Police Department
Albuquerque (NM) Police Department
Oregon State Police
Bangor (ME) Police Department
Washington County (VT) Sheriff's Department
Santa Barbara (CA) Police Department
New Hampshire State Police
Kansas City (MO) Police Department

A data collection form was developed that included the inventory of driving and post-stop behaviors that had been identified during the literature review and interviews with expert patrol officers. The narrative sections of the arrest reports then were reviewed to identify the behaviors that motivated the enforcement stops; the records

were coded for driving and post-stop behaviors. A data collection form was completed for each arrest record that included the behaviors and associated BAC. Additional cues were added to the data collection form to account for officers' narrative descriptions. Totals of 169 separate driving cues and 50 post-stop behaviors are represented in the low BAC arrest report data base. The results of the review and evaluation of arrest reports are presented in Appendix D.

TASK 5: CONDUCTED ON-THE-ROAD OBSERVATIONS WITH POLICE

A data collection form for the Phase I ride-along observations was developed based on the interview responses, literature review results, and arrest report data base. Infrequent cues identified during the previous research tasks were either eliminated or combined with other similar behaviors, resulting in totals of 91 driving and 41 post-stop cues. The data collection form for the ride-along study was designed to assist project staff in the real-time, systematic recording of relevant information concerning DWI cues, procedures, and detection strategies.

Systematic field observations were planned of expert officers in the performance of DWI patrol duties. The purpose of these observations was to record officers' observations of which cues they associated with possible impaired driving, especially at lower BACs. A further objective, and one that distinguishes this research from previous NHTSA DWI cue studies, was the collection of breath test data from all motorists stopped during the ride-along observations who exhibited any indication of alcohol consumption, regardless of the disposition of the stop (i.e., warning, citation, or DWI arrest).

The Los Angeles Police Department's Valley Traffic Division participated in this important project task by allowing data collection during 81 special DWI patrols over a nine-week period (i.e., three patrols each Thursday, Friday, and Saturday nights). Expert officers were accompanied by trained research assistants who recorded the officers' verbalized observations of driver behavior on data collection forms. Voluntary breath tests were requested of all motorists stopped. Breath tests were obtained using CMI SD-2 hand-held digital breath testing devices. Officers and research assistants were provided training in the study procedures prior to implementation of the special patrols.

Officers made 365 enforcement stops during these special patrols, resulting in 132 DWI arrests. The average BAC of those arrested for DWI was 0.145, with the BACs of those arrested ranging from a low of 0.04 to a high of 0.30; 144 of the 365 drivers tested had BACs of zero. Figure 3 illustrates the distribution of BACs greater than zero. Table 2 summarizes the distribution of all BACs obtained during this Phase I field study.

The average age of the motorists stopped during the ride-along field study was 32 years; driver ages ranged from 15 to 74. The average age of those arrested for DWI was 32.4 years, with the ages of DWI drivers ranging from 18 to 74 years old. Figure 4 presents the distribution of ages of the 132 DWI drivers.

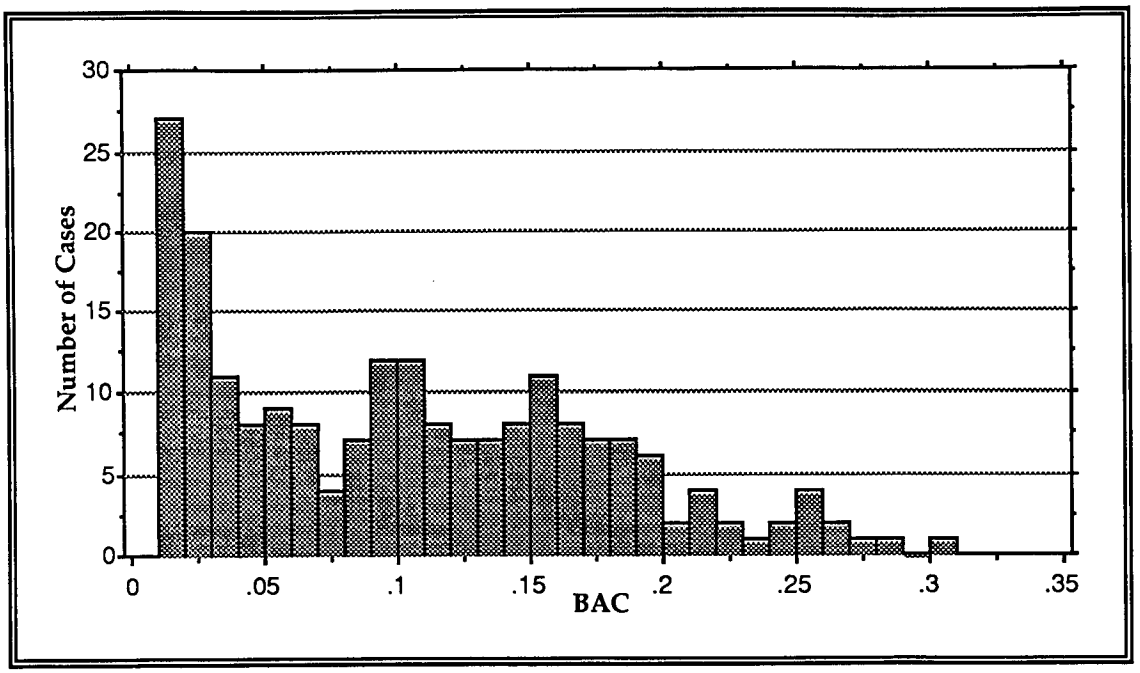

Figure 3. Distribution of BACs greater than zero in the Phase I ride-along study (n=221).

TABLE 2
SUMMARY OF BACs OBTAINED
FROM DRIVERS STOPPED DURING THE PHASE I RIDE-ALONG STUDY

BAC Range	Number of Cases	Percent of Drivers Stopped
zero	144	40
0.01-0.03	58	16
0.04-0.07	29	8
0.08-0.09	19	5
0.10-0.14	42	12
0.15-0.19	39	11
0.20+	20	6
Refused	14	4
TOTAL	365	

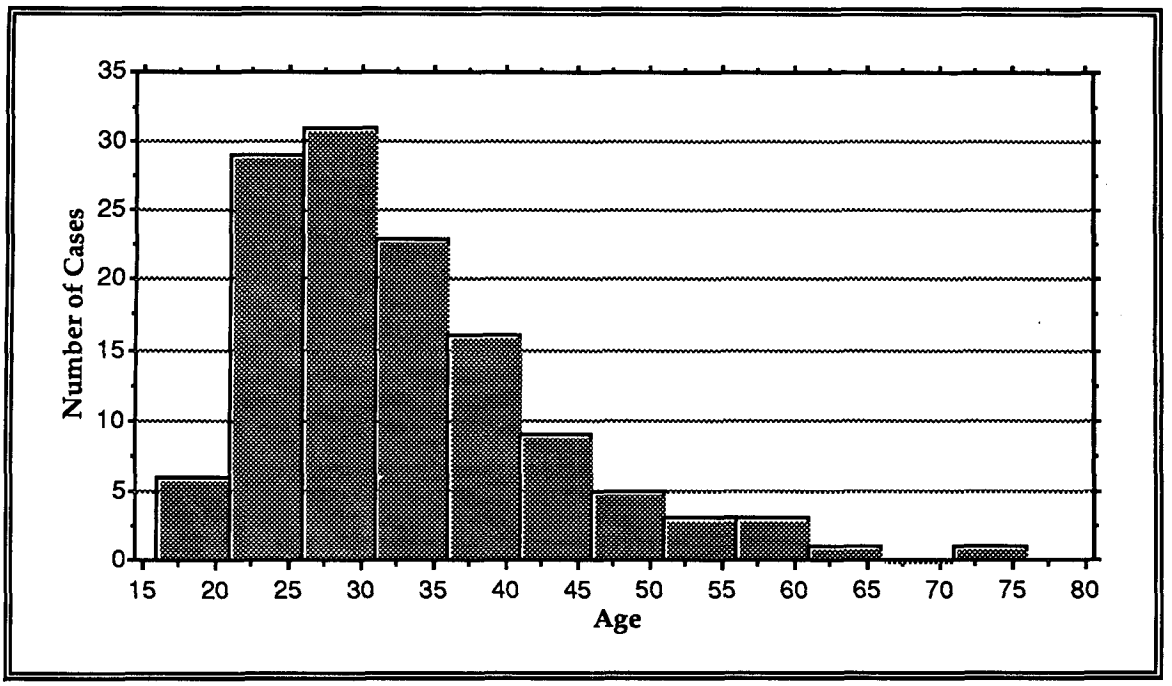

Figure 4. Distribution of DWI driver ages in the Phase I ride-along study.

Calculations were performed for each of the 91 driving and 41 post stop cues listed on the data collection form; the proportions of observations of each cue within three BAC ranges were calculated. That is, for each cue, the proportion of all observations of that cue that was associated with BACs of 0.08 or greater was calculated; then the proportion of all observations of the cue that was associated with BACs of 0.04 or greater was calculated; finally, the proportion of all observations of the cue that was associated with BACs of 0.01 and greater was calculated. The numbers of observations and cumulative proportions were recorded in data tables; those tables are presented as Appendix E. The following example is provided to explain the procedure used to calculate the cumulative proportions.

	WEAVING CUES			
No.	**Cue**	**.01+**	**.04+**	**.08+**
2.1.	Weaving within a lane (includes touching lane lines) [108]	22/.66	9/.45	40/.37
2.2.	Weaving across lane lines [57]	8/.68	3/.54	28/.49
2.3.	Weaving across center divider line [23]	4/.74	2/.57	11/.48

Cue 2.1, *Weaving within a lane,* was observed a total of 108 times during the field study (i.e., the number in brackets following the cue statement). In 40 of the 108 cases the driver was found to have a BAC of 0.08 or greater; this represents a proportion of .37, or 37 percent. Following nine of the observations of weaving within a lane it was found that the driver had a BAC of 0.04 through 0.07. By adding the nine observations to the 40 found at 0.08 and above, it is possible to calculate the proportion of the total

observations in which weaving is associated with a BAC of 0.04 or greater. Likewise, 22 of the observations of this cue were made of drivers who had BACs of 0.01 through 0.03; adding those 22 to the 49 results in a cumulative proportion of .66 at 0.01 and above. By extrapolation, these proportions may be viewed as tentative probabilities: According to these data, if an officer observes a motorist weaving, there is a 37 percent chance the driver has a BAC of 0.08 or more, a 45 percent chance of a BAC greater than 0.04, and a 66 percent chance that the driver's BAC is greater than zero.

Please remember that the preliminary estimates derived from the ride-along field study are based on relatively few observations. One of the objectives of the ride-along study was to identify similar cues that could be combined during subsequent research tasks. For example, it will be recommended in the following paragraphs that Cues 2.2, *Weaving across lane lines,* and 2.3, *Weaving across center divider line,* be combined to form the single cue, as illustrated below.

No.	Cue	.01+	.04+	.08+
2.2.	Weaving across lane lines [57+23=80]	12/.70	5/.55	39/.49

The objective of the next project task was to determine which cues are the most predictive of DWI, and to obtain sufficient data to permit the calculation of reliable probabilities. The data obtained during the ride-along field study were analyzed to identify a usable list of the most promising cues to include on a data collection form to be used during the much more extensive preliminary field study. The data collection form developed for the preliminary field study had to be small enough to be carried conveniently by officers under routine conditions; forms of the approximate size and shape of traffic citations are most appropriate.

The following criteria were developed and applied to identify the cues that should be included on the data collection form in the preliminary field study.

- A visual cue that is associated with a relatively high proportion of BACs at the 0.08 level and above,
- A visual cue that occurs prior to the police officer's decision to take overt action to stop a vehicle, or
- A visual cue that occurs *after* the police officer's decision to take overt action that provides cause for suspicion of DWI, and
- A deviation from normal operator behavior, including vehicle responses to operator actions.

