Jerry Tannahill
Gary C. Baden

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ASSESSMENT OF VEHICLE SAFETY PROBLEMS FOR SPECIAL DRIVING POPULATIONS

A. James McKnight, Molly A. Green,
Frank Masten and Rodger J. Koppa

National Public Services Research Institute
123 North Pitt Street
Alexandria, Virginia 22314

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Dr. McKnight and Mrs. Green are on the staff of NPSRI. Mr. Masten is on the staff of Central Missouri State University. Mr. Koppa is a consultant to NPSRI. Mr. Michael Perel of NHTSA served as Contract Technical Manager.

16. Abstract

This report describes vehicle safety problems reported in interviews with 460 physically limited drivers and 41 physically limited non-drivers. The problems reported involved operation of primary and secondary controls, operating other vehicle mechanisms (e.g., restraints, seat adjustments), seeing properly, getting in and out of the vehicle, and handling certain tasks outside the car. The following needs were identified on the basis of information obtained during the study:

- Better *dissemination of information* to physically limited drivers concerning vehicle design considerations, equipment options, available aids and devices, operating procedures, and procedures for maintaining adaptive control equipment.
- Development of *additional assistive devices*, including a secondary control stalk, rear vision system, supportive restraint systems, and a means of preventing feet from sliding under foot pedals.
- Improvements in *adaptive control systems*, including improvements in reliability, comfort, compactness, and physical appearance.

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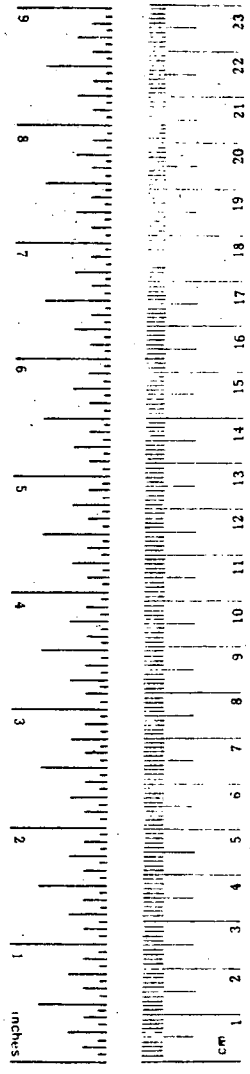
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
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cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
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km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
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l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
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m^3	cubic meters	1.3	cubic yards	yd^3
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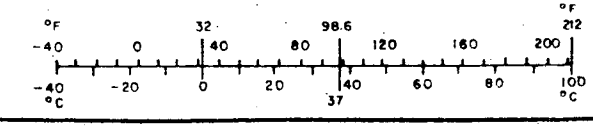

PREFACE

This report describes driving problems reported by 460 physically limited drivers and 41 physically limited non-drivers. Recommendations for alleviating and overcoming these problems are also provided.

The report was prepared by the National Public Services Research Institute. Dr. A. James McKnight served as Principal Investigator, while Ms. Molly A. Green was responsible for administration and supervision of interviews in the Washington, D. C. area. Mr. Rodger Koppa, currently on the staff of the Texas Transportation Institute, served as a consultant to the project staff and supervised interviews in the eastern Texas area. Mr. Frank Masten supervised interviews in the Missouri area. Ms. Diane Katz assisted in preparation of this report. Mr. Michael Perel of NHTSA served as Contract Technical Manager, in which capacity he not only managed the contract but also carried out the processes required to obtain clearance of the survey under provisions of the Federal Reports Act.

The project staff is indebted to the following individuals and organizations for their assistance in development of the interview procedures and in arranging access to physically limited drivers: Mr. Hank Beasley and Mr. John Lancaster of Paralyzed Veterans of America; Mr. Ronald Drach and Mr. Charles Joeckel of Disabled American Veterans; Mr. Anton J. Reichenberger and Mr. John Sykes of the Veterans Administration; Col. Oliver J. Lawless and Capt. Chris Swann of Walter Reed Army Hospital; Mr. Darrell Crain of the National Arthritis Rehabilitation Center.

We also wish to acknowledge the work of the interviewers whose names appear in Appendix D. The organizations that provided assistance to the project are listed in Appendix E. Finally, a note of appreciation is extended to the 501 physically limited individuals whose willingness to relate their experiences and describe their problems will, we hope, ultimately prove of benefit to physically limited drivers everywhere.

DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

TECHNICAL SUMMARY

CONTRACTOR	CONTRACT NUMBER
National Public Services Research Institute	DOT-HS-6-01439
REPORT TITLE	REPORT DATE
"Assessment of Vehicle Safety Problems for Special Driving Populations: Final Report"	February 16, 1979
REPORT AUTHOR(S) A. James McKnight, Molly A. Green, Frank Masten, Rodger J. Koppa	

OBJECTIVE

The objective of the study described in this report was to identify the driving problems encountered by physically limited drivers as well as physically limited individuals capable of driving but not driving at the present time.

BACKGROUND

Physically limited drivers face problems not encountered by the able-bodied. Many of these problems have an adverse effect upon safety, mobility, convenience, and comfort. While there is no evidence that they have resulted in an inordinate accident rate, they represent a potentially fertile area for improving safety of vehicle operation.

METHOD

Data concerning problems encountered by physically limited drivers and non-drivers were obtained through face-to-face interviews conducted in four geographical areas: Metropolitan Washington, D. C.; Missouri; Illinois; and Texas. Interviewers were aided by an Interview Guide that identified problems likely to be encountered by physically limited drivers. The Guide was developed by analyzing the effect of physical limitations upon critical driving tasks. A sample of 461 drivers and 41 non-drivers was obtained. Probability sampling was not possible owing to the lack of available information concerning characteristics of physically limited drivers. However, the sample is believed to be generally representative of physically limited drivers with respect to age and sex characteristics.

RESULTS

Results are classified in terms of three major categories of physical limitation: limited coordination, limited range of motion, limited strength. Major problems can be summarized as follows:

(Continue on additional pages)

"PREPARED FOR THE DEPARTMENT OF TRANSPORTATION, NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION UNDER CONTRACT NO.: DOT-HS-6-01439 . THE OPINIONS, FINDINGS, AND CONCLUSIONS EXPRESSED IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND NOT NECESSARILY THOSE OF THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION."

Use of Conventional Primary Controls--Problems in operation of conventional primary controls include:

- Difficulty in gripping and turning the steering wheel
- Difficulty in reaching and applying the brake quickly; feet slipping under the brake pedals
- Fatigue from prolonged operation of the accelerator
- Difficulty in manual shifting

Use of Adaptive Primary Controls--Problems with adaptive controls include the following:

- Breakdowns and malfunctions in control mechanisms
- Fatigue from prolonged operation
- Control mechanism suspended below steering column
- Lack of qualified mechanics

Use of Secondary Controls--Problems reported in operation of secondary controls (dimmer, wiper, horn, signals) include the following:

- Difficulty in operating while using primary controls
- Difficulty in reaching dash-mounted and floor-mounted controls
- Difficulty in manipulating control mechanisms

Use of Other Mechanisms--Problems in operating other mechanisms include the following:

- Difficulty in operating ignition switch
- Difficulty in reaching and fastening restraints
- Failure of restraint systems to provide support
- Difficulty in reaching and/or operating parking brake
- Difficulty in making seat adjustments
- Difficulty in raising and lowering windows

Seeing--Drivers with visual problems were not included in the sample. However, the following problems were reported:

- Inability to turn head to check the blind spot when changing lanes
- Inability to see out the back window when backing
- View obstructions from high seatbacks, mirror placement, lift mechanisms

Entering and Leaving the Car--While not potentially hazardous, problems in entering and leaving the car tend to limit mobility. They include:

- Primary control mechanisms that get in the way
- Inappropriate seat design (e.g., bucket seats)
- Difficulty in manipulating doors and door latches
- Door openings that are too small
- Difficulty getting the wheelchair in and out of the vehicle
- Difficulty in transferring from the wheelchair to the car seat
- Difficulties with lift systems

Problems Outside the Car--While the study focused upon vehicle-related problems, the following problems outside the vehicle were identified:

- Difficulty in changing tires
- Inability to find help in the event of vehicle breakdown
- Poorly located and designed reserve parking spaces

In addition to these specific problems with the vehicle and its environment, the following general problems were identified:

- Lack of information concerning vehicle selection, available options and special devices, critical operating procedures, and the need for appropriate maintenance.
- Lack of available services
- High cost of adaptive controls
- Poor appearance of special aids

The problems encountered by non-drivers parallel those of drivers. Generally speaking, the non-drivers were more fearful of operating a vehicle given the problems that were encountered.

RECOMMENDATIONS

Based upon the results of the study, the following recommendations for action at the national level were offered:

Dissemination of Information--The information available to physically limited individuals should be improved by (1) expanding content to include a broader array of information, and (2) tailoring the design of materials to available information delivery systems.

Devices and Aids--The range of aids and devices available to physically limited drivers should be expanded to include such devices as (1) a secondary control stalk, (2) foot restraints, (3) wheelchair assists, (4) rearward vision system, and (5) restraint systems designed specifically for physically limited drivers.

Adaptive Control Systems--Research and development should be undertaken to improve the reliability, comfort, physical appearance, and compactness of adaptive control systems.

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INTRODUCTION

The term "physically handicapped" is applied most generally to individuals having some physical impairment that adversely affects their ability to carry out life's activities. In its most specific application, it refers to people whose impairment involves limited ability to effect the motor response needed in life's activities. In the latter category are such people as polio victims, paraplegics, amputees, and hemiplegics (stroke victims), among others.

Among the life activities that are affected by limitations in motor response are those required in operating an automobile. The responses concerned include those involved in manipulating vehicle controls, moving the head and eyes to receive visual input, operating other vehicle mechanisms, getting in and out of the vehicle, maintaining it, and maneuvering between the vehicle and other locations. A great deal of effort has been devoted to finding ways of allowing physically handicapped people to drive safely and comfortably despite their limitations.

The term "handicapped" implies a disadvantage. The efforts of people labeled "physically handicapped" to see that their condition does not place them at a disadvantage makes use of the term not only inaccurate but somewhat insulting. In this report, we use the term "physical limitation" in reference to the conditions mentioned, and "physically limited" in reference to the drivers having these limitations. The term is based upon the objective fact that the physical abilities of the individuals are limited. It is not intended to imply a limitation in either the aspirations of these people or their success in realizing those aspirations.

EFFECT OF PHYSICAL LIMITATIONS UPON DRIVING SAFETY

A limitation in a driver's ability to manipulate controls or receive needed visual inputs obviously raises a question as to whether that driver is capable of operating safely. A number of studies have been undertaken to assess the hazard represented by physically limited drivers through examination of their accident and violation records. A recent study by Negri (1978) showed that physically limited drivers have significantly higher accident rates than their able-bodied counterparts. This finding is contrary to earlier research by Crancer and MacMurray (1968), Wysander (1973), Hyman (1973), and the District of Columbia (1973), all of which found physically limited drivers and able-bodied drivers to have similar accident records. 1/ McFarland (1968) actually found lower accident rates among the physically limited, although not in comparison with professional drivers.

Moving from accidents to violations, there is evidence that physically limited drivers are as law-abiding as able-bodied drivers. The studies of Crancer and MacMurray, McFarland, and Wysander showed lower conviction rates for physically limited drivers, while Hyman's study revealed no differences. All of the above studies dealing with accidents and violation rates are described in detail in a recent review of the literature on special driving populations by Brainin, et al (1976).

The discrepancies among the various studies may be explained in part by differences in the method used to identify physically limited drivers. Those based upon licensing records include only those whose limitations are severe enough to result in their license bearing a restriction. Those that identified physically limited drivers through hospitals or rehabilitation agencies would tend to include the less severely limited drivers.

Taken as a whole, the results of the various studies that have been performed tend to lend no support to the fear that physically limited drivers present an inordinate hazard to the public. This does not mean that the various limitations have no effect upon safety of operation. It is widely believed that they do, but the danger they represent is offset by the tendency of physically limited drivers to drive fewer miles, do their driving under less hazardous conditions, and to exercise more caution when they do drive. The literature does not establish whether these factors are responsible for the low accident and conviction rates of physically limited drivers. No good information exists concerning the amount and type of driving in which physically limited drivers engage.

1/ The results cited in reference to the work of Crancer and MacMurray apply only to the accident and violation rates of men. While the study also included the driving records of women, questionable accident and violation rates for one age category rendered the results inconclusive in the opinion of the authors.

SAFETY MEASURES

It really doesn't matter whether physically limited drivers present a greater or lesser safety problem than their able-bodied counterparts. What is most important is that they present a different problem. Any physical limitation that affects the driver's ability to handle the car or receive visual inputs is bound to impose demands upon the driver that are substantively different from those imposed upon the able-bodied. Special measures must be taken to help drivers cope with those demands. The measures that have been taken can be categorized as follows:

Primary Control Aids--Devices that assist drivers in operating primary controls, including:

- Hand-operated brake and accelerator (i.e., adaptive controls)
- Low effort power steering
- Spinner knobs and cuffs for better grip and one-handed steering
- Left foot accelerator

Secondary Control Aids--Devices that assist drivers in operating other mechanisms over which control must be exercised while driving, including:

- Steering column mounted dimmer and horn
- Right side turn indicator

Aids to Bodily Movement--Devices designed to assist the driver in entering and leaving the vehicle as well as moving within the vehicle, including:

- Electrical lifts
- Transfer boards
- Helper bar, gutter strap

Other Aids--Devices designed to assist in carrying out other tasks, including:

- Parking brake extension
- Extension hook
- Placards, signs
- Special mirrors

These devices have gone a long way to improve the mobility and safety of the physically limited driver. But how far? The following questions arise as to the adequacy of measures that have been thus far taken to aid physically handicapped drivers:

- How well do existing aids succeed in meeting the needs of physically limited drivers?
- What are the specific shortcomings of existing aids?
- What problems do the aids themselves create?
- What problems require the development of new aids?

STUDY OBJECTIVE

The objective of the study described in this report was to identify problems encountered by physically limited drivers and non-drivers and to outline solutions to these problems. For purposes of the study, a *physically limited driver* was defined as an individual who is currently operating a motor vehicle with some physical disorder that (1) can affect the safety of vehicle operation, and (2) is potentially capable of being ameliorated through design or re-design of the vehicle, use of special equipment, or modification of the vehicle's operating alignment.

While the study was concerned primarily with identifying problems encountered by physically limited individuals who are currently driving, the contract also called for interviewing individuals who were no longer driving. The purpose of interviewing non-drivers was to identify the problems that were sufficiently severe to result in loss of mobility. For the purposes of this study, this *physically limited non-driver* was a physically limited individual who has the ability to operate an automobile but has elected not to. The individual may never have driven since being afflicted by the disability or may have driven and subsequently given it up.

METHODOLOGY

There was no way of knowing in advance the kinds of problems that would be encountered by drivers having various physical limitations. Therefore, any objective survey in which physically limited drivers respond to a predetermined list of problems was not possible. It was necessary to use a data collection method that both enabled and assured the identification of problems by the drivers themselves.

The remainder of this section will describe (1) development of an interview guide, (2) the selection of a sample of physically limited drivers for interviewing, (3) the selection and training of interviewers, and (4) analysis methods.

Use of the "critical incidence" technique appeared to be the only approach that would elicit specific driving problems from physically limited drivers. There are a number of variants of the critical incidence technique. One involves keeping daily records of incidents. This was considered inappropriate because the frequency with which significant problems arise is too low to have yielded substantial numbers of incidents during the span of the project. A second approach is one in which individuals prepare written reports of incidents that occurred in the past. This was not considered appropriate because of (1) the inability of drivers to recall many of the incidents that occurred in the past, and (2) the anticipated reluctance of physically limited drivers to record in writing incidents that might reflect adversely upon their fitness to drive.

The alternative chosen was a face-to-face interview. This approach had the following advantages:

> Stimulating Recall--An interview situation permitted a series of probing questions to stimulate the driver's recall of incidents that might otherwise be overlooked.
>
> Anonymity--There was no need to record names of drivers since information supplied could be clarified on the spot. Given the sensitivity of the information provided, a guarantee of anonymity was considered necessary.

The effectiveness of an interview approach to collection of critical incidence information would depend largely upon the success of the interviewer in formulating questions capable of stimulating recall. To formulate such questions, an interviewer would have to have

some idea of the types of problems that drivers with specific limitations might encounter. Such knowledge demands a thorough understanding of both the needs of driving and the relation of various physical limitations to these needs. Such specialized knowledge is available to few people. The only way in which it could be brought into the interview process was by applying the knowledge that did exist to the development of an interview guide that could be used by interviewers lacking such knowledge. The interviewers would, of course, have to be skilled in the process of obtaining information from people. However, they would not have to have the deep understanding of driving and physical limitations that would be required in formulating the questions in the first place.

DEVELOPMENT OF INTERVIEW GUIDE

The development of an interview guide involved the following steps:

- Review of the literature
- Identification of problems and solutions
- Development of preliminary guide
- Development of final guide

Literature Review

A literature review was performed to collect information on the following subjects:

- Specific disorders capable of influencing the safety of motor vehicle operation.
- Relationships between disorders and driving safety.
- Means by which the effect of disorders might be ameliorated or overcome through modification of the vehicle.

The following sources of pertinent literature were investigated:

- Dunlap Associates Report of "Special Driving Populations"--This report contains some seventy references to articles concerning the physically handicapped. Out of these, some 50 appeared to be relevant to the present project. All of these were reviewed save for a few written in foreign languages.

- NHTSA Technical Library--A computer search of NHTSA's Highway Safety Literature yielded a printout of 740 abstracts. Of these, only 75 appeared relevant to project objectives and 40 were duplications of references from the Dunlap Report. The remaining 35 references were reviewed.

- National Medical Library--A search was made of the National Medical Library's "Medline" file of reports completed since 1974. Eight additional references were obtained from this source and reviewed.

- American Psychological Association--A search of the APA's abstract file was confined to the intersection of (1) physical handicaps and age as independent variables, and (2) driving as the dependent variable. This produced 14 items, of which only three appeared relevant. These were reviewed.

- Smithsonian Science Information Exchange--The SSIE provides descriptions of ongoing research. A search was requested and produced the names of two organizations, one of which was Dunlap and Associates. The other was the Rehabilitation Medical Institute of New York University. All the literature available from this organization was reviewed.

The books and articles employed as background materials are listed in Appendix A.

Selection of Disorders

The literature review encompassed all physical problems capable of having an effect upon driving. On the basis of information gained from the literature, several specific problems were eliminated. These included the following:

> Loss of Consciousness--Problems that result in loss of consciousness, including diabetes, epilepsy, and cardiovascular problems, were eliminated because of the inability to overcome the effects of these problems through vehicle modification or other engineering approaches. The problem is largely a medical one and amenable primarily to medical solutions.

Sensory Impairment--Visual and auditory handicaps were eliminated because they, too, are correctable primarily through medical solutions. While the specific remedies are essentially an engineering design problem (e.g., glasses, hearing aids), they apply to individuals rather than the vehicles they drive or the environment in which they operate.

Progressive Diseases--Diseases that involve progressive deterioration, such as amotrophic lateral sclerosis, or multiple sclerosis, were largely excluded. The reason is that the period of time during which the problem is severe enough to affect driving yet capable of being overcome is usually quite brief. However, some multiple sclerosis victims had driven extensively with their limitation and were included.

Rarity--The fact that a disease is extremely rare does not make it less of a problem for those afflicted. However, the likelihood of being able to identify and gather information from sufficient numbers of such individuals was not great. Moreover, it is not likely that vehicle modifications would be directed toward the unique problems of the individuals involved.

When the above exclusions had been made, the list of physical limitations that defined the scope of the study were as follows:

Paraplegia	Arthritis
Quadraplegia	Amputation
Poliomyelitis	Spondylitis
Cerebral Palsy	Congenital Deformity
Hemiplegia	

Classification of Disabilities

The above list of disorders does not represent a particularly useful classification in the study of driving problems. Within most of the disorders identified, effects upon driving can differ substantially as a function of the specific nature and the seriousness of the affliction. For example, the effects of amputation upon driving clearly depend on what part of the body was amputated. Arthritis, polio, and congenital deformity also affect different parts of the body with differing effects upon driving. Quadraplegia is probably the only category that involves a fairly homogeneous set of driving problems.

A classification system that subdivided each disorder by part of the body would have produced an extremely large number of categories. Trying to provide specific guidance to each category would have produced an interview guide that was rather unwieldy. Therefore, the various specific physical disorders were grouped into the following three functional categories:

> Coordination--This group included all disorders that limited the driver's ability to coordinate motion of bodily members. All of the members are present and are capable of motion. It is simply that the motion cannot be adequately controlled. The specific physical limitations include paraplegia, quadraplegia, polio, hemiplegia, and cerebral palsy.
>
> Range of Motion--This category included those disorders that limit the ability of individuals to reach and operate various components of the automobile. It includes amputation, congenital deformity, and dwarfism.
>
> Strength of Motion--This category includes disorders that limit the strength and endurance of the driver in carrying out operating tasks. It includes arthritis and a variety of physical problems that resemble it closely.

Within each of these functional groups, the individuals were subdivided according to the specific part of the body affected, including the following:

- Upper torso
- Lower torso
- Shoulders
  - Bilateral
  - Left
  - Right
- Elbows
  - Bilateral
  - Left
  - Right
- Wrists
  - Bilateral
  - Left
  - Right
- Hands
  - Bilateral
  - Left
  - Right
- Hips
  - Bilateral
  - Left
  - Right
- Knees
  - Bilateral
  - Left
  - Right
- Ankles
  - Bilateral
  - Left
  - Right
- Feet
  - Bilateral
  - Left
  - Right

This classification was believed to be highly functional in classifying driving problems in that drivers falling in a particular category would be expected to have similar problems, while those in different categories would be expected to have different problems.

Identification of Problems and Solutions

The next step in developing a guide to identification of driving problems was to prepare an exhaustive inventory of the problems that drivers in each category might be expected to encounter. Developing this list was largely a matter of determining what driving tasks would be affected by each category of physical limitation, and what the effects would be likely to be. While the literature provided some insights into difficulties experienced by physically limited drivers, it fell far short of identifying all or even most of the problems that could be encountered.

The approach used in identifying potential driving problems involved examining all of the tasks that drivers had to perform and evaluating each in relation to every one of the specific categories of deficiency involved. This was done in two stages.

In the first stage, members of the project staff reviewed the 1800 tasks listed in the Driver Education Task Analysis (McKnight and Adams, 1970). The activities in each task were examined to determine whether they could possibly be affected by the types of physical limitations being considered. Those tasks that would be unaffected by any of the physical limitations, or would be so totally affected that they would not ordinarily be performed by a physically limited individual, were eliminated from further consideration. The remainder were assembled into a list of limitation-affected tasks.

The second step in preparing an inventory of driving problems was to have the entire list reviewed by individuals knowledgeable in the various physical limitations and their affect upon driving. Each task was examined against each of the categories of physical limitation in order to identify the specific problems that drivers having that specific limitation would experience in performing that task.

The result of this activity was a comprehensive inventory of potential driving problems, each associated with a particular set of specific physical limitations. This inventory of problems would serve to guide interviewers in probing for critical incidents during the interview process.

Preparation of Preliminary Interview Guide

The development of an Interview Guide involved (1) translating the specific driving problems into a list of "prompts" for the interviewer, and (2) formulating general interview procedures.

Preparing List of Prompts

Each of the potential driving problems was converted into a question form. For example, many physically limited drivers have difficulty using the foot brake or, when they have adaptive control system, the hand brake. It can show up in simple inability to brake, overbraking and locking the wheels, accidental brake application, or moving quickly from brake to accelerator when stopped on a hill. This problem appeared as follows:

DO YOU HAVE ANY PROBLEM WITH BRAKING?

Have you had any problems:

a. Because you tried to brake and couldn't?

b. Because you inadvertently locked the wheels or put the car into a skid by applying the brakes too hard?

c. Because you hit the brake accidentally?

d. Because you had to stop on a hill and had difficulty going from the brake to the accelerator quickly?

Each of the prompts was assigned a number. Next, a "Prompt References" sheet was prepared. This sheet was a matrix made up of (1) functional disability categories (coordination, range of motion, strength of motion), and (2) the part of the body affected. In each cell of the matrix were placed the numbers of the problems that were related to the various combinations of functional limitation and parts of the body. The Prompt Reference would enable an interviewer to determine which specific set of prompts was appropriate to specific limitations of the individual about to be interviewed.

General Procedure

A set of procedures for applying the Prompt References through an interview process was developed. The objective of the procedure was to help assure that the greatest amount of accurate information would be elicited. The interview was divided into four phases: (1) introduction, (2) problem description, (3) prompting, and (4) closing.

Introduction

The procedure called for opening the interview with a brief explanation of the project, including its nature, purpose, and sponsorship. The goal of the project was explained as that of finding out what problems were presented by driving and what could be done to make automobiles easier and safer for disabled drivers to operate. Drivers were assured that the information furnished in the interview would be held confidential and that all identifying information would be removed, making it impossible for anyone to associate information furnished with the individual furnishing it.

A limited amount of biographical information was obtained at the beginning of the interview, including whether the individual drove, the nature of the disability, the parts affected, how long the individual had been driving with the disability, and how the vehicle was equipped with options, accessories, and adaptive equipment. This information was needed in guiding the interview. Collection of additional information was delayed until after the interview had been completed in order to avoid establishing a "question-and-answer" format that would tend to inhibit the spontaneous identification of problems.

Problem Description

Once the introduction was completed, drivers were asked to describe any disability-related driving problems. A "problem" was anything the driver considered to be a problem. However, the interviewer attempted to focus upon those problems that affected the safety of operation, with less attention to those affecting the comfort and convenience categories.