A review of ride-along field study results led to 44 cues recommended for further evaluation during the preliminary field study. In several cases cues were combined to form a single cue. For example, the two cues involving weaving across lane and center divider lines (cues 2.2/2.3) were combined, as described previously, as well as the two straddling cues (3.1/3.2), speeding and unsafe speed (4.1/4.11), accelerating rapidly

forward and backward (5.1/5.2), failure to stop for stop sign and red light (7.1/7.2), driving wrong way and into opposing lane (10.2/10.3), etc. The results of the ride-along field study and detailed discussions of the selection procedures and rationales for combining similar cues are provided in Appendix E. The cues recommended to be included on the data collection form for the preliminary field study are presented in Table 3.

TABLE 3
CUES RECOMMENDED FOR THE PRELIMINARY FIELD STUDY
With cumulative probabilities based on ride-along study data
* = combined cues

Cue Description [total number of observations]	Proportion of Observations at BAC Level and Above .01+	.04+	.08+
Weaving Cues			
Weaving within a lane (includes touching lane lines) [108]	.66	.45	.37
Weaving across lane lines or center divider line* [80]	.70	.55	.49
Straddling Cues			
Straddling lane or center divider line* [73]	.53	.41	.33
Driving left or right of center [26]	.69	.46	.35
Speed Cues			
Speeding, more than 10 mph over limit or unsafe for conditions* [100]	.52	.40	.32
Slow speed [29]	.59	.35	.24
Accelerating rapidly forward or for no apparent reason* [37]	.49	.27	.24
Varying speed [29]	.59	.31	.28
Responding to Lights and Signs Cues			
Failure to stop for a stop sign or red light* [17]	.53	.41	.35
Operating Vehicle Equipment Cues			
Driving without headlights at night (includes tail lights if from rear) [32]	.56	.41	.31
No, obscured, or stolen plate, or expired registration [11]	1.0	.50	.50
Drifting Cues			
Drifting during a curve [15]	.67	.47	.40
Driving Cues			
Following too closely [10]	.70	.60	.60
Driving in opposing lanes, or wrong way on a one way street* [11]	1.0	.82	.64
Driving on other than the designated roadway [3]	1.0	1.0	.67
Driving without seatbelt or child restraint violation* [31]	.68	.52	.39
Failing to yield right of way [6]	.33	.33	.33
Turning Cues			
Turing with a wide radius (drifting during turn) [62]	.53	.42	.37
Illegal turn [23]	.70	.57	.48
Improper turn (too fast, jerky, sharp, etc.) [51]	.55	.37	.31

Continued

Cue Description [total number of observations]	Proportion of Observations at BAC Level and Above .01+	.04+	.08+
Striking Cues			
Almost striking a vehicle or other object* [25]	.76	.68	.60
Swerving Cues			
Swerving [2]	1.0	1.0	1.0
Stopping Cues			
Stopping in lane or for no apparent reason* [21]	.67	.48	.43
Stopping problems* (in intersection, on sidewalk, too far from curb, at angle, etc.) [52]	.71	.56	.52
Steering Cues			
Irregular steering motions [10]	.80	.60	.60
Backing Cues			
Backing improperly [7]	.71	.71	.71
Signaling Cues			
Failure to signal turn or lane change, or signal inconsistent with act* [39]	.54	.33	.23
Changing Lanes Cues			
Improper or unsafe lane change* (abrupt, frequent, cutting off) [49]	.65	.49	.37
Driver Response Time Cues			
Slow or failure to respond to police signals* [94]	.73	.59	.50
Stopping inappropriately in response to officer* (before officer initiates) [21]	.76	.67	.57
Other Cues			
Appearing to be drunk [78]	.94	.87	.81
Drinking in vehicle [14]	.93	.79	.71
Unusual behavior* (throwing something from vehicle, parked with lights on, gesturing) [8]	1.0	.89	.63
Post-Stop Cues			
Difficulty with motor vehicle controls [7]	.57	.43	.43
Difficulty exiting vehicle [19]	.89	.79	.79
Fumbling with DL/registration [47]	.74	.62	.53
Repeating questions/comments [27]	.74	.67	.67
Swaying, unsteady or balance problems* [75]	.91	.91	.81
Leaning on vehicle or object [31]	.84	.68	.65
Odor of alcohol from driver [141]	.93	.85	.74
Provides incorrect inf or claims to have forgotten, changes story/answers* [33]	.76	.76	.76
Slow to respond to officer/must repeat questions [59]	.86	.78	.71
Slurred speech [61]	.92	.92	.89

Data concerning 41 post-stop behaviors were collected during the ride-along field study. The results show a consistently sharp increase in the incidence of all of the post-stop cues at the 0.08 BAC level. Although the results presented in Appendix E are interesting, little utility is derived from the knowledge that approximately equal proportions of drivers are argumentative and cooperative in all three BAC categories, or that there is a 93 percent chance that a motorist has had something to drink if alcohol

that there is a 93 percent chance that a motorist has had something to drink if alcohol can be detected on his or her breath (and a 74 percent likelihood that the driver's BAC is 0.08 or above). In the first instance, the information is contradictory, but in the second it quantifies what to many officers is obvious.

Several officers who were interviewed during the study mentioned that when they describe a motorist's post-stop behaviors in court they often are challenged by defense attorneys because information about post-stop cues usually is not included in DWI training. An officer's extensive field experience, and a driver's obvious signs of impairment, can be excluded from consideration because training based on empirical data about post-stop cues is lacking. For this reason, ten post-stop behaviors were recommended for inclusion in the preliminary field study.

None of the other post-stop cues was recommended for the preliminary field study for a variety of reasons. For example, the behaviors that relate to attitude provide conflicting guidance--as many drivers are argumentative as are cooperative. Further, a cheerful attitude should not be a cause for suspicion of impairment. Also, cues that simply state the obvious appear to be of little possible utility to officers (e.g., open container). In this regard, we included the odor of alcohol from the driver (but not from a vehicle), not because it might be useful to officers to know the obvious, but to provide the basis for including the cue in formal training, which then will permit officers to refer to the cue in their expert testimony.

Finally, some cues were eliminated because they might be indicators more of social class than of alcohol impairment. For example, the interview and archival research indicated that a flushed or red face might be an indication of alcohol-impairment in some people. However, a flushed or red face and bloodshot eyes are open to subjective interpretation and could be due to allergies or caused by outdoor work. A disheveled appearance similarly is open to subjective interpretation. We attempted to limit the recommendations to clear and objective post-stop behaviors.

TASK 6: CONDUCTED PRELIMINARY FIELD STUDY

The objective of the preliminary field study was to obtain sufficient data to permit the calculation of probabilities that the 44 cues recommended for consideration at the end of Task 5, are predictive of DWI. Several important activities were required before the preliminary field study could begin, including, development of a data collection form and preliminary training materials, selection and recruitment of law enforcement agencies, and training of the participating officers. Figure 5 presents a copy of the data collection form. The forms were the dimensions of most police citation books (4 inches by 8 1/4 inches) and they were similarly bound; that is, as a form was completed and removed for submitting to Anacapa, a new form was exposed for recording the next detection event.

Front

NHTSA DWI/DUI DETECTION FORM

Agency: _____ Officer ID: _____

Month____Day____1995 Time of stop: _____

Disposition: ☐ Warning ☐ DUI Arrest ☐ Traffic Citation

BAC: ☐ Test: ☐ Blood ☐ Breath ☐ Urine ☐ Refused

Please check all cues that were observed (then over...)

(01) ☐ Weaving within a lane (includes touching lane lines)
(02) ☐ Weaving across lane lines or center divider line
(03) ☐ Straddling lane or center divider line
(04) ☐ Driving left or right of center
(05) ☐ Speeding, 10+ mph over limit or unsafe for conditions
(06) ☐ Slow speed
(07) ☐ Accelerating rapidly forward or for no apparent reason
(08) ☐ Varying speed
(09) ☐ Failure to stop for a stop sign or red light
(10) ☐ Driving without headlights at night
(11) ☐ No, obscured, or stolen plate, or expired registration
(12) ☐ Poor shifting, grinding gears, or stalling
(13) ☐ Drifting during a curve
(14) ☐ Following too closely
(15) ☐ Driving in opposing lanes, or wrong way on a one-way street
(16) ☐ Driving on other than the designated roadway
(17) ☐ Driving without seatbelt or child restraint violation
(18) ☐ Failing to yield right of way
(19) ☐ Turning with a wide radius (drifting during turn)
(20) ☐ Illegal turn
(21) ☐ Improper turn (too fast, jerky, sharp, etc.)
(22) ☐ Almost striking a vehicle or other object
(23) ☐ Swerving
(24) ☐ Stopping in lane or for no apparent reason
(25) ☐ Stopping problems (intersection, sidewalk, too far from curb)
(26) ☐ Irregular steering motions
(27) ☐ Backing improperly
(28) ☐ Failure to signal turn or lane change; signal inconsistent
(29) ☐ Improper/unsafe lane change (abrupt, frequent, cutting off)
(30) ☐ Slow or failure to respond to police signals
(31) ☐ Stopping inappropriately in response to officer
(32) ☐ Appearing to be drunk
(33) ☐ Drinking in vehicle
(34) ☐ Unusual behavior (throwing something from vehicle, gesturing to officer, parked with lights on, etc.)
(35) ☐ Other (Describe)_____

Over for post-stop cues...

Reverse

NHTSA DWI/DUI Detection Form -- Page 2

Post-Stop Cues

Please check all cues that were observed ...

(36) ☐ Difficulty with motor vehicle controls
(37) ☐ Difficulty exiting vehicle
(38) ☐ Fumbling with driver's license or registration
(39) ☐ Repeating questions/comments
(40) ☐ Swaying, unsteady or balance problems
(41) ☐ Leaning on vehicle or object
(42) ☐ Odor of alcohol from driver
(43) ☐ Slurred speech
(44) ☐ Slow to respond to officer/must repeat questions
(45) ☐ Provides incorrect information, claims to have forgotten information, changes answers or story, etc.
(46) ☐ Other: _____

Comments: _____

Thank You!

Figure 5. Data collection form used in the preliminary field study (reduced).

Training materials also were prepared that described the cues listed on the data collection form and provided detailed instructions concerning the data-collection procedures that were to be followed by participating officers. In particular, the materials instructed officers to conduct breath tests using a field testing device on all motorists who exhibited any objective symptoms of alcohol-impairment (or

consumption), even if the officer estimates a subject's BAC to be low and legal based on field sobriety test (SFST) performance.

Five law enforcement agencies were recruited to participate in the preliminary field study; participation involved completing a data collection form following each traffic stop, regardless of the disposition of the stop (i.e., warning, citation, or DWI arrest). Officers checked boxes on the forms to indicate which pre- and post-stop cues were observed. A key site selection criterion was agreement of the law enforcement agency managers to permit their officers to obtain the BACs of all drivers who exhibited objective signs of alcohol, even if no arrest were to be made. Records of low BACs would be necessary to calculate the probabilities of cues predicting the lower levels.

The preliminary field study was conducted during February and March of 1995. A total of 5,091 completed forms was received; Table 4 lists the numbers of completed data collection forms contributed to the field study by the participating agencies. The numbers of motorists stopped who were found to have BACs ≥ 0.01, ≥ 0.05, and ≥ 0.08 are included in the table.

TABLE 4
LAW ENFORCEMENT AGENCIES THAT PARTICIPATED IN THE PRELIMINARY FIELD STUDY AND NUMBERS OF DATA COLLECTION FORMS RECEIVED

Law Enforcement Agency	Total Number of of Stops (forms)	Number of Cases by BAC ≥0.01	≥0.05	≥0.08
Ontario (CA) Police Department	2,933	46	44	43
Modesto (CA) Police Department	672	19	19	18
Utah Highway Patrol	694	74	46	35
Santa Barbara (CA) Police Department	604	15	15	15
San Bernardino (CA) Police Department	188	15	14	14
Totals	5,091	169	138	125

Appendix F presents the results of the preliminary field study as a series of 44 tables. Each table displays the results for a different cue. The tables list the cues as they appeared on the form and show the total number of enforcement stops in which the cue was observed by officers during the field study. This value is provided for "All Hours" and for the nighttime hours of "1700-0700" (5:00 PM - 7:00 AM). Also presented in the tables are the numbers and proportions of all observations of a specific cue that were found in association with the three BAC levels. Please note that the three levels are cumulative; that is, the ≥0.05 level includes all cases with BACs equal to or greater than 0.05 (including those greater than 0.08), and ≥0.01 level includes all cases in which motorists were found to have BACs greater than zero.

A feature that distinguishes the current study from previous DWI detection research has been our efforts to obtain low BAC data in order to identify any driving

cues that are reliable predictors of alcohol-impairment at lower BAC levels. BACs were measured and recorded by officers during the preliminary field study for all drivers who were found to exhibit any objective sign of alcohol consumption (including the faint odor of an alcoholic beverage on the breath). The summary of preliminary field study results, presented in Appendix F, includes the low BAC data and the cumulative proportions of drivers found to be operating at three BAC levels (i.e., ≥0.01, ≥0.05, and ≥0.08) for each cue listed on the data collection forms. Although the proportions, and by extrapolation the probabilities, increase at the lower BAC levels, it is important to question to what extent the inclusion of lower BAC data contributes to a particular cue's probability of detecting a drinking driver. In other words, "Are there any good predictors of low BAC levels?"

Figure 6 summarizes an analysis of the low BAC data obtained during the preliminary field study. The seven cues are listed in the figure that met the criteria of having been observed at least 15 times during the study, with a p value of at least .30 at the 0.08 level. The figure shows that the low BAC occurrences of the cues do not contribute much to the p values at the lower BAC levels, compared to the occurrences above the 0.08 level. We will return to the figure in a moment.

The values presented in Table 3 can be used to evaluate the utility of specific cues as predictors of BAC level. For example, it can be calculated that the probability of finding a driver at the 0.08 level or above by stopping vehicles for all traffic infractions or behaviors is .025, or 2.5 percent (i.e., 125 divided by 5,091). However, the summary of results, and Figure 6, indicate that the probability of a BAC equal to or greater than 0.08 is 41.4 percent if the vehicle is observed straddling a lane line; the probability increases to 47.6 if the vehicle is observed weaving; and, the probability jumps to 59.2 percent if the vehicle is observed to weave across lane lines. These cues discriminate between alcohol-impairment and unimpaired driving, and provide substantial improvement in the DWI-detection capabilities of an observer.

Similarly, it can be calculated from the values in the table that the probability of finding a driver with a BAC *greater than zero* by stopping vehicles for any traffic infraction or behavior is .033, or 3.3 percent (i.e., 169 divided by 5,091). However, the probability of finding a driver with a BAC *greater than zero but less than 0.08* is only .009, or slightly less than one percent (i.e., 44 divided by 5,091--44 is the number of drivers with BACs within these limits during the field study). Together, these data show that the low probability of detection at the low BAC levels does not improve much even when cues that discriminate at the 0.08 level are observed. In short, the cues that are key predictors of DWI at the 0.08 BAC level fail to emerge with useful probability (p) values at the lower BAC levels (e.g., 6.3 percent for weaving).

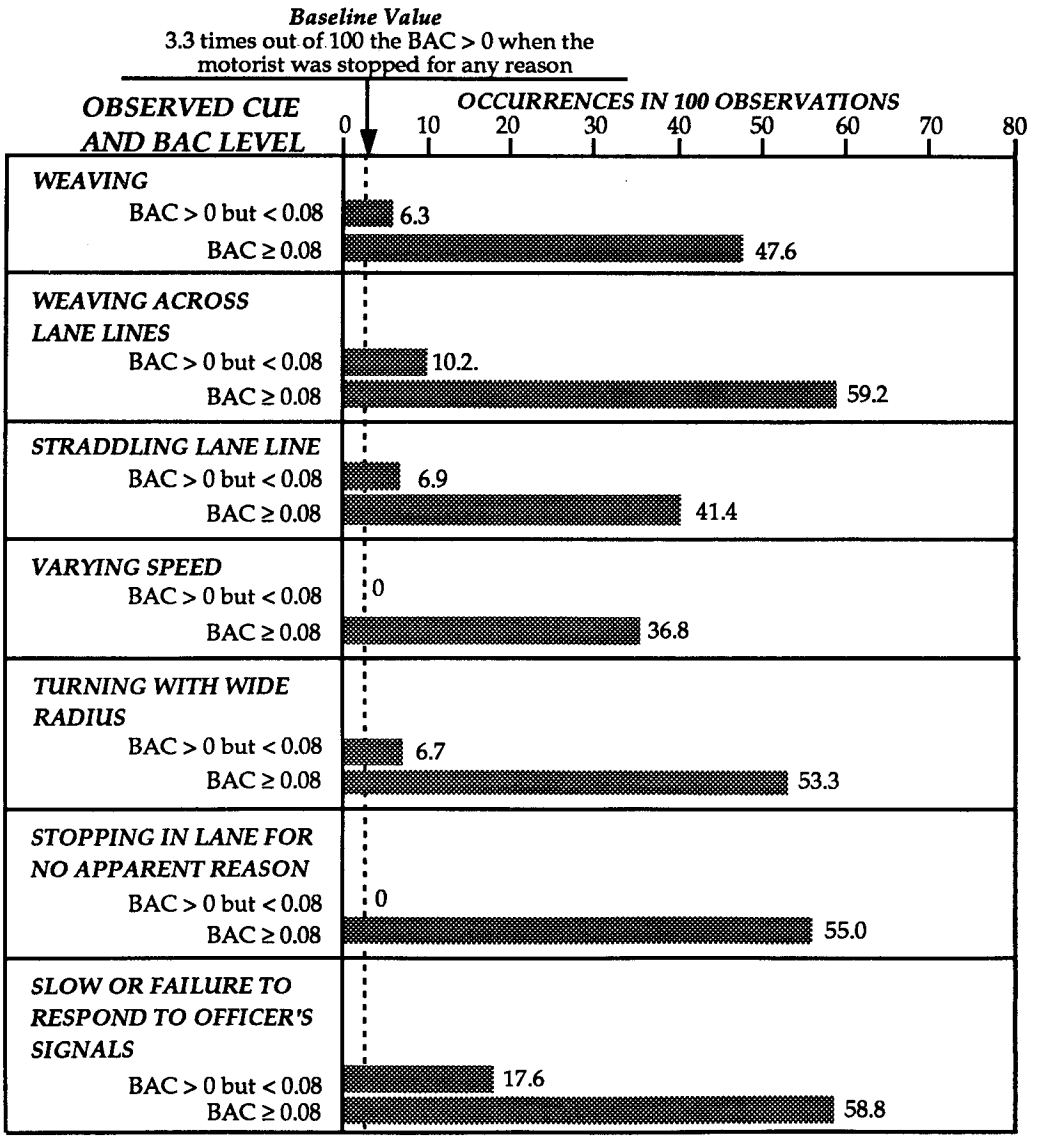

Figure 6. Contributions of low BAC cases to probabilities for key cues.

TASK 7: INTEGRATED PHASE I RESULTS AND PREPARED INTERIM REPORT

All Phase I project tasks, including the preliminary field study, were documented in an interim report. Analyses found that the results of the preliminary field study provided additional validation of the original DWI detection guide. A few new cues were identified by the current research program, but nearly all of the previously-identified cues were confirmed, although some current probabilities were found to have shifted slightly, possibly in response to changes in drinking and driving behaviors since the original study; small numbers of observations of certain cues might be responsible for some of the differences. A result of particular interest is that no cues were identified that appear to reliably discriminate at BAC levels below 0.08.

Results of the Phase I research tasks led to a recommendation to proceed to Phase II of the project. In Phase II, a draft detection guide, printed materials, and training video would be developed, based on the original NHTSA detection guide, as modified by the results of the Phase I preliminary field study. The criteria established for including cues in the draft materials were, a minimum of 15 observations and a probability of a BAC equal to or greater than 0.08 of at least 30 percent during the preliminary field study. Cues that were listed on the original DWI detection guide (at the 0.10 level) were retained for further evaluation during Phase II, even if they failed to meet these criteria. In addition, the cues "Illegal turn" and "Improper turn" were combined to form a single cue, "Illegal or improper turn." The resulting list of cues recommended to be included in the draft training materials is presented in Table 5.

TABLE 5
CUES RECOMMENDED TO BE INCLUDED IN THE DRAFT TRAINING MATERIALS

DRIVING CUES

Problems Maintaining Proper Lane Position

- Weaving
- Weaving across lane lines
- Straddling a lane line
- Swerving
- Drifting
- Turning with a wide radius
- Almost striking a vehicle or other object

Speed and Braking Problems

- Stopping problems (too far, too short, or too jerky)
- Slow speed (10+ mph under limit)
- Accelerating or decelerating for no apparent reason
- Varying speed

Vigilance Problems

- Driving without headlights at night
- Failure to signal or signal inconsistent with action
- Driving in opposing lanes or wrong way on one-way
- Slow response to traffic signals
- Slow or failure to respond to officer's signals
- Stopping in lane for no apparent reason

Judgment Problems

- Following too closely
- Improper or unsafe lane change
- Illegal or improper turn (too fast, jerky, sharp. etc.)
- Backing improperly
- Driving on other than the designated roadway
- Stopping inappropriately in response to officer
- Appearing to be impaired
- Inappropriate or unusual behavior (throwing, arguing, etc.)

POST-STOP CUES

- Difficulty with motor vehicle controls
- Difficulty exiting the vehicle
- Fumbling with driver's license or registration
- Repeating questions or comments
- Swaying, unsteady, or balance problems
- Leaning on the vehicle or other object
- Slurred speech
- Slow to respond to officer/officer must repeat
- Provides incorrect information, changes answers
- Odor of alcoholic beverage from the driver

PHASE II

The purpose of Phase II of the project was to develop, evaluate, and refine a new DWI detection guide and training program, based on the results of the Phase I research, and to validate the guide at the 0.08 BAC level. Phase II comprised the five major project tasks illustrated in Figure 7, and described in the following pages.

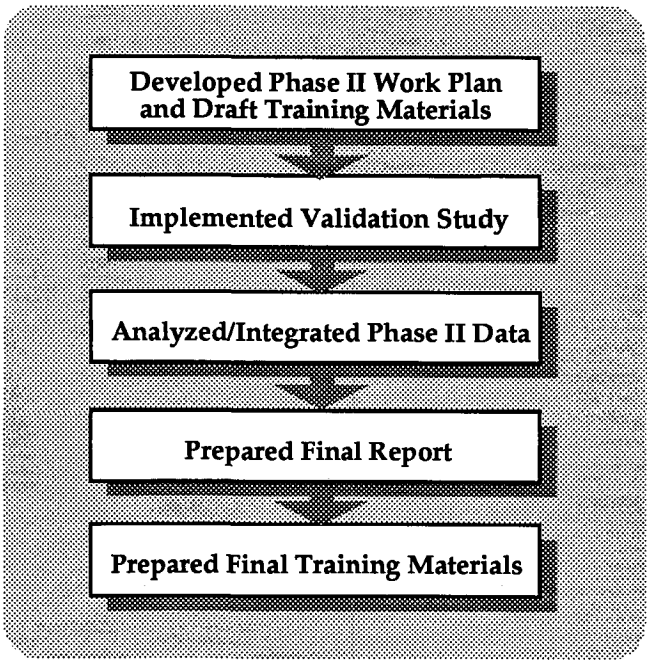

Figure 7. Sequence of Phase II project tasks.

TASK 8: DEVELOPED PHASE II WORK PLAN AND DRAFT MATERIALS

A work plan was prepared to guide the performance of all Phase II project tasks. The plan included detailed specifications for the printed training materials and video, and an experimental design, data evaluation procedures, and site-selection criteria for the validation study. The components of the Phase II plan are summarized in the following paragraphs.

Specifications For The Training Materials And Video

The approach stressed continuity with the original detection guide and training materials. Because the original DWI materials have been accepted by law enforcement and the courts and used throughout the U.S. for 17 years, it seemed wise to link the current research and development effort to the materials that have trained a generation of officers in DWI detection. Although clearly linked to the original materials, it was decided that the new versions should incorporate lessons learned during the intervening years, as well as the differences determined by the results of the Phase I research.