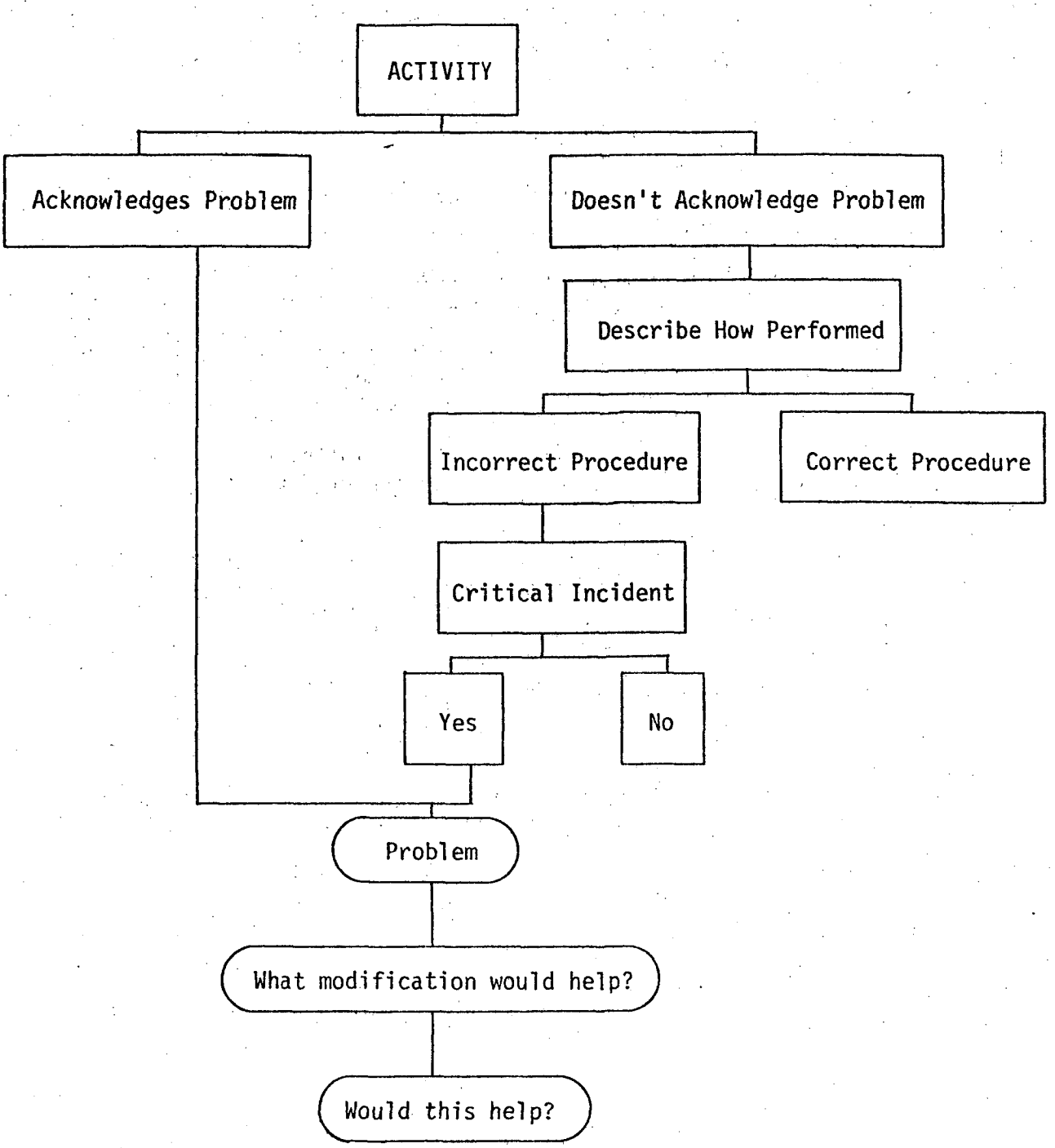
Once the spontaneously offered problems (if any) were exhausted, the procedure called upon the interviewer to probe for possible problems by the "prompt" questions. As explained earlier, a prompt involved a question related to a task known to be a potential problem for drivers having the interviewee's particular disability. Where drivers acknowledged having a problem with the task, they were simply asked to describe the problem. Where drivers failed to acknowledge the problem, they were asked to describe how they carried out the task. If their description revealed a potential hazard, then they would be asked if they had had any critical incidents. For example, bilateral lower limb amputees might be asked if they had difficulty turning on windshield wipers when it started to rain. If they answered "no," they would be asked to describe their procedure in turning on the wipers. If they described use of a steering column-mounted wiper control, nothing further would be said. If, on the other hand, they mentioned having to release the steering wheel in order to reach a dash-mounted wiper control, they would be asked if it had ever resulted in a problem. Even if they did not acknowledge any critical incident, their response would be described as a "problem" since it involves a manifestly unsafe action.

While the focus of the study was primarily upon identification of driving problems, the collection of data was broadened to include information as to possible *solutions* to problems encountered. Physically limited drivers cannot be expected to design modifications to help overcome the effects of their problems. Although many have done so, with results ranging from the extremely crude to the moderately sophisticated. What the physically limited driver can do is to provide insight into the suitability of any suggested solutions to their particular problems.

Had there been sufficient resources to visit each physically limited driver twice, the appropriate procedure would have been to confine the first interview to collection of problem information, develop possible solutions based upon these problems, and then return to obtain an assessment of the suitability of the proposed solutions. However, neither time nor funds permitted such a two-stage approach. Therefore, it was necessary to provide interviewers with information as to types of modifications that represent potential solutions and then have the physically limited drivers react to them.

The interview process, including the prompting process and the assessment of potential solutions, can be depicted graphically as follows:

PROMPTING PROCESS



Closing the Interview

Approximately one hour was allocated to the interview process. This time allocation was based upon an estimate as to how much time it would take to extract the maximum information drivers would be able to furnish. As the end of the interview approached, or as individuals were unable to describe any more problems, the interview closed with the remaining biographical questions, relating to license restrictions, amount and purpose of driving, use of medication, vehicle make and model, and a general invitation to provide information that might result in making cars easier to drive.

Pretesting

Once the interview guide was completed, it was administered to 9 physically limited drivers, representing a variety of specific disorders. These preliminary interviews revealed several deficiencies requiring (1) additions to the lists of accessories and adaptive equipment, (2) improved wording of prompts, and (3) a change in format for describing the amount of time devoted to different types of driving from actual percentages to adjective descriptions (e.g., "almost all," "very little").

The revised procedures were then applied to another 9 physically limited drivers to verify their adequacy. Discovering no major problems, the Interview Guide was prepared in final form and submitted to the Office of Management and Budget for clearance. A copy appears in Appendix B.

Non-Drivers

Once Interview Guides had been prepared for physically limited drivers, comparable guidance material was prepared for interviews with non-drivers. Biographical questions were re-worded to apply to the period of time during which the individual drove. The prompts were also placed in the past rather than present tense (e.g., "did you..." rather than "do you...").

SAMPLE SELECTION

The contract under which the problem took place called for interviews with 400 physically limited drivers and 100 physically limited non-drivers. The sampling process involved (1) establishing sample characteristics, (2) selecting sampling sites, and (3) sample solicitation.

Establishing Sample Characteristics

If recommendations resulting from the study were to have general application, it was important that the problems reported by drivers surveyed during the study be generally representative of those encountered by drivers throughout the country. A true probability sample was out of the question since it would have required identifying the population of physically limited drivers in advance. The only source of such information was raw census data, which could not be used for selection of individuals.

The objective of the project was to obtain insight into the problems encountered by physically limited drivers, not to develop precise estimates of particular population parameters. Therefore, all that was necessary is that the sample be free from any bias that would result in the omission of significant problems or the over-estimation of insignificant ones. This meant the sample had to include:

- Sufficient numbers of drivers in each functional category to permit reliable sampling.
- Age and sex distributions that are generally characteristic of physically limited drivers in the various categories.
- Samples drawn from at least two geographical areas within the country.

General quotas for each functional area were established as follows: Coordination - 200, Range of Motion - 100, Strength of Motion - 100. The greater sampling of the drivers with limited Coordination reflects the greater number of specific disorders that make up this category. Within each of the categories, quotas were further subdivided by age, sex, and part of body affected, using unpublished statistics obtained from the U.S. Public Health Service. They appear in Appendix C. These quotas were to be treated as sampling objectives, and not strict requirements. First of all, they were based upon statistics obtained from the physically limited population as a whole, not as a portion of it licensed to drive automobiles. Although statistics concerning the driving population were unavailable, one might expect the population of physically limited drivers to be somewhat younger and to include a higher proportion of males than does the entire population of physically limited people. Secondly, any attempt to match population characteristics had to take place within the numbers responding to a solicitation. Only where the number volunteering to be interviewed exceeded the quotas could any selection be exercised.

The primary function of the quotas was to provide a basis for evaluating the representativeness of the sample finally obtained. For example, the arthritic population should be an older one and contain a higher proportion of females than the other two functional categories. The Range of Motion category, on the other hand, should be a younger population and primarily male. The Coordination group should fall somewhere between the other two categories relative to both age and sex.

Site Selection

Two primary sample locations were selected: the Metropolitan Washington, D. C. area, and the State of Missouri. The basis of this selection was the availability of individuals knowledgeable in the relationship between physical limitations and driving safety and who had skill and experience in interviewing. The selection of the two sites--one a Metropolitan East Coast location, the other a rural mid-west location--was expected to give the sample as broad representation as possible relative to variables that might mediate the relationship between physical limitations and driving safety.

As the study progressed, two secondary sites were opened in order to permit sampling of certain categories of physically limited drivers not readily available in the other two sites. Opening of these sites was permitted by the availability of personnel qualified for the work by extensive research in driving by the physically limited. Consideration was given to establishment of a West Coast site. However, the benefits of opening an additional site were not commensurable with the cost of doing so.

Sample Solicitation

The solicitation of a subject sample was greatly hampered by the inability of the project staff to gain access to names and addresses of physically limited drivers. The only organizations having such information were the public and private groups giving assistance to physically limited drivers, such as hospitals, vocational rehabilitation agencies, and various associations of physically limited individuals (e.g., Paralyzed Veterans of America, Arthritis Foundation). Officials of these organizations felt that releasing names would violate constituents' privacy. The three major forms of solicitation employed were as follows:

Mail Solicitation--While not permitting release of the names of their constituency, disability assistance agencies were willing to mail out solicitations encouraging participation and inviting those interested to get in touch with the project staff. Many enclosed return envelopes to encourage and facilitate a response.

Direct Contact--Those organizations having direct contact with physically limited drivers (hospitals, clinics) permitted representatives of the project staff to speak directly with individuals and request an interview.

Individual Referral--Most of the physically limited drivers interviewed were able to provide names of friends and acquaintances who were also physically limited. Because they allowed their own names to be used, the leads they provided were very helpful in enlisting the cooperation of others.

Early in the project, thought had been given to using licensing records as a route to identification of physically limited drivers. While State licensing officials were very cooperative, the information they had available would only permit identification of drivers whose limitation required some license restriction. Most of the drivers in the Strength of Motion category would not be under licensing restriction.

It turned out that license restriction was not a good way of identifying physically limited drivers of any type. A search of the Virginia licensing records identified only 55 drivers operating under restrictions that implied a physical limitation (e.g., adaptive controls, right-side turn indicators, etc.). Slightly less than half of the entire interviewed drivers were operating under license restrictions resulting from their physical limitations. This included about 1/4 of those in the Coordination category. Doubtless a high percent of those in the Physically Limited population are not so severely afflicted as to deserve license restrictions. However, it is also likely that substantial numbers of the more severely afflicted drivers obtained licenses before being afflicted and have simply escaped notice.

Individuals volunteering or agreeing to be interviewed were telephoned and were asked a few questions to verify the nature and extent of their disability and their driving status (i.e., driver, non-driver). Except for those contacted directly at hospitals and clinics, appointments were made to visit individuals in their home or place of work.

SELECTION AND TRAINING OF INTERVIEWERS

The persons responsible for conducting the interviews in the two primary and two secondary areas were as follows:

Washington, D. C. area - Molly A. Green (National Public Services Research Institute)

Missouri - Frank L. Masten (Central Missouri State University)

Texas - Rodger Koppa (Consultant)

Illinois - Warren P. Quensel (Consultant)

From the staff of each of these institutions, three to four interviewers having the following qualifications were selected: (1) training and/or experience in the behavioral aspects of traffic safety, (2) some knowledge of physical limitations, (3) experience in interviewing, (4) a pleasant non-threatening personality, (5) access to an automobile, (6) the ability to conduct at least five one-hour interviews a week, and (7) the ability to meet the scheduling restrictions of drivers being interviewed.

A list of the interviewers appears in Appendix D to this report.

Each of the interviewers participated in a two-day training program. This training program encompassed the following subjects:

Project objectives

The nature of driving processes

The nature of physical limitations

Common driving problems

Adaptive controls and other aids

Interview data requirements

Interview procedures

Practice interviews

The first few actual interviews were critiqued by the site supervisor and discussed with the interviewer. Most of the deficiencies uncovered in these early interviews had to do with (1) missing items of objective data, (2) misclassification of disabilities, and (3) inadequately delineated narrative information (mixing descriptions of problems with ancillary, non-problem related information).

ANALYTIC METHODS

Results obtained from the interviews were analyzed in the following manner:

Biographical Information

Responses to all items of information under the heading of "Biographical Information" were tallied and frequency distributions prepared for each functional category of limitation.

Problem Descriptions

The descriptions of problems were obtained in narrative form and, therefore, had to be coded before they could be analyzed. A 6-digit code number was used.

> Vehicle Component--The first two digits of the code number identified the specific vehicle component to which the problem related (e.g., steering wheel, door, hand control). Those problems not relating to any specific component (e.g., general fatigue) were assigned a special code number.
>
> Difficulty--The second two digits identified the nature of the difficulty encountered (e.g., can't reach, difficult to operate, interference).
>
> Conditions--The last two digits identified the specific conditions under which the problem arose. The great majority occurred either all the time or whenever the vehicle was in operation and, therefore, fell under one of two code numbers. Examples of specific conditions were "when turning corner," "when stopping."

Problem Solutions

The solutions offered by the interviewees to the problems they reported were reviewed but not tallied. Obviously, the important concern is whether or not a proposed solution is a good one, and not how often it was suggested. Those that had merit were recorded and are described in the following section.

RESULTS

The following presentation of results focuses primarily upon physically limited drivers, including (1) *characteristics* of the physically limited driver sample, and (2) *driving problems* encountered by the physically limited drivers. A short section at the end describes both characteristics and the problems of the physically limited non-driver sample.