Concerning lessons learned, the original detection guide listed 20 cues along with the probabilities that a motorist exhibiting a cue would be found to have a BAC ≥0.10; the cues were listed in descending order of probability. However, while conducting the motorcycle DWI detection study in 1993, it was found that, once officers are trained, they usually did not pay much attention to the specific probabilities of DWI associated with the various cues; that is, the cues on the detection guide tend to be treated equally by officers in the field. Officers reported anecdotally that if a cue is predictive enough to be on the guide, it is sufficient to justify an enforcement stop. Further, some officers reported that they resented having to memorize the cue probabilities during training. This information led NHTSA to decide to refrain from including the actual probabilities of cues in the motorcycle DWI detection guide, video, and booklet. Instead, the motorcycle cues were presented in two categories: Excellent Cues (cues with probabilities ≥ .50), and Good Cues (cues with probabilities between .30 and .49) (Stuster, 1993).

A similar logic was followed while developing the current materials. However, rather than presenting the cues in categories that emphasize probability, the driving cues were presented in four functional categories: Problems Maintaining Proper Lane Position, Speed and Braking Problems, Vigilance Problems, and Judgment Problems; Post Stop Cues were listed separately on the back of the guide. Figure 8 depicts the draft DWI detection guide that was developed for the Phase II validation study.

DWI DETECTION GUIDE

NHTSA has found that the following cues are either good or excellent predictors of DWI.

Problems Maintaining Proper Lane Position

- Weaving • Weaving across lane lines • Swerving
- Straddling a lane line
- Turning with a wide radius • Drifting
- Almost striking a vehicle or other object

Speed and Braking Problems

- Stopping problems (too far, too short, or too jerky)
- Accelerating or decelerating for no apparent reason
- Varying speed • Slow speed (10+ mph under limit)

Vigilance Problems

- Driving without headlights at night
- Failure to signal or signal inconsistent with action
- Driving in opposing lanes or wrong way on one-way
- Slow response to traffic signals
- Slow or failure to respond to officer's signals
- Stopping in lane for no apparent reason

Judgment Problems

- Following too closely
- Improper or unsafe lane change
- Illegal or improper turn (too fast, jerky, sharp. etc.)
- Backing improperly
- Driving on other than the designated roadway
- Stopping inappropriately in response to officer
- Inappropriate or unusual behavior (throwing, arguing, etc.)
- Appearing to be impaired

Post Stop Cues

- Difficulty with motor vehicle controls
- Difficulty exiting the vehicle
- Fumbling with driver's license or registration
- Repeating questions or comments
- Swaying, unsteady, or balance problems
- Leaning on the vehicle or other object
- Slurred speech
- Slow to respond to officer/officer must repeat questions
- Provides incorrect information, changes answers
- Odor of alcoholic beverage from the driver

Figure 8. Draft DWI detection guide developed for the Phase II validation study.

It is believed that organizing the cues in groups of similar behaviors facilitates use of the cue guide and contributes to an understanding of the ways in which alcohol impairs driving performance. Also, excluding references to cue probabilities relieves officers of the burden of memorizing information that they might only be required to recall during training (or in court if the probabilities were included in the training).

Informal interviews were conducted with law enforcement officers to identify the features of effective training videos. Generally, officers reported that they greatly prefer videos that feature actual law enforcement personnel rather than actors. It was believed that using real officers in the video, especially officers who participated in the research, would stimulate the interest of law enforcement viewers and lend credibility to the training program. In addition, it was determined that the officers appearing in the video should represent the broad range of agencies that conduct traffic enforcement (i.e., sheriffs, municipal police, state police, highway patrols). Further, it was considered important for the officers to reflect the diversity of modern law enforcement, including both men and women officers and supervisors. The intention, in this regard, was to create a training program to which the largest number of law enforcement viewers might relate personally, and find relevant and credible.

One of the most important specifications for the current training program was a shift from the detection of "drunk" drivers, the objective of the original program, to the detection of "impaired" drivers. The cues that have emerged from the current study apply to drivers with BACs of 0.08 and above; to be instructive and credible the cues must be illustrated as realistically as possible. For example, it was determined that the illustration of weaving should be of the type associated with a BAC of 0.08, rather than the extreme weaving portrayed in the original training film. DWI instructors would be asked to provide specific guidance during production of the video to ensure the accuracy and relevance of the examples of both driving and post stop cues.

Finally, it was specified that the new training video, like the one it will replace, should be limited to about 16 minutes duration in order that it might be appropriate for roll call, or refresher, training, as well as for incorporation in formal DWI training courses. Further, the detection guide and training booklet should resemble the form and style of the original materials.

Experimental Design and Data Evaluation Procedures for the Validation Study

The purpose of the validation study was to assess the validity of the cues that were included on the draft DWI detection guide and associated training materials. In other words, the question answered by the validation study is, "Do the cues belong on the guide?" To make these judgments it is necessary to calculate the proportions of all observations of a cue in which an arrest is made, and by extrapolation, derive the probabilities that the cues are predictive of DWI; that is, the same analyses must be made of the validation study data that were performed at the conclusion of the

preliminary field study. The results of the two field studies then must be compared. Differences in p values obtained during the preliminary and validation studies might be attributable to sampling error (i.e., smaller vs. larger numbers of cases or observations of a cue) or the effects of the training materials on officer performance.

Because the results of the two field studies were to be compared, it was important that officers use the same data collection form and follow the same procedures in the validation study as in the preliminary field study, with two exceptions: In the validation study, 1) Officers viewed the draft training video and received copies of the detection guide and training booklet, instead of orientation materials that described all 44 cues on the data collection form; and, 2) Officers were required to obtain and record BACs only for drivers arrested for DWI, although they were requested to record lower BACs when available for drivers who had been drinking, even though they were determined to be unimpaired.

Site-Selection Criteria

The site-selection plan specified that attempts would be made to recruit one law enforcement agency from each of the 13 states that presently maintains a 0.08 BAC limit for DWI. Further, the participating agencies should include a mix of jurisdictions that represent rural, urban, and highway driving conditions, and a combination of routine and special DWI patrols. Aside from operating under a 0.08 BAC limit and geographic representation, the primary site selection criterion for the validation study was the willingness of law enforcement personnel to abide by the study procedures. Prior training in DWI detection was not a requirement because training would be provided by roll-call video sessions and copies of the DWI detection guide and booklet. Willingness to implement enforcement stops in response to the driving cues listed on the guide, and to complete a data collection form following every stop, were the primary requirements. The necessary levels of motivation and commitment to perform these tasks usually are found only in agencies where the management and officers place a high priority on DWI enforcement.

TASK 9: CONDUCTED VALIDATION STUDY

The recruitment of law enforcement agencies to participate in the validation study commenced immediately upon receiving NHTSA approval of the draft DWI detection guide, training video, and booklet that were developed according to the specifications identified during Task 7. Managers of law enforcement agencies from each of the 13 states with 0.08 BAC limits at the time of the study agreed to participate. Training materials, data collection forms, and summaries of study procedures were shipped to all 13 agencies. Two of the 13 agencies later regretfully declined to participate in the validation study due to conflicting requirements.

Participating law enforcement officers reviewed the video and printed training materials, and were asked to implement enforcement stops in response to the DWI cues described in the training and listed on the DWI detection guide. Officers then completed a data collection form following each traffic enforcement stop, regardless of the disposition of the stop; the forms used in the validation study were

identical to the forms used during the preliminary field study. Each participating agency followed the study procedures for a period of four weeks. Table 6 lists the 11 sites that participated in the validation study along with the numbers of data collection forms received, by disposition of stop. (Note: Vermont was represented by a DWI task force composed of officers from 10 municipal and county jurisdictions, coordinated by the Burlington Police Department.)

TABLE 6
LAW ENFORCEMENT AGENCIES THAT PARTICIPATED IN THE VALIDATION STUDY AND NUMBERS OF DATA COLLECTION FORMS RETURNED BY DISPOSITION OF ENFORCEMENT STOP

Agency	Total Stops	Warnings	Percent Warnings	Citations	Percent Citations	DWIs	Percent DWIs
Maui (HI) PD	143	53	37%	29	20%	61	43%
Portland (ME) PD	44	22	50%	19	43%	3	7%
Virginia Beach (VA) PD	1,353	165	12%	1,001	74%	187	14%
Oregon State Police	769	379	49%	273	36%	117	15%
Vermont Task Force	148	71	48%	70	47%	15	10%
Albuquerque (NM) PD	152	46	30%	19	13%	87	57%
Overland Park (KS) PD	396	72	18%	309	78%	15	4%
New Hampshire State Police	30	9	30%	2	7%	19	63%
Miami (FL) PD	21	3	14%	8	38%	10	48%
Santa Barbara (CA) PD	148	70	47%	60	41%	18	12%
Birmingham (AL) PD	1,400	113	8%	1,245	89%	42	3%
Totals/*Mean %*	4,604	1,003	22%	3,035	*66%*	574	*12%*

TASK 10: ANALYZED PHASE II DATA

The proportions of all stops that resulted in DWI arrests ranged from a low of three percent in Birmingham, Alabama, to a high of 63 percent in New Hampshire; the mean proportion of DWI arrests over all sites was 12 percent. The numbers of enforcement stops made by the participating agencies, and the proportions of stops that resulted in DWI arrests, reflect the range of demographic conditions and the mix of routine nighttime patrols and special DWI enforcement that were objectives of the site selection strategy.

Figure 9 presents the distribution of the 468 known BACs of drivers arrested for DWI during the validation study. DWI arrests were made by participating officers at BACs ranging from a low of 0.01 (in a zero tolerance state, that is, where the legal limit is near zero for drivers under 21 years old) to a high of 0.40. The driver in the latter case lost control of his vehicle while attempting a turn; remarkably, he survived the crash and was capable of providing a breath sample for analysis.

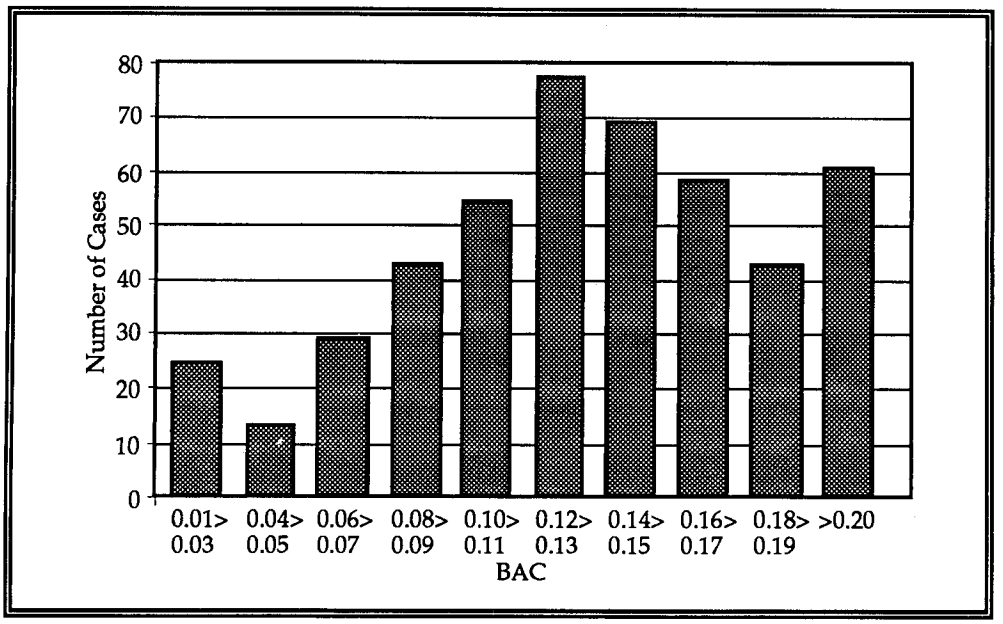

Figure 9. Distribution of BACs obtained during the validation study.

Tables 7 and 8 present the results of the validation study as well as the preliminary field study, so that comparisons can be made. The tables include all 44 of the cues contained on the data collection form; the 25 driving and 10 post stop cues that were included in the draft training materials appear in italics. By comparing the two columns that list the proportions of total observations of a cue that resulted in DWI arrests (labeled "p of DWI"), it is found that of the driving cues listed on the draft DWI detection guide, 22 cues had higher p value in the validation study than in the preliminary study, the p value for one cue was the same, and the p values of 2 cues were slightly lower in the validation study.