SAMPLE CHARACTERISTICS

Before describing the problems encountered by physically limited drivers, let us first look at the characteristics of the sample itself. The final sample included 460 physically limited drivers, and 41 physically limited non-drivers, for a total of 501 individuals. Early in the data collection period, it became apparent that target quotas for non-drivers would not be realized, for reasons that will be noted in discussion of this group. The number of physically limited drivers was increased to offset this shortfall. The following sections will deal exclusively with drivers. The characteristics of non-drivers, and the problems they reported, are described at the end of the Results section. The chart on the following page shows the final sample size distribution by specific disability for both the Drivers and Non-Drivers.

Age and Sex

The age and sex distribution of the sample in each category of limitation are shown in Table 1. The results generally conformed with expectation.

Lack of Coordination

The age distribution of this category tends to show a higher proportion of younger drivers than would be expected from the age distribution of individuals having the various disabilities making up this category. What this probably means is that younger physically limited individuals are more likely to drive than their older counterparts. Indeed, had it not been for sizeable numbers of hemiplegics in the sample, there might have been even fewer older drivers.

The sex distribution shows males to be somewhat overrepresented; based upon health statistics, we would have expected them to make up about 55% of the sample. A part of the difference may be attributed to the fact that a higher percent of males drive automobiles.

Range of Motion

Drivers in this category, like those in the Coordination category, show overrepresentation at the younger age levels. Here again, the difference is probably due to a greater tendency for the younger people to obtain licenses and drive.

SAMPLE SIZE DISTRIBUTION BY SPECIFIC DISABILITY

DRIVERS	
Coordination	
Paraplegia	95
Polio	64
Hemiplegia	33
Quadraplegia	23
Cerebral Palsy	20
Multiple Sclerosis	9
Spondylitis	5
Range of Motion	
Amputee	79
Congenital Deformity	6
Strength of Motion	
Arthritis	125
TOTAL DRIVERS	460
NON-DRIVERS	
Coordination	
Paraplegia	6
Polio	5
Hemiplegia	8
Quadraplegia	12
Cerebral Palsy	5
Range of Motion	
Amputee	2
Congenital Deformity	1
Strength of Motion	
Arthritis	2
TOTAL NON-DRIVERS	41

TABLE 1

AGE AND SEX

Percentage distribution of physically limited drivers by age and sex

AGE	LIMITATION			
	COORD. %	RANGE %	STRENGTH %	TOTAL %
19 and under	.8	1	0	.6
20 - 29	19	10	7	14
30-39	26	29	8	22
40-49	28	25	10	22
50-59	18	22	32	23
60-69	7	9	31	14
70-79	.8	2	10	4
80 and over	0	0	2	.4
SEX				
Male	67	74	42	62
Female	33	26	58	38

The sex distribution in this category shows underrepresentation of males relative to the afflicted population in general (over 80% of amputees are male). We would have expected the percentage of males among drivers to be higher. The relatively low portion of males may be the result of sampling error, or it could be a result of over-sampling among the younger age levels. In any case, the sex distribution is not so far from expectation as to suggest that the sample was a highly unrepresentative one.

Strength of Motion

The disorder that makes up this category, arthritis, is associated with advanced years. It is also more likely to occur among females than males. The sample reflects both of these tendencies. The percent of females making up the sample is somewhat below the 2/3 proportion that characterizes the arthritic population in general. This may be due, in part, to the fact that males tend to outnumber females in the older driving population.

Mileage

Annual mileage figures are presented in Table 2. It is evident that drivers in the Strength of Motion category (arthritics) compile considerably less mileage than drivers in the other two categories. This difference is due at least in part to the age levels of drivers making up this category. However, it may also be attributed to a relative lack of aids to make driving easier for those in this category (as will be discussed later).

The most surprising finding is not evident from the table itself. It concerns the small number of drivers in the Range and Coordination categories compiling less than 5,000 miles a year. It is only about half that reported in 1970 census figures for drivers of the same age and sex within the general population. The distribution of drivers in categories above 5,000 miles is fairly congruent with that of drivers in general.

As pointed out in the Introduction, many believe that one of the reasons for the low accident rate of physically limited drivers is that they do not drive as much as the able-bodied. Had this been so, one would have expected to see a higher number in the "less than 5,000" category. The explanation may lie in the fact that the census figures used for comparison are ten years old. People are driving more than they did ten years ago, particularly female drivers. However, many physically limited drivers with whom these findings have been discussed believe they are an accurate reflection of the relative exposure of physically limited and able-bodied drivers. They expected to see fewer physically limited drivers

TABLE 2

MILEAGE DISTRIBUTION

Percentage distribution of miles traveled per year by category of limitation

MILEAGE PER YEAR	LIMITATION			
	COORD. %	RANGE %	STRENGTH %	TOTAL %
Less than 5,000	13	9	27	16
5,000 - 7,999	20	23	37	25
10,000 - 14,999	36	32	24	32
15,000 - 19,999	14	16	5	12
20,000 - 24,999	9	11	1	7
25,000 - 29,999	3	5	2	3
30,000 and above	5	4	4	4

in the "under 5,000 miles" category. Drivers in this category are likely to be individuals who are dependent upon their legs and public transportation for mobility. For physically limited drivers, these two sources of mobility are, respectively, impossible and very difficult. In any case, the results cast doubt upon the hypothesis, advanced by some, that reduced exposure explains the relatively low accident rate of physically limited drivers.

Driving Experience

The experience of the driver sample, both as drivers and as physically limited drivers, is presented in table 3A. The greater experience of drivers in the Strength of Motion category is a reflection of greater age; because that disorder is one that comes with advancing age, the years of driving with the limitation are much less. All told, the 460 drivers making up the physically limited population represent close to 6,000 person-years of driving with physical limitations.

The purpose, time, and location of travel for drivers in each of the three categories of limitation is shown in Table 3B.

Drivers in the Coordination and Range of Motion categories devoted a greater proportion of their automobile driving to work purposes, both commuting and driving on the job. These differences are probably a reflection of age and sex differences; fewer of the drivers in the Strength of Motion category would be expected to be gainfully employed. Probably the most striking finding is the number of people in all three categories who drive their car for work purposes. A significant number devoted all or almost all ot their time to driving for work purposes. Drivers in the Strength of Motion category devoted a greater proportion of their time to driving for social and recreational purposes. The absolute amount of driving devoted to social and recreational purposes may not be as great, but it accounted for a higher share of their driving.

Drivers in the three categories were fairly similar to one another with respect to the time of day when their driving occurred. Drivers in the Strength of Motion category drove a little less during rush hour, as would be expected from the fact that less of their driving was devoted to commuting. However, more than half did at least "some" rush hour driving.

There are no marked differences among the three groups as to where driving occurs. Drivers in the Strength of Motion category are somewhat less likely to drive on freeways than drivers in the Coordination category, with drivers in the Range of Motion category falling in the middle. The proportion of driving on highways, city streets, and residential streets is probably determined more by where the drivers live than their own selection of driving environments.

TABLE 3A

DRIVING EXPERIENCE

Percentage distribution of driving experience by category of limitation

EXPERIENCE	LIMITATION			
	COORD. %	RANGE %	STRENGTH %	TOTAL %
YEARS DRIVING				
1 - 2	2	1	2	2
2 - 3	4	0	1	2
3 - 7	8	4	1	5
7 - 12	14	6	5	10
12 - 20	20	31	8	19
20 - 30	25	26	13	22
30 - 40	17	13	33	21
40 - 50	6	16	23	13
50 and over	4	4	13	6
YEARS DRIVING WITH LIMITATION				
1 - 6 months	3	0	3	3
6 months - 1 year	6	7	6	6
1 - 2 years	4	8	6	5
2 - 3 years	8	1	5	6
3 - 7 years	16	22	21	18
7 - 12 years	21	19	28	23
12 - 20 years	19	24	22	21
20 - 30 years	19	9	6	14
30 - 40 years	3	5	3	3
40 and over	2	5	0	2

TABLE 3B

PERCENT OF TRAVEL BY PURPOSE, TIME AND ROADWAY

	ALMOST ALL			MOST			SOME			LITTLE			NONE		
	CO	RM	SM	CO	RM	SM	CO	RM	SM	CO	RM	SM	CO	RM	SM
GOING TO AND FROM WORK	% 12	% 5	% 4	% 20	% 16	% 11	% 32	% 40	% 21	% 10	% 9	% 5	% 26	% 30	% 59
FOR WORK PURPOSES	3	1	3	6	5	7	25	25	7	14	16	11	52	53	73
FOR SOCIAL/ REC PURPOSES	28	23	41	13	9	10	47	58	35	11	7	8	0	3	6
RUSH HOUR	8	8	3	17	7	7	52	63	51	16	16	25	6	6	13
NON-RUSH HOUR	14	8	12	14	9	12	62	74	68	7	6	5	2	3	2
NIGHT	2	3	1	3	2	1	70	77	56	21	12	28	3	6	14
ON FREEWAYS	6	3	3	10	4	3	66	70	63	16	17	25	1	5	5
ON HIGHWAYS	7	4	2	8	3	3	76	79	83	8	10	7	2	3	4
CITY STREETS	6	4	4	18	10	16	69	80	78	7	4	1	0	1	1
RESIDENTIAL STREETS	4	1	6	12	4	11	75	88	79	9	4	4	0	2	0

CO = Coordination

RM = Range of Motion

SM = Strength of Motion

DRIVING PROBLEMS

The primary objective of the project was to identify problems encountered by physically limited drivers and non-drivers. Discussion of these problems will be classified by task. Within each task, results were reported in the three general disability categories: coordination, range of motion, strength of motion. Potential problem solutions are discussed along with the descriptions of the problems to which they relate.

Use of Primary Controls: Conventional

Table 4 presents the frequencies of problems encountered with conventional controls: steering wheel, brake, accelerator and gearshift.

Steering Wheel

Problems in merely *turning the steering wheel* are reported primarily by quadraplegics and arthritics. When negotiating sharp corners, difficulty in use of the steering wheel often results in wide turns and encroaching upon opposing lanes of traffic. Four of the arthritics did not have power steering and would presumably have been aided by it. Power steering not only reduces the effort required to turn the wheel but, because of the smaller steering wheel, allows the car to be turned more quickly. The drivers who have power steering and still reported this problem would presumably have benefited from a smaller wheel or greater assist. Difficulty in *gripping the steering wheel* was reported primarily by arthritics. Here again, power steering would have helped in 4 cases. Spinner knobs and even vinyl wheel covers might also have helped.

Steering failure refers primarily to loss of power steering due to an engine stalling. It can become extremely hazardous for anyone who lacks strength enough to overcome the increased steering resistance. Solutions to this problem include (1) keeping the engine properly tuned to prevent stalls, (2) an extended warmup period on cold, wet days. One of the steering failures involved a malfunction in a foot steering mechanism operated by an upper limb amputee.

Brake

The single most common problem in braking was having the *feet slip under the brake pedals*, thus interfering with application of hand brakes. It is most common among quadraplegics, paraplegics, and others who lack either control of their legs or the ability to sense where they are.

TABLE 4

USE OF CONVENTIONAL CONTROLS

Frequency of problems encountered in use of conventional controls by drivers in three categories of physical limitations.

PROBLEM	LIMITATION			
	COORD.	RANGE	STRENGTH	TOTAL
STEERING				
Turning steering wheel	11	3	8	22
Gripping steering wheel	4	5	9	18
Steering failure	6	2		8
Knee gets in the way while steering	1			1
BRAKE				
Feet slip under brake pedal	57	8	1	66
Too strenuous/difficult to use	5		3	8
Can't use quickly	0	3	2	5
Feet slip off brake pedal	1		1	2
Brakes too tight for others to drive			1	1
Brakes locked	2			2
ACCELERATOR				
Strain from prolonged application	15	3	9	27
Reaching accelerator	0	3	1	4
Feet slip under accelerator	1			1
Foot slips off accelerator	1			1
BRAKE AND ACCELERATOR CONFIGURATION				
Differential height	4	1	0	5
Proximity of pedals	1	1	1	3
Distinguishing between pedals	1	1	0	2
Coordinating limbs with driving tasks	1	0	0	1
GEAR SHIFT				
Coordinating floor shift with other tasks	0	1	2	3
Coordinating column shift with other tasks	3	1	1	5
Can't operate gear shift or clutch	4	1	1	6

The solution most frequently used is some form of "foot fence", that is, a barrier that is high enough to inhibit forward motion of the feet, yet not so high as to make it impossible to withdraw the feet in a hurry (if they surmount the barrier). A heavy mat with lateral ribbing about 1/2 to 1" in height would meet this need. A surer solution would, of course, be to remove the pedals entirely. However, this would not allow the vehicle to be operated by able-bodied drivers, including other members of the family and parking attendants.

The simple *effort required in applying the brake* was reported as a problem by 8 drivers. These were primarily people in the Lack of Coordination category who had insufficient use of the lower limbs to use manual brakes. Use of low-effort power brakes would presumably have overcome the problem for the 6 individuals who lacked power brakes on their cars.

Inability to get the foot to the brake quickly enough was reported by 5 individuals. For the 2 arthritics, it was primarily a matter of strength, while, in the case of the amputees, it was often awkwardness due to use of the prosthetic. A power brake might have helped, since it has reduced travel and hence lower pedal height.

Feet slipping off the brake and onto the accelerator occasionally arises with the able-bodied. However, it is a more common problem with drivers who have limited feeling in their legs and feet. Since the drivers reporting this problem had power brakes and automatic transmissions, pedal width does not seem to be a solution. It is possible that some of these drivers really should have hand brakes.