The two cues for which p values were slightly lower in the validation study are "Weaving across lane lines," with a difference of -0.05 and "Appearing to be drunk," with a difference of -0.03. Overall, the average change in the p value of the 25 driving cues listed on the detection guide was +0.20. Some of the differences between the p values obtained during the preliminary and validation studies might be attributable to sampling error, although nearly all of the validation study p values were within the confidence intervals of the preliminary values. However, the consistency of the changes (22 out of 25 cues increased) and the magnitude of the average change in p values (+0.20), strongly suggest that the draft training materials improved officer DWI detection performance.

TABLE 7
RESULTS OF THE VALIDATION AND PRELIMINARY FIELD STUDIES:
DRIVING CUES

	Validation Study			Preliminary Study		
DRIVING CUES	Total	DWIs	p of DWI	Total	DWIs	p of DWI
Weaving within a lane	347	180	**0.52**	63	30	0.48
Weaving across lane lines	334	182	**0.54**	49	29	0.59
Straddling lane lines or center divider line	89	54	**0.61**	29	12	0.41
Driving left or right of center	87	42	0.48	21	1	0.05
Speeding, 10+ mph over or unsafe for conditions	1800	169	0.09	434	28	0.06
Slow speed	88	42	**0.48**	52	11	0.21
Accelerating/decelerating for no apparent reason	53	37	**0.70**	25	10	0.40
Varying speed	57	28	**0.49**	19	7	0.37
Failure to stop for a stop sign or red light	522	38	0.07	201	12	0.06
Driving without headlights at night	173	24	**0.14**	156	12	0.08
No, obscured, or stolen plate, or expired reg.	216	17	0.08	314	8	0.03
Poor shifting, grinding gears, or stalling	10	4	0.40	4	0	0.00
Drifting during a curve	37	19	**0.51**	4	2	0.50
Following too closely	54	20	**0.37**	11	0	0.00
Driving in opposing lanes, or wrong way	46	25	**0.54**	13	5	0.38
Driving on other than the designated roadway	35	28	**0.80**	9	3	0.33
Driving without seatbelt or child restraint	174	31	0.18	158	5	0.03
Failure to yield right of way	44	10	0.23	34	2	0.06
Turning with wide radius (drifting during turn)	60	41	**0.68**	15	8	0.53
Illegal turn	57	11	**0.19**	100	2	0.02
Improper turn (too fast, jerky, sharp, etc.)	50	25	**0.50**	24	6	0.25
Almost striking a vehicle or other object	61	48	**0.79**	13	8	0.62
Swerving	55	43	**0.78**	11	4	0.36
Stopping in lane for no apparent reason	42	23	**0.55**	20	11	0.55
Stopping problems	42	29	**0.69**	12	5	0.42
Irregular steering motions	28	18	0.64	10	1	0.10
Backing improperly	9	5	**0.56**	4	1	0.25
Failure or inconsistent signal	132	24	**0.18**	38	2	0.05
Improper/unsafe lane change	37	13	**0.35**	11	1	0.09
Slow or failure to respond to signal or oficer	77	50	**0.65**	17	10	0.59
Stopping inappropriately in response to officer	51	35	**0.69**	8	2	0.25
Appearing to be drunk	92	83	**0.90**	14	13	0.93
Drinking in vehicle	48	35	0.73	19	5	0.26
Unusual behavior	23	11	**0.48**	8	2	0.25
(Other) Defective equipment	747	22	0.03	---	---	---
(Other) Tags, etc.	223	9	0.04	---	---	---
(Other) Failure to dim headlights	61	10	0.16	---	---	---

TABLE 8
RESULTS OF THE VALIDATION AND PRELIMINARY FIELD STUDIES:
POST-STOP CUES

	Validation Study			Preliminary Study		
POST-STOP CUES	Total	DWIs	p of DWI	Total	DWIs	p of DWI
Difficulty with vehicle controls	75	73	**0.97**	14	14	1.00
Difficulty exiting vehicle	159	153	**0.96**	26	24	0.92
Fumbling with drivers license or registration	184	167	**0.91**	30	26	0.87
Repeating questions or comments	187	178	**0.95**	37	32	0.86
Swaying, unsteady or balance problems	398	385	**0.97**	67	55	0.82
Leaning on vehicle or object	126	124	**0.98**	13	10	0.77
Odor of alcoholic beverage from driver	566	488	**0.86**	112	75	0.67
Slurred speach	400	389	**0.97**	60	54	0.90
Slow to respond to officer/officer must repeat	198	190	**0.96**	45	37	0.82
Provides incorrect info, changes answers	98	89	**0.91**	15	9	0.60

Table 7 includes three "other" cues that were recorded in the comments section of the data collection forms: "Defective equipment," "Tags (city licenses, etc.)," and "Failure to dim headlights." None of these additional cues achieved the criterion probability, although drivers who failed to dim their headlights were found to be DWI 16 percent of the time. This cue also has face validity as an expected effect of impaired vigilance capabilities, despite the relatively low probability. Also, recall that cues 20 and 21 ("Illegal turn," and "Improper turn,") were combined following the preliminary field study to form a single cue on the draft DWI detection guide; the p value for the combined turning cue is 0.34 (36 DWIs in 107 total observations of the two cues).

Substantially more cues were observed and recorded during the validation study than in the preliminary study. Only two of the 44 cues listed on the data collection form were observed fewer times during the validation study: "No, obscured, or stolen plate, or expired registration," and "Illegal turn." Overall, the greater number of observations obtained by officers during the validation study provides a robust data base and relatively narrow confidence intervals for nearly all of the cues. Confidence intervals are the statistical expressions of certainty about an estimated value. The p values calculated from the sample of observations made during the validation study are really estimates of the actual values that would be obtained if disposition data were available for *all* enforcement stops in which weaving was observed in the U.S. For example, "Weaving" was observed 347 times during the validation study and resulted in 180 DWI arrests (p = 0.52). Based on the large number of observations, we are 95 percent certain that the actual p value is between 0.47 and 0.57; 0.52 (i.e., a 52 percent probability of DWI) remains the best estimate of the actual value, based on the large sample of weaving observations obtained during the validation study.

Generally, fewer observations of a cue will result in wider confidence intervals. For example, "Varying speed" was observed only 57 times during the validation study, and the driver was found to be DWI in 28 of those occurrences (p=0.49). The relatively small number of observations of this cue results in a confidence interval that extends from 0.36 to 0.62. However, even with the broad interval, we are 95 percent certain that the drivers will be DWI in at least 36 out of every 100 observations of this cue; the best estimate of the probability is 49 percent.

Only four of the cues that meet the probability criterion (≥30 percent) have a lower limit to their confidence interval that is lower than the criterion value. Those cues are listed in Table 9. It is recommended that three of the four cues be retained in the final versions of the detection guide and training materials, despite the lower limits to the cues' confidence intervals. However, it is recommended that "Backing improperly" be dropped from the materials due to the small number of observations (n=9). Appendix G presents the results of the confidence interval analysis for all of the cues listed in Tables 7 and 8.

TABLE 9
CUES THAT MEET THE PROBABILITY CRITERION BUT HAVE LOWER LIMITS TO THEIR CONFIDENCE INTERVALS THAT ARE BELOW 0.30

Cue	p value Validation Study	Confidence Interval Lower Limit	Confidence Interval Upper Limit
Improper or unsafe lane change (n=37)	0.35	0.20	0.50
Backing improperly (n=9)	0.56	0.24	0.88
Following too closely (n=54)	0.37	0.24	0.50
Unusual behavior (n=23)	0.48	0.28	0.68

Many of the completed data collection forms contained officers' comments that described the observed driving behaviors or provided additional information about the enforcement stop. A few examples are provided below.

> "The driver failed to respond to my lights and siren, so I used my loudspeaker to advise him to pull over to the right. Instead, he stopped in the middle of a major road during rush hour." (BAC, 0.12)

> "The driver was weaving, swerving, varying speed, and following too closely. He admitted to drinking two 12-packs of beer." (BAC, 0.18)

> "Observed a man urinating at the roadside. He drove off as I pulled up, then proceeded to weave across lane lines before pulling over." (BAC, 0.20)

Although most cases involving extreme behavior were found to be associated with high BACs, there were exceptions. For example, a motorist was observed varying speed, turning with a wide radius, failing to signal a turn, driving without a seatbelt, and almost striking a parked car; he also had trouble stopping and was found to be drinking in the vehicle. However, the driver's BAC was only 0.03; he

was arrested for DWI, despite the low BAC. In some cases, drivers who appeared to be greatly impaired had not been drinking at all. For example:

> "Observed weaving, weaving across lane lines, slow speed, varying speed, and drifting during a curve, but no post stop cues. It was a tired driver."
>
> "Observed 11 driving cues, including weaving, swerving, and almost striking a vehicle. It was the worst driving I have seen in a long time. The operator had been falling asleep at the wheel."
>
> "I stopped the vehicle for weaving, straddling the lane line, speeding, and failing to signal lane changes. The operator was eating dinner while driving."
>
> The officer observed a vehicle weaving, weaving across lane lines, varying speed to as low as 38 mph in a 55 mph zone, and driving on the shoulder. He found that the vehicle's "check engine" light had come on, which startled the driver, who then dropped her purse on the floorboard and still attempted to drive while retrieving the spilled items.

It is cases such as these, and far less-extreme examples, that help explain the probabilities of DWI that emerged from the validation field study. In other words, not all drivers who exhibit even a highly predictive cue are impaired by alcohol. If a specific cue's probability of DWI is .52, it means that the drivers will be impaired in about 52 out of every 100 cases in which the cue is observed. It also means that there will be another explanation (or no explanation) in about 48 out of every 100 cases. The "other" cases are irrelevant to the operational utility of the cues when large proportions of drivers exhibiting the cues are found to be DWI. A cue that predicts DWI with a 30 percent probability has considerable predictive utility compared to the three percent probability found for all nighttime traffic stops.

Analyses were performed to calculate the probability of DWI when more than one cue is observed. The first step in the process was to exclude from the data set all cases in which the officer only reported driving cues (i.e., pre-stop cues) that were not listed on the detection guide. The cues not listed on the guide, but included on the data collection form were, "Driving left or right of center," "Speeding," "Failure to stop for a stop sign or signal," "No, obscured, or stolen plate," "Poor shifting," "Driving without seatbelt," "Failure to yield right of way," and "Drinking in the vehicle."

Speeding was the only cue reported in most of the 1,800 cases in which speeding was observed. Similarly, most of the 522 observations of motorists running stop signs or lights, and the more than 400 reports of operating without a license plate or with expired registration or tags, were single cue cases. To these numbers must be added nearly 700 single cue stops for defective equipment. The probabilities that these cues predict DWI were found to be relatively low, for example nine percent for speeding, seven percent for running a stop sign or light, and three percent for defective equipment. The data set is reduced to 1,256 useful enforcement stops when these single cue, low-probability cases are eliminated. Although the reduced data set includes only 27 percent of the total number of cases, it comprises nearly 80 percent of the DWIs. Table 10 summarizes the data used in the multiple cue analysis.

TABLE 10
SUMMARY OF THE REDUCED DATA SET
USED IN THE MULTIPLE CUE ANALYSIS

Number of Cues Observed	Number (percent) of DWIs	Number (percent) of non-DWIs	Number (percent) of All Cases
1	156 (34%)	618 (77%)	774 (62%)
2	118 (26%)	122 (15%)	240 (19%)
3	74 (16%)	36 (4%)	110 (9%)
4	43 (9%)	14 (2%)	57 (5%)
≥5	62 (14%)	13 (2%)	75 (6%)
	453 (100%)	803 (100%)	1,256 (100%)

Table 10 shows the relationship between the number of cues observed by an officer and the disposition of the resulting enforcement stop. In particular, 77 percent of all stops that resulted in warnings or citations were made following the observation of one of the driving cues on the detection guide. In contrast, only 34 percent of the DWI arrests were made following one-cue enforcement stops. Conversely, 66 percent of DWI arrests were preceded by two or more driving cues, while only 23 percent of non-arrest stops involved multiple cues. This relationship is reflected in the mean numbers of driving cues observed by officers: 1.2 cues for stops that resulted in warnings or citations, compared to 2.7 cues for stops that resulted in DWI arrests. This difference is attributable to two factors: 1) Alcohol-impaired drivers make more errors than unimpaired drivers; and, 2) Many of the cues on the detection guide are not vehicle code infractions that might precipitate an immediate enforcement stop, but rather are indicators of impairment. For example, officers might initiate an enforcement stop immediately for an illegal turn, but when a vehicle is observed to weave slightly, officers usually permit the vehicle to proceed in order to further evaluate the driver's performance. An enforcement stop is made if additional cues are observed that support the officer's hypothesis.