Accelerator

Strain from prolonged application of the accelerator is a problem to many physically limited drivers. Cruise control eases the strain on the open highway, but not elsewhere (2 of the drivers, see Table 4, had cars equipped with cruise control). Installation of a hand control might have been warranted in some cases. A similar solution might have been appropriate for the 4 drivers who had difficulty reaching the accelerator.

One driver, an arthritic, reported fatigue from attempting to maintain a steady pressure on a *hanging accelerator;* the foot cannot rest on the pedal as well. A treadle can be installed to change the angle of control application.

The problem of *feet slipping* off the accelerator pedal or sliding under it is obviously much less a problem in the case of the accelerator than the brake.

Brake-Accelerator Configuration

A few problems involve the relationship between brake and accelerator. The one problem that occurred with any appreciable frequency involved the *differential height* of the two controls. Some drivers had difficulty moving quickly from the accelerator to an elevated brake pedal. Power brakes, with their limited travel, would place the pedals at a similar height.

The 3 remaining problems--the *proximity* of the pedals to eachother, *difficulty in distinguishing* between them, and *moving from one to the other* while attending to control of the car--are all problems that might be alleviated with hand controls (they occurred among drivers in the Lack of Coordination category).

Gear Shift

Several drivers reported difficulty coordinating use of the gear shift with other tasks, primarily steering. Drivers with hand controls, or limited use of one arm couldn't steer and operate a floor or console shift. Such drivers probably should not operate vehicles with center consoles, both for this reason and the difficulty it creates getting in and out of the car (see Table 9). Several amputees also had difficulty coordinating steering with use of a column shift. Better prostheses might have helped. Two drivers had difficulty operating the button on console shift levers.

Use of Primary Controls: Adaptive

The installation of adaptive controls gives mobility to drivers who would otherwise be unable to drive. However, there are a number of problems associated with the controls themselves. Table 5A shows use of adaptive controls while Table 5B shows problems encountered.

General Problems

A number of problems apply to *hand controls in general*, that is, both braking and acceleration controls. The most frequently mentioned of these is a malfunction in the control itself. Common problems include bolts dropping out and cables breaking or binding. Probably the most hair-raising episode reported was that of a driver whose hand control became stuck as he was overtaking a line of slow-moving traffic on a two-lane bridge. Being unable to reduce speed, he swerved into the left lane, only to be faced with an oncoming truck. Fortunately, some accommodating maneuvers by the other vehicles gave the driver enough time to regain control.

TABLE 5A

ADAPTIVE CONTROLS

Frequency of adaptive control usage by drivers in three categories of physical limitations.

CONTROL	LIMITATION			
	COORD.	RANGE	STRENGTH	TOTAL
Hand controls	129	24	2	185
Foot controls	1	1		2
Dimmer on hand control	71	8		79
Dimmer extension switch	2			2
Horn on hand control	18	1		19
Spinner knob	28	5		33
Spinner cuff	7			7
Left foot accelerator	3			3
Brake extension	4	2		6
Pedal extension	1			1
Parking brake extension	3			3
Electric parking brake	6			6
Key extension	1			1
Panel control extension	1			1
Lift	22	2		24
Door pull			1	1
None	51	62	118	231

TABLE 5B

USE OF ADAPTIVE CONTROLS

Frequency of problems encountered in use of adaptive controls by drivers in three categories of physical limitations.

PROBLEM	LIMITATION: COORD.	RANGE	STRENGTH	TOTAL
GENERAL				
Failure of control	19	6	0	25
Fatigue	14	8	0	22
Knee gets in way	17	2	0	19
Poor location	15	1	1	17
Can't find qualified mechanics to fix	6	2		8
Confusion--lack of standardization	2	1		3
Installation process reduces resale value of car	2			2
Reach	1	1		2
Coordinate use with other tasks	2			2
Other people cannot operate	1			1
Difficult to use	1			1
Rubber tip on hand controls slips	2			2
HAND BRAKE				
Failure	10	3		13
Too strenuous/difficult to use	5			5
STEERING KNOB				
Interferes with steering	3	1		4
Too strenuous/difficult to use		3		3
Broke	2			2
Steering cuff broke	1			1
ACCELERATOR				
Binds or sticks	2			2

Accelerator and brake control *malfunctions* are obviously potential hazards. Frequent inspection and servicing are the only ways to prevent such malfunctions from arising. Unfortunately, the majority of drivers using hand controls (paraplegics and quadraplegics) lack the agility needed to perform a good inspection. Garage attendants, mechanics, and members of the family can perform the function if provided adequate guidance in the form of servicing instructions.

The second most frequently reported problem associated with adaptive controls is *fatigue*. After 15-30 minutes of driving, hands can get tired. Cruise control can help. However, as noted earlier, it's only appropriate on the open road. Continued design study is needed to furnish a control system that has adequate tension without requiring as much force as some controls now do.

Location of controls is also a source of frequent complaint. Many hand controls have elements that are suspended below the steering column, causing drivers to bang their knees, both while they are driving and when they are getting in and out of the car. With several hand control systems, the opening between the controls and the floor is quite small. This problem is alleviated in adaptive control systems that fit flush against the steering column.

Lack of mechanics qualified to fix hand controls is a general problem. While only 8 drivers thought to mention this problem, a survey would probably disclose that it is rather widespread. The same is probably true of the concern for *reduced resale value* for cars marred by the installation of controls. While only 2 drivers complained about it, most of the people who have adaptive controls would appreciate a design that requires minimum drilling of holes, or other modifications that mar the interior.

Confusion in control application occurs primarily when a driver has switched from one type of adaptive control to the other. Most of the reported incidents occurred during the first hours of operation, generally when the vehicle is being operated in an off-street area. While standardization is obviously desirable, it need not become a goal itself but rather could be the product of a single "optimum" design. Other problems mentioned include (1) performing other tasks when the hands are occupied with hand controls and steering wheel, (2) hand controls that make the car difficult to use by the able-bodied, (3) applying hand controls as quickly as conventional controls, 1/ and (4) rubber tip slipping off the control levers.

1/ This was not a universal problem. Indeed, many physically limited drivers felt they could apply the hand controls faster than able-bodied drivers could apply foot controls, a contention supported by research.

Hand Brake

The problems of *control malfunction*, *fatigue*, and *difficulty of operation*, reported for hand controls in general, were also reported for the braking control in particular.

Hand Dimmer

One driver reported difficulty in using the hand dimmer while steering and operating hand controls. As will be noted in the next section, a column-mounted secondary control is not an advantage unless its location is coordinated with that of hand controls.

Steering Knob

The greatest difficulty with steering knobs and cuffs was the tendency to *catch in clothing*, interfering with steering. In one instance, a driver broke her finger in this way. Three drivers reported strain and *fatigue* in gripping the spinner knob. Given the number of drivers who used spinner knobs and cuffs (47), the number of problems reported is fairly low.

Use of Secondary Controls

In this report, the term "secondary controls" refers to a control device that is necessary to the safe operation of the vehicle and which may have to be operated while the vehicle is in motion. Secondary controls include the devices/knobs, turn signals, headlights, dimmers, and windshield wipers.

The nature of the problems encountered with secondary controls is shown in Table 6. It is quite evident that the problems encountered with each control fall into the same general categories, namely:

TABLE 6

USE OF SECONDARY CONTROLS

Frequency of problems encountered in use of secondary controls by drivers in three categories of physical limitation.

PROBLEM	LIMITATION: COORD.	RANGE	STRENGTH	TOTAL
GENERAL PANEL CONTROLS				
Coordinating use while driving	47	14	3	64
Reaching	16	1	1	18
Turning	2	2	0	4
Gripping	1	2		3
Locating	1			1
Pulling	1	0	0	1
Pinch controls			1	1
SIGNALS				
Coordinating use of turn signal with other tasks	5	1	1	7
Coordinating use of flashers with driving			1	1
Reaching flashers		1	1	2
Activating flashers	1			1
HEADLIGHTS				
Turning light switch	2	0	4	6
Coordinating use of light switch with driving	1			1
Reaching light switch		1		1
DIMMER				
Problem reaching dimmer switch	17	8	4	29
Problem coordinating use of dimmer switch	18	6	3	27
Locating dimmer switch	1	3	1	5
Feet get in the way of dimmer switch	2	0	0	2
Dimmer switch broke	2	0		2
WIPERS				
Reaching wiper switch	5	1	3	9
Coordinating use of wipers with driving	4		1	5
HORN				
Reaching horn	2	3		5
TEMPERATURE CONTROLS				
Coordinating use of controls with driving	3	1		4
Reaching controls	4			4

Reach--Where controls are mounted on the dashboard, the driver must reach forward to activate the control. Many physically limited drivers have difficulty doing this, particularly those who are restrained by a fixed shoulder harness.

Coordination--A driver who is operating a hand control with one hand and the steering wheel with the other cannot activate a panel-mounted secondary control without releasing one of the primary controls. The same general problem is faced by the upper limb amputee who has only one usable arm and hand. In order to free one hand, drivers may have to steer with one knee, the elbow (reaching through the steering wheel), or the thumb of the hand operating the hand control. All of the above are potentially dangerous.

Manipulation--Many of the secondary controls consist of small knobs or switches that physically limited drivers have difficulty grasping, twisting or pulling.

Location--Secondary controls can be difficult to locate when drivers have limited coordination or lack sense of touch (i.e., prosthetics). It isn't made any easier if the driver is attempting to drive with one hand at the same time.

Many drivers pulled off the road in order to turn on windshield wipers, headlights, or heater. The best solution to the problem of operating secondary controls, while at the same time maintaining control of the vehicle, would appear to be mounting the activation switches in a secondary control stalk on the steering column. This would allow the driver to manipulate them without releasing the hand control or steering wheel. For most drivers, the operation of temperature controls can be tended to at times other than when the vehicle is in motion. However, for most paraplegics and quadraplegics, regulation of temperature within the vehicle is extremely critical and, therefore, must be considered in the same category as secondary controls.

Merely mounting secondary controls on the steering column will not necessarily solve the problem. This is evident in the number of drivers who had difficulty actuating a turn signal while operating the car. One driver was an amputee who could have benefited from a right-side directional. The others were merely drivers whose limited coordination and strength made it difficult for them to steer and actuate the turn signal at the same time. To be fully effective, secondary controls must:

- Consist of easily operated activation mechanisms, e.g., a lever or toggle instead of a knob.

- Must be positioned so that the driver can reach them with the fingers of one hand while maintaining a grip on the primary control.[1/]

- Be readily distinguishable from one another so that the operator can apply the correct control without looking.

Many automobiles are designed with column-mounted secondary controls. However, few have *all controls* mounted on the column. Moreover, column-mounted secondary controls tend to be characteristic of European cars whose small size and general body type is not generally amenable to use by many categories of physically limited drivers.

Offering a column-mounted control stalk as a production option is likely to prove too expensive to merit much attention by automobile manufacturers. However, what might prove feasible is a post-production add-on, designed specifically for physically limited drivers, that could be attached to the steering column and patched into the main connector in the firewall. Each make (and many models) would require its own unique connector. However, the number of different control stalks would be much more limited.

Operating Other Mechanisms

There are a number of other mechanisms within the automobile which cause problems for physically limited drivers even though they do not compete with operation of the automobile. These include the ignition, parking brake, restraints, seat adjustment, windows, and a few other minor items. Table 7 displays problems reported in connection with these mechanisms.

Ignition Switch

Inserting and twisting an ignition key can be a problem for drivers who have prosthetic devices as well as many who have limited coordination or strength. Even reaching the ignition switch can be a problem for drivers who have difficulty leaning forward.

The most common solution to this problem is to attach the key to some device that easily grasps and extends the reach of the driver. Most of the drivers reporting difficulty with the ignition switch were

[1/] One ingenious driver had rigged switch buttons into the door panel where they could be activated with the elbow.

TABLE 7

OPERATING OTHER MECHANISMS

Frequency of problems encountered in use of other mechanisms by drivers in three categories of physical limitations.

PROBLEM	LIMITATION			
	COORD.	RANGE	STRENGTH	TOTAL
IGNITION				
Turning ignition switch	3	2	8	13
Reaching ignition switch	2	3		5
SAFETY RESTRAINTS				
Fail to provide balance support	36	3	4	43
Difficult to operate	18	2	14	34
Rub against neck	10		6	16
Reaching safety restraints	5	1	2	8
PARKING BRAKE				
Difficult to operate	39	5	16	60
Reaching brake	6		2	8
SEAT ADJUSTMENT				
Seat adjustors difficult to operate	7	1	8	16
Reaching seat adjustors	2	0	1	3
Failure of seat adjustors	1			1
WINDOWS				
Difficult to roll up	15	8	28	51
Coordinating use while driving	10	4	1	15
Hard to push power button	1		1	2
OTHER DEVICES				
Glove compartment - difficult to reach	2			2
Door locks - difficult to reach	3	1	4	8
Door locks - difficult to use	1		2	3
Hood release - hard to reach	9	0	14	23
Hood release - hard to operate	1		3	4

unfamiliar with such a device.

Restraints

The single biggest problem that drivers have with restraints is their *failure to restrain.* Most quadraplegics, as well as some paraplegics and arthritics, have difficulty remaining in an upright position and staying behind the wheel when the car makes a sharp turn. The latter problem also occurs among some upper limb amputees. The inertial reel type of shoulder restraint used in most new cars is activated upon impact and, therefore, does not provide continuous support. It could be replaced with the older type of shoulder harness, or, better still, an "H"-type racing harness. One of the problems with a shoulder restraint is that it is designed to be used in conjunction with a lap belt. The majority of paraplegics and quadraplegics are reluctant to use a lap belt because it can restrict circulation or even lead to abrasions. Both tend to produce dicubitus ulcers (a condition generally requiring hospitalization). The "H"-type harness, with its wide lap belt, provides about the same support as a lap belt and shoulder strap while creating fewer pressure points.

The other major problem that physically limited drivers have with restraint systems is *fastening and unfastening* them. The problem is similar to that encountered in use of ignition keys. Connectors need to be redesigned in a way that will permit them to readily be fastened by people with limited dexterity.

Reaching lap and shoulder restraints can also be a problem for many drivers who have only limited use of the arms and limited upper torso mobility. Automobile engineers have spent many years designing restraint systems that are readily accessible when needed, and yet out of the way when not in use. For physically limited drivers, accessibility might be given greater emphasis. Because of their need for support, most physically limited drivers would use upper body restraints if they were accessible and easy to fasten.

Discomfort from a shoulder restraint rubbing the neck is a greater problem for physically limited drivers than able-bodied drivers because of the difficulty they have in adjusting the strap while the vehicle is moving. The restraining clips found on newer cars would keep slack in the strap and prevent this problem.

Parking Brake

The standard foot-operated parking brake simply cannot be reached and applied by drivers who lack normal use of lower limbs. Some of the drivers interviewed carried a stick of some kind to solve the problem of reach. However, many drivers simply lack the strength required to operate by hand what is intended as a foot operated device.

A console-mounted parking brake is easy to reach and requires less force. However, as will be noted later, a console hinders entry from the passenger's side and is not recommended for physically limited drivers. Also, the release button on the console-mounted parking brake is difficult for many physically limited drivers to operate.

Parking brake extension levers are commercially available and easy to operate. They constitute an adequate solution to the parking brake problem for most physically limited drivers. There are a few people, however, who lack the coordination, range of motion, or strength to manipulate even such an aid. For them, an electric motor attached to the pedal by a screw jack arrangement may provide a solution.

Seat Adjustments

Manual adjustment of the seat requires manipulation of some type of lever and application of force to the seat itself. Both can be difficult for drivers lacking coordination, strength, or at least one of the upper and lower limbs. Merely reaching the seat adjustment is a problem for some.

Some drivers select bucket or split bench seats to make adjustment easier. The split bench is the better of the two alternatives in that it doesn't hinder entry from the passenger's side.

The most effective, albeit expensive, solution to the problem is simply a power-operated seat, an option on most American cars. Some 89 of the drivers interviewed had this option. None of them were among the drivers reporting the seat adjustment problem.

Three drivers reported inability to move the seat close enough or far enough from the vehicle controls. This is largely a matter of poor vehicle selection.

Windows

Drivers with limited coordination or strength or drivers needing prosthetic devices often have difficulty rolling windows up and down for ventilation, to ask directions, to pay tolls, and so on. The obvious solution is simply to buy a car with power windows. However, this is a lot of expense simply to lower the driver's window.

An electric motor could be connected to the window crank on the inside of the driver's door panel without requiring modification of the door. A motor does, however, add "one more thing that can go wrong." A more economical and reliable solution would be simply an extension to the window crank. To be of maximum benefit, it should have:

- A long handle to provide mechanical advantage.
- A large knob for easy grasping.
- A ratchet arrangement to make it unnecessary for the handle to be turned through 360-degrees.
- A hinged arrangement to allow the handle to be swung out of the way when it's not in use.

From all indications, such a device would have a fairly large market among all categories of physical limitation.

Other Mechanisms

The number of complaints concerning the difficulty of reaching and operating the door locks, hood release, and glove compartment latch probably underestimate the number of drivers actually experiencing these problems.

The limited agility of many physically limited drivers makes it difficult for them to reach the locks on all doors before leaving and after entering the car. The simplest solution is automatic door locks. Some 41 drivers in the sample had cars equipped with this option.

A commercially available "extension hook" is useful in operating each of the mechanisms listed above. Its 18-24 inch length is sufficient to reach most of the latches and other devices that must be manipulated by the driver. The hook at the end permits toggles and pull knobs to be operated by drivers who lack sufficient strength in their fingers to gain a secure grasp.

Seeing

Drivers with vision defects were not included in the study sample since the remedy to their problem is primarily medical rather than automotive. However, some problems that physically limited drivers have in seeing adequately arise through other than visual defects. These are summarized in Table 8.

Blind Spot

The single greatest problem in seeing properly was *inability to turn the head* far enough to check the "blind spot" before initiating a lane change. Almost all quadraplegics as well as a large number of paraplegics and arthritics have a problem seeing any vehicle in the right or left rear quarter. They avoid accidents primarily by signaling well in advance and making lane changes very slowly.

Some of the drivers who have difficulty turning their head manage to check the blind spot by bracing themselves against the steering wheel and rotating their entire upper body. However, this often results in a momentary loss of directional control.

One solution to this problem is simply to make it unnecessary for drivers to turn their heads in order to see. What is needed is a total "rear vision system" capable of allowing drivers to scan 180 degrees to the rear of their car with only eye movement. Convex mirrors increase the field of view but also alter perspective in an inherently dangerous way (near objects look far away). More recently, a combination of flat and convex mirrors--the old truck "fish-eye" mirror--have been mounted on the left and right sides of passenger vehicles. The convex mirror enables the driver to detect the presence of another vehicle in the blind spot while flat mirrors allow an accurate estimation of distance.

Even the best of available arrangements fall far short of meeting the requirement for an integrated rear vision system. The development of such a system, while a necessity in the case of the physically limited, would also be of great benefit to the general driving public. It is surprising that mirrors are as primitive as they currently are.

Many physically limited drivers are unable to reach outside mirrors for purposes of adjustment while still remaining in the position in which they will drive the car. Mirrors that are adjustable from inside would help. An alternative would be commercial type mirrors with lock-downs to reduce the amount of adjustment that is necessary.

TABLE 8

SEEING

Frequency of problems encountered in Seeing while driving by drivers in three categories of physical limitations.

PROBLEM	LIMITATION: COORD.	RANGE	STRENGTH	TOTAL
BLIND SPOT				
Turning to look over shoulder	34	3	52	89
Turning to look over shoulder while steering	16	11	7	34
MIRROR ADJUSTMENT				
Reaching rearview mirror	4	1		5
REAR WINDOW				
Seeing through rear window	8	0	7	15
BLOCKED VIEW				
Inside mirror blocks vision	3	0	2	5
Can't see over high seatbacks	2		2	4

View Obstructions

Limitations in the ability of drivers to move their heads makes it particularly important to keep the driver's view unobstructed.

The *rearview mirror* positioned at the top of the windshield often blocks the driver's view of traffic lights and various signs. Frequently, they are dependent upon movement of other traffic to tell them when a light has turned from red to green. There doesn't appear to be any ready solution to this problem. The small prisms that were stuck to windshields during the "sunvisor" era in the late 40's would allow drivers to see traffic lights, but signs would be illegible. The only alternative would appear to be to alert drivers to the problem so that they can bring their cars to a stop before lights and signs disappear from view.

A few drivers complain that *high seatbacks and headrests* obstruct their vision during lane changes and while they are backing. An improved mirror system would help overcome this problem.

The complaint of being unable to see out the *back window* comes primarily from drivers of all types of vehicles and is a real handicap in parallel parking. It is particularly a problem for vans with rear lift systems where (1) the lift system tends to block rearward visibility, and (2) it is particularly important to be able to see out the rear in order to know whether there is adequate room to lower the lift. Better side mirrors would probably help, particularly if they are extended somewhat from the side so as to be able to capture the area directly to the rear of the car. In vans, a rear window prism would allow drivers to view the surface area below van window height and thus better judge distance from parked vehicles when backing.

Dirt and ice on the rear window obscures vision and are difficult for many physically limited drivers to remove. Rear window wipers and defrosters are an important option.

Entering and Leaving the Car

Among the most frequent unsolicited complaints from physically limited drivers are those having to do with the difficulty of getting in and out of the car. A large number involve simply the effort involved in opening and closing the door, getting in and out of the car, and sliding across the seat. The largest number of complaints (41) came from paraplegics and polio victims, who had to open the door from a wheel chair, and transfer out of it into the car. However, a large number of complaints (39) also came from arthritics who found the whole operation very taxing. In all, there were 153 different complaints about the difficulty of getting in and out of the automobile.

In addition to the more general complaint, many drivers identified the problem of getting in and out with the car controls, seats, and doors, as well as the wheelchair and lift systems. These problems are encapsulated in Table 9.

Controls

The steering wheel, parking brake, and elements of hand controls tend to form a barrier to entrance and egress. Purchase of tiltup steering wheels and hand controls that do not hang below the steering column will certainly help to alleviate the problem. Swivel seats would help facilitate access from the driver's side. However, they are essentially bucket-type seats and make it difficult to slide into them from the passenger's side. It is important that drivers have ready access from the passenger's side so they will not be forced to enter the car from the street side when the car is parked along the curb.

Seats

Safety belts are not the only form of restraint. Bucket seats resist lateral movement and help keep the driver from sliding sideways across the seat during a turn. Unfortunately, they also function in the same way when the driver is trying to get in and out of the car from the passenger's side. Banging the head against the rearview mirror is a fairly common occurrence.

One way of gaining the benefits of bucket seats in a bench-type seat is through a covering that has very low friction on the passenger's side and high friction in the driver's position. An alternative would be a high friction surface with friction backing that could be placed on a regular seat cover on the driver's side.

TABLE 9

ENTERING AND LEAVING THE VEHICLE

Frequency of problems encountered while entering and leaving the vehicle by drivers in three categories of physical limitations.

PROBLEM	LIMITATION: COORD.	RANGE	STRENGTH	TOTAL
GENERAL				
Difficult to get in and out of car	41	15	39	95
CONTROLS				
Steering wheel interferes with entry/exit	6	2		8
Emergency brake interferes with entry/exit	2	0		2
Hand controls interfere with entry/exit	2	3		5
SEATS				
Height and width of seats cause difficulty in entry/exit	7		2	9
DOORS				
Outside buttons hard to operate	4	2	22	28
Hard to open and close	13	4	14	31
Inside handles hard to use	2		11	13
Hard to open from wheelchair	1			1
WHEELCHAIR				
Difficult to get wheelchair in and out of car	43	7	4	54
Rips upholstery	14	4	0	18
Back seat hump obstructs wheelchair positioning	15	0		15
Can't fit wheelchair in trunk	3			3
LIFT				
Difficult to operate	1			1
Broke	4			4
Drains battery	1			1
Can't find qualified mechanic to fix	1			1
Can't find parking space big enough	1			1
Stops too high from ground	1			1

Doors

A number of problems are associated with the doors of the car. The biggest problem encountered in doors was simply *opening and closing* them. Most of these complaints came from drivers who operate full-sized cars. In the case of drivers in wheelchairs, the problem is compoun ed by the large doors that characterize the two-door models preferred by most of the drivers. Lack of strength is part of the problem. The other part of it is lack of leverage when attempting to open the door from a wheelchair or when one hand is using the car for support.

The *outside door latches* are not easily manipulated by drivers with limited coordination or strength, or drivers with prosthetic devices. Rotating or liftup door handles are much easier to use. The only real remedy to this problem is to check the operability of outside door latches before purchasing a vehicle.

An equally great problem is that of keeping the door open while maneuvering oneself into the car. In many models, it may be possible to modify detents in a way that will resist inadvertent closing. Especially designed props that could be inserted between the door and the frame are also a possibility. A few drivers had installed strong springs that would open the door whenever the latch was released and a slight pressure applied. The drivers reported a few inadvertant door openings. A move to smaller cars would certainly ameliorate the problem of opening doors. However, it would make the door opening smaller and complicate the task of getting into the car.

The design of *inside door handles* is less constrained by style than outside handles and, therefore, less of a problem. However, the inside handles on many cars are small and difficult to grasp, causing problems to drivers lacking in strength. It should be possible to fabricate some extension to the door handle that would give drivers greater mechanical advantage.

Handling the Wheelchair

Drivers can have more *trouble getting the wheelchair in and out* than they have doing the same with themselves. Most of the drivers in this category operate a two-door vehicle. This allows them to get in the car, fold the wheelchair, and slide it behind the driver's seat. However, a significant number of drivers, including 17 of the 54 mentioning the wheelchair problem, own four-door vehicles. They enter the back seat, pull the wheelchair in, and then crawl into the front seat. Most of them plan to select a two-door vehicle in their next purchase.

Another reported problem is *tearing of upholstery* by the wheelchair as it is taken in and out of the back seat. Drivers are concerned more with the adverse effect upon resale value than upon pure esthetics. Plastic or cloth protectors on the back seat appear to be a better solution to the problem than attempts to modify the wheelchair itself.

Anchoring the *shoulder harness* behind the driver's seat creates a barrier to passage of the wheelchair through the rear doorway. Some sort of hook mounted above the driver's window would allow the harness to be pulled directly forward rather than across the rear doorway while the wheelchair was being transferred.

A problem encountered in getting the wheelchair out of the car comes in extracting them from the *rear seat floor well* between the outside frame and the drive shaft hump. Many drivers have placed wooden boards across the floor of the rear seat to cover over the rear wells.

When accompanied, drivers often have the passenger put the wheelchair in the trunk. *Lack of adequate trunk space* is an occasional problem. Drivers need to be alerted to this problem and encouraged to make sure that the trunk of any new car will accommodate the wheelchair.