Analysis of the reduced data set summarized in Table 10 reveals that if any combination of two driving cues on the guide is observed, the probability of DWI is at least 49 percent; the probability of DWI would be equal to the probability of the more predictive cue if either cue's probability were greater than 49 percent. This estimate is obtained by calculating the proportion of all two-cue stops that resulted in DWI arrests (i.e., 118 divided by 240). The probability of DWI increases to at least 67 percent if any three cues on the detection guide are observed (i.e., 74 divided by 110), to at least 75 percent if any four cues on the list are observed (i.e., 43 divided by 57), and to 83 percent if five or more cues are observed (i.e., 62 divided by 75). Further analysis revealed that the probability of DWI is at least 69 percent if either weaving cue is observed (i.e., either "Weaving within a lane" or "Weaving across lane line") along with any other cue listed on the detection guide. Table 11 presents the results of the multiple cue analysis.

TABLE 11
RESULTS OF THE MULTIPLE CUE ANALYSIS

Number of Cues Observed	Number of DWIs	Number of All Cases	Probability of DWI
1	156	774	The probability of the cue
2	118	240	At least 49%*
3	74	110	At least 67%
4	43	57	At least 75%
≥5	62	75	83%
	453	1,256	

*If weaving and any other cue are observed, probability ≥69%

TASKS 11 AND 12: PREPARED TRAINING MATERIALS AND FINAL REPORT

The analysis of validation study data confirmed the predictive validity of all but two of the cues that were included in the draft training materials: "Driving without headlights at night," and "Failure to signal or signal inconsistent with action." Neither of the cues achieved the 30 percent criterion during the preliminary field study that was established for cues to be included on the draft guide. However, the cues were included in the draft training materials because they had achieved acceptable probabilities during the original study and had been a part of DWI detection training for the past 17 years. Although the two cues achieved higher p values during the validation study than in the preliminary study, the values were still lower than the criterion. Table 12 summarizes the data for these two cues.

TABLE 12
A TALE OF TWO CUES

Cue	p value Validation Study	p value Preliminary Study	p value Original Study
Driving without headlights at night	0.14 (n=173)	0.08 (n=156)	0.30
Failure to signal or signal inconsistent	0.18 (n=132)	0.05 (n=38)	0.40

Both cues listed in Table 12 convey face validity as driving behaviors that reasonably might be expected of alcohol-impaired drivers, and both cues have been useful predictors of DWI in the past. More important, multiple cues were recorded in more than half of the cases in which the cues were found in association with DWI. Because of the effects of multiple cues on DWI probability, it is recommended that these cues be retained in the final version of the training materials for use only when they are paired with another cue on the guide.

Three cues achieved the 0.30 criterion during the validation study that had been excluded from the draft detection guide based on the probabilities obtained during the preliminary field study: "Driving left or right of center," "Irregular steering motions," and "Drinking in vehicle." The lower limits of the confidence intervals of these three cues also are greater than the 0.30 criterion. Table 13 presents the p values for the three cues that were calculated from preliminary and validation study data.

TABLE 13
THREE CUES THAT EMERGED DURING THE VALIDATION STUDY

Cue	p value Validation Study	p value Preliminary Study	p value Original Study
Driving left or right of center	0.48 (n=87)	0.05 (n=21)	n/a*
Irregular steering motions	0.64 (n=28)	0.10 (n=10)	n/a
Drinking in vehicle	0.73 (n=48)	0.26 (n=19)	n/a
	* Similar to, "Tires on center or lane marker" (p=0.45)		

None of the three cues listed in Table 13 was included on the original DWI detection guide, although "Driving left or right of center" is similar to the original cue, "Tires on center or lane marker" (p=0.45 in the 1980 guide). The driving behavior described by the original version of the cue was addressed in the current research program by other lane position cues in an attempt to discriminate impairment at BACs below 0.10. In this regard, James O'Hanlon's research concerning lateral displacement within a lane as an indicator of impairment suggested that "Driving left or right of center" might be a useful diagnostic of BAC levels below those that result in the more extreme, "Tires on center or lane marker" (personal communication, 1994). Further, tires touching the lane lines would be difficult to distinguish operationally from "Straddling lane or center divider line" or "Weaving across lane lines or center divider line."

Analysis of the cases in which "Driving left or right of center" was reported found that three or more cues were observed in 37 out of the 42 cases that resulted in DWI arrests (it was one of at least five cues reported in 20 cases); it was the only cue observed in only one case. Further, the mean BAC of all DWI cases in which this cues was involved was 0.12. In short, the data indicate that "Driving left or right of center" contributed very little to predicting DWI and failed to discriminate lower BAC levels. For these reasons, the cue is not recommended to be included in the final version of the training materials, despite the p value obtained during the validation study.

The second cue listed in Table 13, "Irregular steering motions," was identified during the comprehensive literature review that was performed early in the current research program. This cue focuses on "control reversals," or frequent oscillations of

the steering wheel as the driver attempts to maintain a course. Control reversals have been established as effects of fatigue and central nervous system depressants in many forms of equipment operation (Adams, 1989). The cue was listed on the data collection form in the preliminary field study to determine if officers could detect control reversals that were of insufficient magnitude to cause vehicle weaving. This was another attempt to identify cues that might discriminate impairment at lower BAC levels. However, analysis found multiple cues reported in all 18 of the DWI cases in which this cue was observed. Further, at 0.19, the mean BAC for the cases was relatively high. For these reasons, "Irregular steering motions" is not recommended to be included in the final version of the training materials.

Finally, "Drinking in the vehicle" was included in the preliminary field study on the basis of officer interview and arrest report data. The results of the validation study indicate a relatively high probability of DWI for this cue, however, it is reasonable to question whether this behavior might be considered too obvious to be included on the detection guide. Rather than risk trivializing the training materials, "Drinking in the vehicle" is not recommended for the final version. The behavior remains an infraction that justifies an immediate enforcement stop in nearly all jurisdictions in the U.S.

Summary of Recommendations for Final Version of Training Materials

Only one cue was recommended to be dropped from the DWI detection materials; although "Backing improperly" achieved the criterion probability, the small number of observations limited confidence in the cue. All of the other cues listed on the draft detection guide were confirmed as valid predictors of DWI at the 0.08 BAC level, with two possible exceptions, "Driving without headlights at night," and "Failure to signal or signal inconsistent with action." All of the cues listed on the draft guide, including the two found to have relatively low probabilities, are recommended for the final version of the training materials. The two exceptional cues should be explained as particularly predictive when observed in association with other cues on the detection guide.

It is recommended that the ranges of the probabilities of cues in each of the four functional categories be listed on the detection guide. It is recommended that "p≥.85" be indicated for the category of post stop cues, on the reverse of the guide. Further, it is recommended that guidance concerning probabilities when multiple cues are observed be provided with the following words.

Weaving plus any other cue: p = at least .65
Any two cues: p = at least .50

Figure 10 illustrates the recommendations for the final version of the DWI detection guide, based on Phase II results. It is recommended that all changes to the detection guide be reflected in the final versions of the training video and booklet. A copy of the final version of the printed training materials is included as Appendix H.

DWI DETECTION GUIDE

Weaving plus any other cue: p = at least .65
Any two cues: p = at least .50

PROBLEMS MAINTAINING PROPER LANE POSITION
- Weaving
- Weaving across lane lines

p=.50-.75
- Straddling a lane line
- Swerving
- Turning with a wide radius
- Drifting
- Almost striking a vehicle or other object

SPEED AND BRAKING PROBLEMS **p=.45-.70**
- Stopping problems (too far, too short, or too jerky)
- Accelerating or decelerating for no apparent reason
- Varying speed
- Slow speed (10+ mph under limit)

VIGILANCE PROBLEMS **p=.55-.65**
- Driving in opposing lanes or wrong way on one-way
- Slow response to traffic signals
- Slow or failure to respond to officer's signals
- Stopping in lane for no apparent reason
- Driving without headlights at night*
- Failure to signal or signal inconsistent with action*

JUDGMENT PROBLEMS **p=.35-.90**
- Following too closely
- Improper or unsafe lane change
- Illegal or improper turn (too fast, jerky, sharp. etc.)
- Driving on other than the designated roadway
- Stopping inappropriately in response to officer
- Inappropriate or unusual behavior (throwing, arguing, etc.)
- Appearing to be impaired

POST STOP CUES **p≥ .85**
- Difficulty with motor vehicle controls
- Difficulty exiting the vehicle
- Fumbling with driver's license or registration
- Repeating questions or comments
- Swaying, unsteady, or balance problems
- Leaning on the vehicle or other object
- Slurred speech
- Slow to respond to officer/officer must repeat
- Provides incorrect information, changes answers
- Odor of alcoholic beverage from the driver

---

* p≥ .50 when combined with any other cue:
- Driving without headlights at night
- Failure to signal or signal inconsistent with action

The probability of detecting DWI by random traffic enforcement stops at night has been found to be about three percent (.03).

Figure 10. Recommended final version of the DWI detection guide.

APPENDIX A

INDIVIDUALS AND ORGANIZATIONS THAT PARTICIPATED IN THIS RESEARCH AND DEVELOPMENT PROJECT

LAW ENFORCEMENT PERSONNEL INTERVIEWED REGARDING DWI DETECTION AT BACS BELOW 0.10

The following law enforcement personnel were interviewed to obtain expert opinion concerning the driver behaviors predicitive of DWI at lower BAC levels.

Individual	Agency
Ofcr. Jack Bell	Arizona Department of Public Safety
Ofcr. Vern Ally	Arizona Department of Public Safety
Sgt. Gil Melendez	Glendale (AZ) Police Department
Ofcr. Jeff Lawson	California Highway Patrol, Bakersfield
Ofcr. Travis Mitchell	California Highway Patrol, Bakersfield
Ofcr. Victor Lacey	California Highway Patrol, Bakersfield
Sgt. Roman Finale	California Highway Patrol, Santa Barbara
Ofcr. Staci Morse	California Highway Patrol, Ventura
Ofcr. Steve Towers	California Highway Patrol Academy
Agent Randall Poff	Chula Vista (CA) Police Department
Cmmrcl. Trffc Ofcr. Steve Blair	Fremont (CA) Police Department
Sgt. Loriaux	Fremont (CA) Police Department
Sgt. Bill Martin	Huntington Beach (CA) Police Department
Ofcr. Jim Johnson	Los Angeles (CA) Police Department
Sgt. Art Haversat	Los Angeles (CA) Police Department
Sgt. Dennis Zine	Los Angeles (CA) Police Department
Sgt. Bob Riebolt	Los Angeles (CA) Police Department
Ofcr. Tim Smith	Los Angeles (CA) Police Department
Lt. Charles Kunz	Los Angeles (CA) Police Department
Dpty. Phil Willis	Santa Barbara County (CA) Sheriff's Department
Ofcr. Don Chase	Santa Barbara (CA) Police Department
Ofcr. Larry Rodriquez	Santa Barbara (CA) Police Department
Lt. John Thayer	Santa Barbara (CA) Police Department
Sgt. Harold Johnson	Edmonton (Alberta) Police Service
Captain Luis Velez	Colorado Springs (CO) Police Department
Major R.D. McGee	Metro-Dade (FL) Police Department
Chief Calvin Ross	Miami (FL) Police Department
Trpr. Kevin Conger	Maine State Police
Ofcr. Jim Dearing	Bangor (ME) Police Department
Ofcr. Bruce Coffin	Portland (ME) Police Department
Ofcr. Thomas Regan	Bangor (ME) Police Department
Chief Tom Dailey	Kansas City (MO) Police Department
Cpl. Hogard	Leawood (KS) Police Department
Chief E. Douglas Hamilton	Louisville (KY) Police Department
Cpl. Tom Woodward	Maryland State Police
Sgt. Bill Towers	Maryland State Police
Trpr. Bennett	Maryland State Police
Cpl. Olinik	Annapolis (MD) Police Department
Sgt. Legge	Anne Arunde (MD) City Police Department
Dpty. Chief Edgar F. Koch	Anne Arunde (MD) City Police Department
Sgt. Thomas Didone	Montgomery County (MD) Police Department
Sgt. Robert Frisch	Baltimore (MD) Police Department
Ofcr. Michael McKnight	Baltimore (MD) Police Department
Ofcr. John Kalinski	Baltimore (MD) Police Department