Transfer

One of the most difficult tasks in entering and leaving the car is transfer between a wheelchair and the car seat. Commercially available aids to the transfer process include the following:

> Sliding board--A board placed between the seat of the wheelchair and the seat of the car, across which the driver can slide.
>
> Gutter hook--A strap attached to a hook that can be placed in the gutter channel, allowing individuals to lift themselves from the chair to the seat.
>
> Handle--A handle attached inside the car above the doorway that drivers can use to lift themselves.
>
> Automatic lifts--Electrically operated devices that will actually lift the driver from the wheelchair to the seat of the car and fold away when not in use.

The gutter hook and handle are also valuable aids to drivers who are not bound to a wheelchair but need something to hang onto while unlocking and opening the car door, and lowering themselves into the car seat. A strap or handle inside the car also aids in moving from the passenger to the driver's side of the car seat.

Lifts

Drivers who are unable to transfer from a wheelchair to the car seat require a van, which allows them to operate the vehicle from the wheelchair. If they are to operate the vehicle alone, they need a lift system that will elevate the wheelchair to the height of the van floor. Some 24 of the drivers interviewed, almost all quadraplegics, had vans equipped with electrical lifts. Most were very pleased with the equipment. Problems are most noticeable in their relative absence.

Problems Outside the Car

The interview focused upon problems with the vehicle itself, since these are the problems easily remedied. It is obviously more cost-effective to modify one vehicle for the physically limited driver who is using it, than to attempt to modify the entire driving environment. However, a number of problems occurring outside the car were reported and are listed in Table 10.

Parking Space

Lack of adequate parking was the chief unsolicited complaint insofar as the operating environment is concerned. Inability to find places *reserved for handicapped* drivers was a frequent problem. Spaces that were provided were often (1) too far away from the buildings to which drivers needed access, (2) not located next to driveways, curb ramps, or other points of access to the sidewalk, (3) often located next to parking meters, signposts, and other structures that bar use of lift systems and opening of car doors, and (4) are already occupied by vehicles not driven by handicapped drivers.

Parking spaces in shopping centers are typically *too narrow* to meet the special needs of the physically handicapped driver. This is true even of those spaces reserved for their use. Specifically, they do not allow the door to be opened fully. This both limits the access and prevents the detent from holding the door open. Drivers who have electric lifts cannot use them except in end spaces, and then must lower the lift right into the stream of traffic.

Much public attention has been devoted to assuring adequate and accessible parking for physically limited drivers. However, merely allocating spaces is not enough. The size and location of those spaces must take account of the special needs of physically limited drivers. Traffic engineers and others bearing responsibility for meeting the needs of physically handicapped drivers need to know more about what those needs are. And, of course, enforcement of parking restrictions is needed in order to keep allocated spaces from being occupied by able-bodied drivers.

TABLE 10

PROBLEMS OUTSIDE OF THE CAR

Frequency of problems encountered while outside the vehicle by drivers in three categories of physical limitations.

PROBLEM	LIMITATION			
	COORD.	RANGE	STRENGTH	TOTAL
PARKING				
Lack of reserved spaces	35	5	10	50
Lack of wide enough spaces	35	11	1	47
Difficult to use meter	1			1
TIRES				
Difficult to change tire	21	4	11	37
BREAKDOWNS				
Can't find help	4			4

Changing Tires

Servicing and maintenance of the automobile is obviously difficult for most physically limited drivers to perform. And most are content to entrust these tasks to mechanics and service station attendants. Their major problems concern *emergencies* that occur on the road, the most common of which is a flat tire. Removing the spare tire, jacking up the car, and changing the wheel are difficult for most drivers who are limited in their strength or coordination. For some, it's clearly impossible. For others, the task could be carried out with (1) ways of relocating the spare tire to make it more accessible, (2) design of special aids for extracting the spare tire, raising it to the wheel, and lifting the flat tire into the car, and (3) design or redesign of tools to reduce required effort (e.g., extended jack handle). Physically limited drivers should also be encouraged to carry aerosol inflaters to enable them to take the car as far as the service station without changing the tire.

Breakdowns

Obtaining help when the car is disabled is another frequent problem. Increasing numbers of physically limited drivers have taken to installing CB radios. The percent of drivers having CB radios was about 15%, pretty evenly distributed across the three disability categories. There are commercially available placards to alert passing drivers that the driver of a disabled car is physically limited. Many drivers are reluctant to advertise their plight because of their vulnerability. (Many won't even use a handicapped driver license plate or decal.) The CB radio might help to overcome their reluctance to seek help by (1) providing channels monitored by police and rescue services, and (2) allowing the driver to talk with another driver before making his needs known. Certainly any driver who plans to take lengthy trips or drive in areas where there is little traffic should use a CB radio. One driver reported having to push his wheelchair five miles down a dirt road when his car became stuck in the sand. (He purchased a CB radio shortly thereafter.) Several others reported having been virtually imprisoned inside their disabled vehicles when unable to lower their windows to attract attention.

General Problems

In addition to the problems concerned with specific components of the vehicle and particular aspects of the environment, four more general types of problems were frequently reported: lack of information, lack of services, poor equipment appearance, and cost.

Lack of Information

Many of the drivers interviewed lacked information as to the nature of the driving problems they would encounter or the procedures and equipment available to help them overcome these problems. Those who had contact with large rehabilitation centers were fairly well informed. However, those who were treated in hospitals, clinics, or by private physicians were very deficient in their knowledge of the impact that their disorder would have upon their driving. Information needs can be summarized as follows:

Vehicle Design

The number of elements of basic vehicle design influence the safety and comfort of operation, including:

- two-door versus four-door
- bench seat versus bucket seats (and console)
- type of inside and outside door handles
- dimensions of trunk relative to wheelchair.

Physically limited drivers often cannot test drive a vehicle before purchase, particularly if hand controls are needed. They often do not know the implications of various design alternatives to operation. Several of the drivers who were in wheelchairs had purchased four-door cars. They did not realize how difficult it would be to get the wheelchair into the car. They were forced to enter the back seat, pull in the wheelchair after them, and then climb over into the front seat.

Options

Many drivers were unaware as to the extent to which various options would improve their comfort and safety. Important options include:

- power brakes
- power steering
- power seats

- power windows and door locks
- heavy duty batteries
- cruise control.

Drivers who were aware of these options were often unfamiliar with the range of options available. For example, some drivers had trouble turning the steering wheel even with power steering. A low effort system, while having some undesirable features as far as the able-bodied are concerned, would have been of some benefit to them.

Devices

A variety of devices have been prepared specifically to aid physically limited drivers. These include:

- adaptive controls
- secondary control extensions (e.g., hand dimmer, parking brake extension)
- steering aids (e.g., spinner cuff)
- entry aids (e.g., sliding board, lifts)

Drivers who must have adaptive controls generally obtain information about them from rehabilitation agencies. However, they often lack information as to the pros and cons of various adaptive control designs. As a result, many end up purchasing a second set of controls in order to obtain what they need.

Often the less severely limited drivers struggle along for years with a standard car, not knowing what devices are available to aid them. An example is that of a polio victim who lacked use of her right leg. For a period of three years, she drove 300 miles each weekend to visit her aging mother, operating the accelerator (at extreme discomfort) with her left foot. She did not know that a left foot accelerator could be installed at relatively little cost.

Procedures

Most physically limited drivers initially lack good information as to what problems their limitation might create and what procedures they might adapt to cope with them. Many of the drivers whose feet had slipped under the foot pedals, preventing application of the hand brake, had never been warned about the possibility. The collisions, near-collisions, and injury to the feet that they experience, might have been prevented if they had only been able to anticipate the problem and react quickly.

Maintenance

Most of the failures of adaptive control systems could have been prevented by frequent inspection and servicing (tightening nuts, lubricating cables). The maintenance instructions provided by manufacturers vary in comprehensiveness and detail. Even those that do provide good servicing instructions do not adequately anticipate specific problems and ways to avoid them (e.g., using Lock Tite to prevent loosening of fastenings).

Poor installation often underlies maintenance problems. Many of the shops that install adaptive controls and other devices have very little experience. Complete installation instructions must be provided with the equipment.

Resources

Two recent publications will help to narrow the information gap somewhat. The American Automobile Association has recently published *The Handicapped Driver's Mobility Guide,* a list of organizations providing services to handicapped drivers, including manufacturers of adaptive aids, driving schools, and agencies providing publications and services. Guidance also includes information on vehicle selection, choice of options, and types of equipment.

The Human Resources Center in Albertson, New York, has published *Hand Control and Assistive Devices for the Physically Disabled Driver,* an extremely comprehensive description of available devices and recommendations for the types of devices needed by individuals with various limitations. Specific sources of equipment are not mentioned. Since there is no effective distribution system for placing this publication in the hands of drivers, it is more appropriate for rehabilitation workers than drivers.

These two publications, while excellent, do not completely meet all of the information needs for all drivers. A great many of the problems discovered during this survey are not dealt with, particularly those of a procedural nature. Secondly, many categories of physically limited drivers are not viewed by themselves or others as "handicapped," and are not likely to even see these publications.

Lack of Services

The services that are available to physically limited drivers for assistance in installation, servicing, and repair of adaptive controls and other equipment aids are very limited. People who live outside of metropolitan areas often have to travel long distances for assistance.

In days past, the physically limited drivers would have had access to general mechanics and all-purpose handymen who could tackle a variety of mechanical tasks. One of the reasons for the many jury-rigged systems that were found during the survey was simply the lack of people and shops to undertake fabrication of devices and make limited modifications to the equipment.

Among business enterprises that handle installation of adaptive controls and other aids, there is typically wide variation in the qualifications of personnel and the quality of work performed.

Poor Equipment Appearance

Not a great deal has been done to enhance the physical appearance of adaptive control devices and accessories, in marked contrast with the emphasis placed upon styling in design of the automobile itself. Part of the problem is the equipment itself. It is generally unattractive, often awkward looking, and tends to call attention to the driver's physical limitation. Many physically limited drivers are strongly motivated to appear as if they were fully able-bodied. Some attention to styling of equipment and integrating it into the overall design of the vehicle could probably be accomplished without degrading the functional capability of the equipment.

Installation of adaptive equipment and accessories requires drilling and cutting which can deface the vehicle itself. It not only looks unattractive, but lessens the resale value of the vehicle. More attention needs to be given to ways in which equipment can be installed without damaging or detracting from appearance of the automobile.

Cost

Many of the physically limited drivers who could have benefited from adaptive controls and other aids simply could not afford them. Much of the expense associated with various devices is not traceable to manufacturing costs, but involves the cost of liability insurance. The equipment itself presents no inordinate hazard, nor do the drivers who use it. The primary problem is that a physically limited driver faces a much higher chance of becoming totally disabled or even killed than does the able-bodied driver.

The liability concern not only adds to the cost of the aids and devices, but discourages their manufacture by automobile makers, who could tailor the devices better to their vehicles. It is an issue that requires attention at the national level if it is to be overcome.

Accidents

Originally, the study was to have collected critical incidents involving *accidents* or *near misses*. Preliminary interviews with physically limited drivers revealed that this would be an unproductive line of inquiry. Reports of accidents or violations having anything to do with the driver's physical limitation would be rare. Few of the drivers would report even one. The accident rate of physically limited drivers is similar to that of the able-bodied--only about 1 in 10 drivers have a reportable accident within a year. And, of these accidents, only a minority relate to the individual's physical limitation.

Added to the very low incidence of actual accidents was the effect that any mention of accidents had upon the willingness of drivers to volunteer information. It tended to make them suspicious as to the real purpose of the study and inhibited any volunteering of information about safety-related driving problems.

By focusing upon driving "problems", far more information was gained relative to behaviors having accident-producing potential. Further, in describing their problems, many drivers volunteered information about accidents that they probably would not have provided had they been questioned directly upon the subject.

While data collection focused on "problems", interviewers did probe for instances of accidents associated with those problems that were revealed. In addition, many of the drivers volunteered information about their accidents. The accidents that were revealed through interviews are tabulated in terms of the problems leading to them in Table 11. Only those accidents related in some way to the driver's physical limitation are shown. The total of 37 accidents is rather small, given the number of drivers involved in the period of time over which they have been driving with their limitation.

The leading accident contributor is difficulty in steering. The specific difficulty most frequently reported was inability to turn the steering wheel fast enough to make a sharp corner. Drivers having this problem tend to encroach upon other lanes with the result that there are occasional collisions with parked vehicles.

Failure of hand controls accounted for 15 accidents. Those labeled "general" were primarily instances in which binding or breaking of cables or rods caused the car to continue accelerating when the driver needed to brake. Failure of the hand control brake prevented braking but did not at least result in acceleration. The next two problems--difficulty in braking and coordinating accelerator brake--resulted in insufficient brake application and minor collisions.

TABLE 11

PROBLEMS LEADING TO ACCIDENTS

PROBLEM	LIMITATION			
	COORD.	RANGE	STRENGTH	TOTAL
ACCIDENT				
Hand controls				
General	5	2		7
Brakes	3	1		4
Accelerator or cable	2			2
Rod to gas or brake	2			2
Steering				
Wheel or system	4		4	8
Power		1		1
One-handed	1	1		2
Brake/Accelerator				
Combo or clutch	2	1		3
Accelerator	1			1
Brakes	1			1
Seeing				
Blind spot (turning to look over shoulder)	3	1	2	6
NEAR ACCIDENT				
Hand controls				
General	3			3
Brakes	1			1
Steering				
Wheel or system	3	2	1	6
Cuff	1			1
Brake/Accelerator				
Combo or clutch	1			1
Brakes	1	1		2
PROSTHESIS				
Secondary Controls				
Panel controls/accessories		1		1
Turn signal extension		1		1
Seeing				
Blind spot (turning to look over shoulder)	1		1	2

The problem that many physically limited drivers have in turning their head far enough to check the blind spot has been mentioned previously. Most drivers compensate for their inability by actuating their turn signals early and making lane changes gradually. The fact that only six accidents are associated with this driver error--certainly no more than a comparable group of able-bodied drivers would report--suggests that the compensation is relatively successful.