Continued	
Sgt. Dennison	Prince Georges (MD) City Police Department
Trooper Wayne Huntoon	New Hampshire State Police
Lt. Ray Schultz	Albuquerque (NM) Police Department
Gordon Eden	New Mexico State Police Academy
Sgt. Moser	Winston-Salem (NC) Police Department
Sgt. Eggens	Cincinnati (OH) Police Department
Lt. Chuck Hayes	Oregon State Police, Albany Office
Lt. Bill Johnson	Oregon State Police, Patrol Division
Sgt. Branson	Hayward (PA) Police Department
Lt. Cuddy	Rhode Island State Police
Trpr. Mark Bilodau	Rhode Island State Police
Trpr. Ellsworth	Utah Highway Patrol, Alcohol Unit
Major J.D. Fox	County of Henrico (VA) Police Department
Chief Charles R. Wall	Virginia Beach (VA) Police Department
Depty. David Drekter	Washington County (VT) Sheriff's Department
Deputy Sheriff Kurt Snyder	Washington County (VT) Sheriff's Department
Ofcr. Bret Meyer	Waterbury (VT) Police Department
Trpr. Adam Page	Vermont State Police
Sgt. Schaub	Wisconsin State Police Academy
Chief Philip Arreola	Milwaukee (WI) Police Department
Investigator Waangaard	Racine (WI) Police Department

DWI ARREST RECORDS

The following table lists the agencies and individuals responsible for providing copies of the DWI reports that were assembled to create the low BAC arrest report data base. Nine law enforcement agencies contributed to this Phase I project task.

California Highway Patrol	**Bangor (ME) Police Department**
Assistant Commissioner W.P. Carlson	Officer Thomas Regan
Assistant Commissioner Ted Starr	**Washington County (VT) Sheriff's Department**
Lieutenant Max Santiago	Deputy Sheriff David Drekter
Los Angeles (CA) Police Department	Deputy Sheriff Kurt Snyder
Commander Maurice Moore	**Santa Barbara (CA) Police Department**
Lieutenant Charles Kunz	Lieutenant John Thayer
Sergeant Dean Workington	**New Hampshire State Police**
Officer Tim Smith	Corporal Wayne A. Huntoon
Albuquerque (NM) Police Department	**Kansas City (MO) Police Department**
Lieutenant Ray Schultz	Chief Tom Dailey
Oregon State Police	
Lieutenant Charles E. Hayes	

RIDE-ALONG FIELD STUDY

The following personnel of the Los Angeles Police Department helped coordinate and organize the Phase I ride-along field study.

Lieutenant Tom Kirk	Sergeant Bob Troutt
Sergeant Ron Barnes	Sergeant Glenn Wiggins
Sergeant Rod Grahek	Officer Frank Marquez

We are particularly grateful to Captain Ron Bergmann of the LAPD's Valley Traffic Division and the 13 officers who permitted observers to accompany them on patrol during the ride-along field study:

Officer Doug Anderson	Officer Gene Nabonne
Officer Ken Braken	Officer Dave Perry
Officer James Correll	Officer Bob Rives
Officer Mario Cruz	Officer Santiago Rosales
Officer Dan Hunnicutt	Officer Willy Sampson
Officer Norm Kellems	Officer Ron Stringer
Officer Rick Leiphardt	

PRELIMINARY FIELD STUDY

The following table lists the agencies that participated in the preliminary field study and the liaison personnel who coordinated the data collection effort.

Ontario (CA) Police Department
- Sergeant Bob Ferguson
- Sergeant Ernie Dorame

Modesto (CA) Police Department
- Captain Bob Guthrie
- Sergeant Burl Condit
- Sergeant Jim Johnson

Utah Highway Patrol
- Sergeant Judy Hamaker

Santa Barbara (CA) Police Department
- Chief Richard Breza
- Captain Ed Astaad
- Lieutenant Rick Glaus
- Lieutenant Dave McCoy
- Lieutenant Jim Nalls
- Lieutenant John Thayer

San Bernardino (CA) Police Department
- Sergeant Jennifer Aragon
- Detective Paul Muro

VALIDATION FIELD STUDY

The following table lists the agencies that participated in the Phase II validation field study and the liaison personnel who coordinated the officer training and data collection effort.

Birmingham (AL) Police Department
- Chief Johnnie Johnson
- Sergeant Patricia King

Santa Barbara (CA) Police Department
- Captain Greg Stock
- Lieutenant Gil Zuniga

Miami (FL) Police Department
- Officer Pedro Beltran

Maui (HI) Police Department
- Lieutenant Charles Hirata
- Sergeant Bradley P. Rezentes

Overland Park (KS) Police Department
- Captain Tim Lynch
- Officer Jim Weaver

Portland (ME) Police Department
- Sergeant Steven Mazziotti
- Officer Erin Clark

New Hampshire State Police
- Lieutenant Stuart Bates
- Sergeant Stephen Barrett
- Corporal Wayne A. Huntoon

Albuquerque (NM) Police Department
- Lieutenant Paul Heatly
- Officer Mike Callahan

Oregon State Police
- Lieutenant Charles E. Hayes

Vermont Safe Highways Accident Reduction Program (SHARP)
- Corporal Bill Wolfe, Burlington Police Department

Virginia Beach Police Department
- Officer David Duty

DWI DETECTION TRAINING VIDEO

The following law enforcement personnel participated in the production of the training video, "The Visual Detection of DWI."

Officer Vicki Allen
Sergeant Jennifer Aragon
Sergeant Bob Ferguson
Officer Sal Flamenco
Detective Jim Galloway
Sergeant Judy Hamaker
Sergeant Art Haversat
Lieutenant Roy Huerta
Officer Clark John
Officer Tim Kay
Trooper Marci McGregor
Officer Mike Sandoval
Lieutenant Ray Schultz
Officer Sam Slay
Sergeant Bill Tower
Deputy Phil Willis

APPENDIX B

RESULTS OF THE LITERATURE REVIEW

DWI CUES AT BACS BELOW 0.10
A REVIEW OF THE LITERATURE

The purpose of this review is to prepare information for the research team concerning the determination and validation of visual cues for the detection of motorists who are driving while impaired (DWI) with blood alcohol concentrations (BACs) below 0.10.

BACKGROUND

An emphasis on DWI enforcement during the past decade has been a factor in the significant improvement in traffic safety, as represented by declining fatal and alcohol-involved crash rates. Despite the significant improvements in traffic safety during the past 30 years, particularly during the past decade, more than 40,000 people still perish each year as a result of motor vehicle crashes. The current US traffic fatality rate amounts to a daily average of about 126 people--the equivalent of a Boeing 727 crashing every day of the year.

The economic losses from alcohol involved crashes are staggering at an estimated $21 to $24 billion annually (for property damage alone) (Miller, 1992). In 1990, the combined cost of all traffic collisions was $137.5 billion, including 28 million vehicles damaged, 5.4 million people injured, and 44,531 lives lost (Blincoe & Faigin, 1992).

A reduction in the number of alcohol-involved crashes and the number of alcohol-impaired drivers on the road is a top priority. Numerous studies indicate that when DWI enforcement levels are increased, the number of alcohol involved collisions decrease (Hause, Chavez, Hannon, Matheson, 1977; Voas & Hause, 1987; Blomberg, 1992). However, many officers are unable to identify legally impaired drivers from their driving behavior, or even during the brief interview customary at a sobriety checkpoint. For example, in the Netherlands, as many as 32 percent of drivers with BACs above .05 might escape detection at checkpoints, when officers have the advantage of a face-to-face exchange (Gundy & Verschuur, 1986).

There are at least two clear solutions to the low BAC DWI detection problem: 1) Random Breath Testing (RBT) to objectively detect drivers operating above the legal limit; and, 2) increased officer sensitivity to behavioral cues exhibited at lower BAC levels. Although the RBT method is operating effectively in Australia (McCaul & McLean, 1990), it is probably not an appropriate program for the United States. Fourth Amendment rights currently prevent random breath testing; for example, testing only can occur at a sobriety checkpoint after probable cause has been established (Voas, 1991). Thus, the most likely solution to improving detection of low BACs is to improve the DWI detection ability of law enforcement officers.

In 1980, Harris et al. conducted NHTSA sponsored research to determine the behavioral cues for on-the-road detection of DWI. The final product of this Anacapa Sciences' study was a DWI Detection Guide providing 20 visual cues commonly exhibited by impaired drivers with a BAC equal to or greater than 0.10. The Guide provides the probability for each cue of discriminating between Driving While Impaired (DWI) and Driving While Sober (DWS). The DWI Detection Guide and supporting training materials are part of the DWI Detection and Standard Sobriety Testing course currently distributed by NHTSA (NHTSA, 1990). Surprisingly, although there has been a limited evaluation of the DWI Detection Guide (Vingilis et al., 1983), the only additional research of this type that has been performed since 1980 was a NHTSA sponsored study to develop a motorcycle DWI detection guide (Stuster, 1993).

It is legitimate to question whether a cue guide calibrated for the 0.08 level would appear very similar if not identical to the DWI detection guide developed nearly 20 years ago by Anacapa Sciences. A new, lower BAC limit DWI detection guide might ultimately appear similar to the old guide, but the research is important for at least three reasons.

1. The research that supported the development of the DWI Detection Guide was conducted 18 years ago. Many things have changed considerably since the late 1970s. It is not unreasonable to suspect that some fundamental changes might be reflected in the behavioral cues associated with driver impairment. And, there *might* be behaviors that correlate more closely with lower than higher BACs.

2. At the very least, a periodic reprise of a research and development effort is warranted if the work involves important public policy and enforcement implications. The DWI Detection Guide and training program have not been reviewed or revised since they were developed. Increased awareness of DWI issues and public support for DWI enforcement in recent years contribute to the need to upgrade and make current an important decision aid and training program that is used by law enforcement personnel from across the U.S.

3. It is essential for researchers to view the issue of DWI detection from the perspective of an officer on patrol. A patrol officer wants to know the likelihood that a specific driver behavior is indicative of DWI at the (new) 0.08 level *or above,* or at the 0.04 level *or above.* The "or above" is important because as the BAC level is reduced the probability that a given cue is predictive of DWI rises--because all of the *or aboves* are included in the calculation. From the officer's perspective (in an 0.08 jurisdiction) it is usually irrelevant if the motorist is 0.08, 0.10, or some higher value--it is only important to determine that the motorist is 0.08 *or above.*

Although the modal BAC limit for DWI continues to be 0.10 in the United States, there is a definite trend towards lowering the limit. When the current project started in 1993, only five states had adopted a 0.08 percent legal limit, but by the conclusion of the research the number of states with a 0.08 limit had increased to 15. Further, the Commercial Motor Vehicle Safety Act of 1986 established a nationwide maximum BAC of 0.04 percent for all commercial drivers. In addition, several states have adopted a zero tolerance statute or a 0.02 percent BAC limit for youthful drivers. Studies that suggest low officer DWI detection rates, and improved low BAC detection when using passive alcohol sensors (Kiger et al., 1983; Jones et al., 1985: Vingilis and Vingilis, 1985), suggest the need for a DWI detection guide for levels below 0.10 percent BAC.

RELEVANT RESEARCH

The trend of lowering BAC limits is a reflection of the growing body of evidence that alcohol begins to impair nervous function at BAC levels below 0.10 percent. Moskowitz and Robinson (1988) conducted a comprehensive literature review concerning the effects of alcohol on driving behavior, emphasizing the BACs at which impairment begins. A majority of studies found impairment at low BACs (below 0.07). Many studies found impairment at the 0.04 level and below.

Moskowitz and Robinson computed BACs for all studies, even those that included BAC data in the original report. Often these calculations resulted in higher BACs than were reported in the original study, probably because the older devices were inaccurate. The calculations also allowed for gender differences (by taking into account the different percentages of body water in females and males). If anything, the calculations performed by Moskowitz and Robinson lead to an overestimation of BAC level. If this is the case, the impairments they report at various BAC levels actually might occur at lower BACs than reported later in this review.

In the Moskowitz study, factors were grouped into behavioral categories pertinent to driving. The following categories were affected at 0.05 percent BAC.

- Reaction time
- Tracking
- Divided attention
- Information processing
- Visual functions
- Perception

Driving behaviors that showed impairment at 0.08 percent to as low as 0.03 percent included:

- Steering
- Braking
- Speed control
- Lane tracking
- Gear changing
- Speed judgment
- Distance judgment

In addition, tasks requiring divided attention showed impairment at BACs as low as 0.02 percent. These driver behaviors are listed in the table presented at the end of this section; the table provides a comprehensive inventory of all DWI cues identified during the current review.

Although the Moskowitz and Robinson review is the most extensive source of information available about driver impairment at various BAC levels, several other studies identify potential cues for DWI detection. In an Anacapa Sciences' study conducted for the Insurance Institute for Highway Safety, Casey and Stuster (1982) identified the following 12 risky driving behaviors of both automobile and motorcycle operators.

- Running stop sign or traffic light
- Unsafe passing due to oncoming traffic
- Unsafe turn in front of oncoming or opposing traffic
- Following too closely
- Unsafe lane change or unsafe merging
- Weaving through traffic
- Crossing a double line in order to pass
- Passing on the right
- Excessive speed for conditions
- Improper turn
- Splitting traffic
- Stunts

Similarly, Treat et al. (1980), in a study of risky driving actions and their involvement in traffic collisions, identified the following 13 Unsafe Driving Actions.

- Pulling out in front of traffic
- Following behavior
- Speeding: Absolute/Over limit
- Speeding: Relative/For traffic conditions
- Turning in front of oncoming traffic
- Running stop sign or light
- Changing lanes or merging in front of traffic
- Driving left of center or on centerline
- Passing unsafely
- Driving off road to right
- Backing unsafely
- Turning too wide or too sharp
- Turning from wrong lane

Several of these unsafe driving actions also have been identified as indicators of driving while impaired in the Harris et al. (1980) study: *following too closely, fast speed*

(deleted from the final version of the DWI Detection Guide), *failing to respond to traffic signals or signs,* and *driving into opposing or crossing traffic.*

Additionally, several studies suggest stopping method as a primary difference between DWI and unimpaired driving (Attwood et al., 1980; Bragg et al., 1981; Compton, 1985). Differences included *braking sooner* and *stopping jerkily* when under the influence of alcohol.

In a study developing and validating the sobriety field test battery, Tharp, Burns, and Moskowitz (1981) reported the reasons for stopping suspected alcohol impaired drivers. The most common reasons were traffic infractions (e.g., speeding, failing to stop) rather than non-infraction driving behaviors such as weaving or drifting. There is significant overlap between the behaviors reported by Tharp et al. (1981) and the DWI on-the-road detection cues identified by Harris et al. (1980).

In a study evaluating screening procedures for police officers at sobriety checkpoints, cues noticed by officers were correlated with the BAC levels of the drivers. Compton (1985) found significant differences in stopping behavior. In general, drivers stopped smoothly at low BAC levels (0-0.04) and "jerkily" at higher BAC levels (0.10-0.15). Drivers with a low BAC did not swerve, those with higher BACs (greater than 0.10) did. Cues identified by Compton that related to driving and stopping behaviors, and personal appearance, are presented in the comprehensive table at the end of this review. The cues identified in the Compton study include personal appearance variables not previously identified in the 1980 Harris et al. study. These cues include:

- Odor of alcohol
- Face flushed
- Speech slurred
- Eyes dilated
- Demeanor
- Hair disheveled
- Poor dexterity
- Clothes disheveled

Of these personal appearance variables, *odor of alcohol, face flushed,* and *eyes dilated* appear to be the most promising for DWI detection at low BAC levels.

CONCLUSIONS

The objective of the current study is to develop an appropriate set of behaviors that can be used by field officers to accurately identify motorists who are driving while impaired at the 0.08 level, and to determine if cues are available that predict 0.04 and 0.02 BAC levels. No sources were identified that specifically identify behavioral cues for alcohol impairment at the lower levels. However, a table of potentially applicable behaviors has been prepared, based on a comprehensive review of the literature. This list, presented in the following table, includes all behaviors previously discussed in this

review, and shows the considerable agreement among the studies. The behaviors identified here later will be combined with cues identified during interviews with DWI patrol experts, and from the archival research. The resulting comprehensive inventory of DWI cues then will be used to develop data collection forms for the first of the field studies.

COMPREHENSIVE TABLE OF DWI CUES

BEHAVIOR	SOURCE
Accident	Tharp et al., 1981
Almost striking object	Compton, 1985
Almost striking object or vehicle	Harris et al., 1980
Near accident	Tharp et al., 1981
Acceleration in car following	Mortimer & Sturgis, 1975a
Accelerating or decelerating rapidly	Harris et al., 1980
Accelerator reversals	Damkot, 1981
Accelerator use	Huntley & Centybear, 1974
Accelerator, braking	Crancer et al., 1969
Rate of speed changes	Huntley & Centybear, 1974
Distance judgment	Heacock & Wikle, 1974
Distance judgment	Moskowitz & Robinson, 1988
Time and distance estimation	Bech et al., 1973
Glare adaptation	Mortimer, 1963
Drifting	Compton, 1985
Drifting	Harris et al., 1980
Drifting	Tharp et al., 1981
Driving into opposing or crossing traffic	Harris et al., 1980
Driving left of center or on centerline	Treat et al., 1980
Driving off road to right	Treat et al., 1980
Lane tracking	Moskowitz & Robinson, 1988
Lateral position error	Mortimer & Sturgis, 1975a
Not in marked lane	Tharp et al., 1981
Splitting traffic	Casey & Stuster, 1982
Straddling center or lane marker	Harris et al., 1980
Tires on center or lane marker	Harris et al., 1980
Vehicle alignment	Bragg & Wilson, 1980
Vehicle position	Sugarman et al., 1973
Driving off roadway	Compton, 1985
Driving on other than designated roadway	Harris et al., 1980
On inappropriate area	Tharp et al., 1981
Equipment violation	Tharp et al., 1981

BEHAVIOR continued...	SOURCE continued...
Appearing to be drunk	Harris et al., 1980
Looks intoxicated	Tharp et al., 1981
Odor of alcohol	Compton, 1985
Clothes disheveled	Compton, 1985
Hair disheveled	Compton, 1985
Eyes dilated	Compton, 1985
Face flushed	Compton, 1985
Poor dexterity	Compton, 1985
Speech slurred	Compton, 1985
Demeanor	Compton, 1985
Car following	Attwood et al., 1980
Car following	Attwood et al., 1981
Following behavior	Treat et al., 1980
Following too closely	Casey & Stuster, 1982
Following too closely	Harris et al., 1980
Headway in car following	Mortimer & Sturgis, 1975a
Gear changing	Drew et al., 1959
Gear changing	Moskowitz & Robinson, 1988
Gear changing	Rafaelson et al., 1973
Bright Lights	Tharp et al., 1981
Headlights off	Compton, 1985
Headlights off	Harris et al., 1980
No lights	Tharp et al., 1981
Changing lanes or merging in front of traffic	Treat et al., 1980
Unsafe lane change or unsafe merging	Casey & Stuster, 1982
Pulling out in front of traffic	Treat et al., 1980
Unsafe passing due to oncoming traffic	Casey & Stuster, 1982
Passing unsafely	Treat et al., 1980
Passing on the right	Casey & Stuster, 1982
Crossing a double line in order to pass	Casey & Stuster, 1982
Reaction time	Kielholz et al., 1969
Reaction time	Milner & Landauer, 1971
Reaction time	Sugarman et al., 1973

BEHAVIOR continued...	SOURCE continued...
Reaction time to peripheral stimuli	Moskowitz, 1971
Response time to stop in car following	Mortimer & Sturgis, 1975a
Ran stop light	Tharp et al., 1981
Ran stop sign	Tharp et al., 1981
Running stop sign or traffic light	Casey & Stuster, 1982
Running stop sign or light	Treat et al., 1980
Turning abruptly or illegally	Harris et al., 1980
Turning from wrong lane	Treat et al., 1980
Turning in front of oncoming traffic	Treat et al., 1980
Turning too wide	Compton, 1985
Turning too wide or too sharp	Treat et al., 1980
Turning with wide radius	Harris et al., 1980
Improper turn	Casey & Stuster, 1982
Unsafe turn in front of oncoming or opposing traffic	Casey & Stuster, 1982
Accelerator, braking, signal errors	Crancer et al., 1969
Accelerator, speed, signal errors	Crancer et al., 1969
Backing unsafely	Treat et al., 1980
Car handling	Coldwell et al., 1958
Driving accuracy	Damkot, 1981
Driving errors	Milner & Landauer, 1971
Driving test performance	Kielholz et al., 1969
Evasive maneuvers	Laurell, 1977
Garaging	Bjerver & Goldberg, 1950
Parking	Bjerver & Goldberg, 1950
Signaling inconsistent with driving actions	Harris et al., 1980
Slow response to traffic signals	Harris et al., 1980
Stunts	Casey & Stuster, 1982
Speed changes	Damkot, 1981
Speed control	Moskowitz & Robinson, 1988
Speed judgment	Moskowitz & Robinson, 1988
Speed maintenance	Attwood et al., 1980
Speed maintenance	Attwood et al., 1981
Speed maintenance in car following	Mortimer & Sturgis, 1975a

BEHAVIOR continued...	SOURCE continued...
Speed maintenance	Sugarman et al., 1973
Speed on centerline	Bragg & Wilson, 1980
Driving too slow *(sic)*	Tharp et al., 1981
Slow speed (more than 10mph below the limit)	Harris et al., 1980
Speed below the limit	Compton, 1985
Speed above the limit	Compton, 1985
Speeding	Tharp et al., 1981
Speeding: Absolute/Over limit	Treat et al., 1980
Speeding: Relative/For traffic conditions	Treat et al., 1980
Excessive speed for conditions	Casey & Stuster, 1982
Braking	Drew et al., 1959
Braking	Moskowitz & Robinson, 1988
Braking erratically	Harris et al., 1980
Braking sooner	Attwood et al., 1980
Braking time	Rafaelson et al., 1973
Emergency braking	Laurell, 1977
Number of brake applications	Damkot, 1981
Stopping (without cause) in traffic lane	Harris et al., 1980
Stopping accuracy	Smiley et al., 1975
Stopping fast	Compton, 1985
Stopping inappropriately (other than in lane)	Harris et al., 1980
Stopping jerkily	Compton, 1985
Stopping other location	Compton, 1985
Stopping slowly	Compton, 1985
Stopping smoothly	Compton, 1985
Stopping where indicated	Compton, 1985
Stops in lane without cause	Tharp et al., 1981
Steering	Bjerver & Goldberg, 1950
Steering	Drew et al., 1959
Steering	Huntley & Centybear, 1974
Steering	Landauer et al., 1974
Steering	Mortimer & Sturgis, 1975b
Steering	Moskowitz & Robinson, 1988
Steering performance	Mortimer & Sturgis, 1975b
Time taken to apply steering correction	Mortimer & Sturgis, 1975a

BEHAVIOR continued...	SOURCE continued...
Swerving	Compton, 1985
Swerving	Harris et al., 1980
Tracking	Drew et al., 1959
Tracking	Mortimer, 1963
Tracking	Moskowitz, 1971
Tracking under glare	Mortimer, 1963
Weaving	Compton, 1985
Weaving	Harris et al., 1980
Weaving	Tharp et al., 1981
Weaving through traffic	Casey & Stuster, 1982

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APPENDIX C

RESULTS OF THE INTERVIEWS WITH EXPERT OFFICERS