NON-DRIVER PROBLEMS

The shortfall in the "non-driver" category was mentioned earlier. There was no lack of physically limited people who are not driving cars. The problem was in locating those within their ranks who are actually capable of driving. Not many could be found.

It is quite possible that many of the non-drivers who claimed to be unable to drive really could have driven. There was no way to make such a determination without interviewing each non-driver, something that available resources did not permit. However, the number of such people is likely to be relatively small. A reasonable explanation for the shortfall is simply the small number of people having the ability to drive and choosing not to. The need for mobility is sufficiently great as to place behind the wheel those who are at all capable of operating safely.

The distribution of non-drivers across the category of limitation was as follows: Coordination--36, Range--3, Strength--2. The age and sex distribution paralleled that shown in Table 1 for physically limited drivers. Within the Coordination category, the distribution of specific disabilities was similar to that of physically limited drivers.

The problems given as reasons for not driving were very similar to those problems revealed by physically limited drivers. Those specific problems mentioned four or more times are shown in Table 12.

One factor that most distinguished drivers from non-drivers was *fear*. Whereas physically limited drivers felt they could operate safely despite problems they were encountering, the non-drivers expressed fear that the problems they were encountering would ultimately lead to an accident. In a few instances, the decision not to drive was precipitated by an accident or near-accident.

From the information collected, it would appear that anything that is done to improve the lot of the physically limited driver would also influence the decision as to whether or not to drive. However, this decision seems also to be influenced by the driver's perception and tolerance of risk, concern for safety, ability to abide discomfort, availability of others to do the driving, and sheer determination. Since driving problems are only one of the decision-making factors, changes in the nature of those problems will not necessarily leave a marked affect upon the outcome of the driving decision.

TABLE 12

PHYSICALLY LIMITED NON-DRIVERS

REASONS FOR NOT DRIVING

COORDINATION (N = 36)	LIMITATION: COORD.	RANGE	STRENGTH	TOTAL
Difficulty getting in and out of the car	9			9
Can't afford car with proper equipment	7			7
Difficulty getting wheelchair in and out	6			6
Can't steer properly	6			6
Difficulty backing up	5			5
Difficulty operating windows	5			5
Difficulty remaining upright	5			5
Difficulty turning head	5			5
Difficulty backing car	5			5
Muscle spasms	4			4
Couldn't operate dimmer	4			4

RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT

Some of the problems identified in this report may never be solved. Most, however, could be overcome if sufficient attention were devoted to them at a national level. The activities that need to be undertaken can be divided into three categories: dissemination of information, improvement of adaptive controls, and development of additional aids.

DISSEMINATION OF INFORMATION

A large share of the difficulty encountered by physically limited drivers can be overcome simply by giving them information that will help them to take advantage of the measures already available. These measures include:

- Selecting the most appropriate type of vehicle
- Purchasing the most appropriate options
- Arranging for installation of special devices
- Employing appropriate operating procedures
- Assuring proper maintenance of equipment, particularly adaptive equipment.

These information needs were described in greater depth on Pages 42-44.

The Human Resources Center and American Automobile Association publications mentioned earlier go a long way toward meeting the information needs of physically limited drivers. However, neither deals with the full range of problems identified by this report. They are somewhat short on operating and maintenance procedures as well as the anticipation of problems that may arise. They also tend to focus upon paraplegics and less upon the more ambulatory driver (e.g., arthritics, hemiplegics). Finally, the publications are quite comprehensive and, therefore, quite large. This makes them a bit costly to distribute widely on a complimentary basis. It should be possible to provide a greater range of information in a much smaller publication by:

- Focusing upon information related to most critical problems.
- Preparing separate publications to deal with the different major categories of limitation.

- Limiting reference material to that most likely to be used.

- Limiting the use of photographs, illustrations, and other space-consuming format.

Small manuals or pamphlets prepared in this manner could be widely distributed to physically limited drivers through rehabilitation centers, clinics, hospitals, and private physicians.

ADDITIONAL DEVICES AND AIDS

A number of devices and aids not currently available could have overcome certain of the problems reported during this survey. Foremost among these were the following:

Secondary Control Stalk--Drivers who must use hand controls, and amputees with but one arm, do not have a hand free to operate the dimmer, horn, washers, wiper, or heater controls. One possible solution is an "after-market" device that could be readily mounted on the steering column and connected into the electrical system at the connector in the fire wall, or elsewhere. Essential requirements of such a device are described on pp. 30-31.

Foot Restraint--Muscle spasms and motion of the vehicle often result in a driver's foot sliding under the pedal where it interferes with application of the hand control (p. 25). This problem could be ameliorated through some sort of barrier that would (1) inhibit forward movement of the feet, (2) permit the feet to be pulled backward if they do slide forward, or (3) do not interfere with normal operation of the foot control by an able-bodied driver. This barrier might take the form of a rubberized carpet with raised sections running crosswise, each angled rearward somewhat.

Wheelchair Assist--Difficulty in getting the wheelchair in and out of the car, while not a safety hazard, is one of the most frequent complaints of physically limited drivers (p. 38). A few electrical devices are available but are beyond the means of most potential users. What is needed is a simple device that will aid drivers in moving the wheelchair in and out (1) while they are seated in the front seat, (2) without requiring great strength, and (3) without preventing occupancy of the rear seat by a passenger.

Rearward Vision System--The majority of physically limited drivers have some difficulty in turning their head far enough to see cars in the blind spot or to see directly behind them while backing (p. 35). A system that would give 180-degree rearward vision would be a great benefit to safety and comfort. Currently available flat, convex, and remotely operated mirrors do not comprise a complete system.

Restraints--Conventional restraint systems do not meet the needs of many physically limited drivers (p. 32). Specific shortcomings are:

- The inertial reel type of shoulder harness does not provide upper body support. The diagonal strap restraint causes some discomfort.
- Lap belts cannot be used by many categories of physically limited drivers.
- Buckles tend to be difficult for many physically limited drivers to fasten and unfasten.

The "H-type" racing harness provides upper body support without use of a lap belt. However, it is difficult to fasten and tends to become entangled in the driver or itself as the driver enters and leaves the car. What is needed is a restraint system designed specifically to meet the needs of physically limited drivers.

Manufacturing and marketing of these devices is a task for private industry. However, it is likely to require an extensive research and development process. Manufacturers cannot be expected to bear the cost of such a process, given the limited market for the devices. The research and development of assistive devices, like other efforts aimed at benefiting a relatively small minority of people, can only be undertaken at the national level, under federal sponsorship.

ADAPTIVE CONTROLS

Relatively few problems with adaptive controls were reported by drivers (pp. 27-29). Most problems that were reported tended to be associated with older control systems which have since been replaced. Credit for this favorable state of affairs must be attributed in great meausure to VA standard design criteria for safety and quality of automobiles and adaptive equipment. While these standards apply only to purchase of control systems through VA funds, they have guided the development of all control systems by the major manufacturers.

Despite the generally favorable picture, some avenues of improvement were identified through the survey.

Reliability--While the number of control functions is not large, it is still significant. Major problems are (1) nuts and bolts loosening or falling off, (2) cables binding and occasionally breaking, (3) electrical shorts, resulting in shocks and burns, (4) bending and binding of rods. Most of these problems could have been prevented through better maintenance. However, the attention that physically limited drivers devote to maintenance is about the same as that of drivers in general, while their ability to carry out maintenance chores is strictly limited. Therefore, improvement in reliability would reduce an important source of hazard.

Comfort--Automobile acceleration and braking systems are designed to be foot-operated. Most adaptive controls involve a simple mechanical connection between the foot control and the steering column. Continuous application of the hand acceleration control becomes tiring after 10 to 15 minutes. The present VA standard does not limit the force that must be applied. Drivers would be benefited by design that required the application of less force to the accelerator control while still meeting the condition that the control return to a neutral position when no force is applied.

Appearance--The physical appearance of adaptive controls (p. 45) is not something that can be controlled by federal standards. Moreover, aesthetic considerations must take a back seat to considerations of operability and reliability, as well as compatibility with foot-operated controls. Attempting to produce a stylish control system within existing constraints is a challenging task. However, success in this direction will help physically limited drivers to feel less awkward or out of place in the world of driving.

In addition to improving the appearance of controls themselves, there is a need to improve installation so that controls can be mounted without damage to the vehicle. Even minor damage limits the resale value of the vehicle and makes adaptive control systems more difficult to afford. These aesthetic considerations might appear to have no relation to the safety or mobility of physically limited drivers. However, evidence gained from the survey indicates that the awkward-looking appearance of the equipment and its effect upon vehicle resale value had caused some drivers to delay purchase of the quipment. Those who attempted to drive without the equipment did so at some risk, while those who didn't attempt to drive at all were deprived of mobility. These findings are supported by the opinions of many rehabilitation workers.

Compactness--While there have been definite improvements in the mounting of adaptive controls, many control mechanisms still hang below the steering column where they form a barrier to the driver's entry and exit and where the driver's knee can interfere with application of the controls.

The responsibility for introducing these improvements into adaptive control systems clearly lies with the manufacturers of the systems. However, fulfillment of this responsibility might be enhanced by the following activity at the federal level:

Research and development--Current adaptive control research being sponsored by NHTSA and VA could be expanded to encompass investigation of the problems described.

Regulation--Those aspects of design that are appropriately regulated (e.g., parts suspended below steering column) can be brought under existing VA standards.

Information Dissemination--Implementation of those designed considerations that cannot be regulated could be encouraged through dissemination of information. First, manufacturers should be informed of the results of research and encouraged to implement them by pointing out potential marketing advantages. Secondly, as design improvements are implemented, results should be communicated to potential consumers through the various kinds of publications described earlier.

APPENDIX A

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APPENDIX B

INTERVIEW GUIDES

PHYSICALLY LIMITED DRIVERS

INTERVIEW GUIDE

SPECIAL DRIVING POPULATIONS

Purpose of Guide

The purpose of this guide is to assist interviewers in obtaining information concerning driving problems encountered by individuals with physical disabilities. The guide is intended to provide the interviewer with information that will assist in conducting the interview. It is not intended to identify specific questions to be asked; it is not a questionnaire. Nor, is it intended to tell the interviewer how to interview; such instruction will be provided as part of an interviewer training program.

Contents of Guide

The interview guide consists of (1) A Biographical Information Sheet, (2) A List of Prompts, (3) A Problem Description Sheet.

Biographical Information Sheet -- The Biographical Information Sheet (attachment A) provides the interviewer a format for collecting and recording information needed both to guide the interview and to aid in interpretation of data collected through the interview. Two items have been prepared to help the interviewer complete the Biographical Information Sheet:

- Disability Codes Sheet -- A code for convenience in recording the nature of individual disabilities (attachment B).
- Accessories and Adaptive Equipment Codes Sheet -- A set of codes for convenience in recording the accessories or adaptive equipment installed on the individual's automobile (attachment C).

List of Prompts -- The List of Prompts (attachment D) is a set of questions designed to aid the interviewer in stimulating identification of problems encountered by disabled individuals.

The prompts fall into two categories: (1) driving activities that are known to be affected by various disabilities, and (2) incidents that may arise from failure to carry out the activity properly. The prompts are intended solely to aid the interviewer in obtaining information. They are not questions that should be directed to the individual.

A Prompt Reference Sheet (attachment E) is provided to direct the interviewer to the specific prompts that are appropriate to particular disabilities.

Problem Description Sheet -- The Problem Description Sheet (appendix F) provides a format for recording information concerning driving problems encountered by disabled individuals. The format calls for the following:

- Description of Problem -- A detailed description of the problems as reported by the individual.
- Driver Recommendations -- Recommendations supplied by the driver as to vehicle modifications that would overcome or ameliorate the specific problem reported.
- Driver Reactions -- Reactions of the driver to modifications suggested by the interviewer.

Interview Procedure

For convenience, the interview process may be divided into the following four phases: (1) Introduction, (2) Problem Description, (3) Prompting, (4) Closing.

1. Introduction -- The interview will open with a brief explanation of the project including its nature, purpose, and sponsorship. The following points will be emphasized:
   - The ultimate goal of the project is to make automobiles easier and safer for disabled drivers to operate.
   - All information furnished during the interview will be held confidential and any identifying information removed.

   The interviewer will ask those questions on the Biographical Information Sheet needed to provide the interviewer insight

into the types of problems the individual may have. These questions include the following:

(1) Whether or not the individual drives.

(2) The nature of the individual's disability.

(3) What parts of the body are affected by the disability.

(4) How long the individual has been driving with the disability.

(5) What standard or optional accessories the individual's car is equipped with.

(6) What items of adaptive equipment the individual has added.

The remaining questions in the Biographical Information Sheet will be deferred until the end of the interview in order to avoid a question-and-answer pattern and maintain an informal atmosphere.

2. Problem Description -- Each individual will be asked whether his or her disability has ever resulted in a driving problem.

   If the individual acknowledges a problem the interviewer will obtain the following:

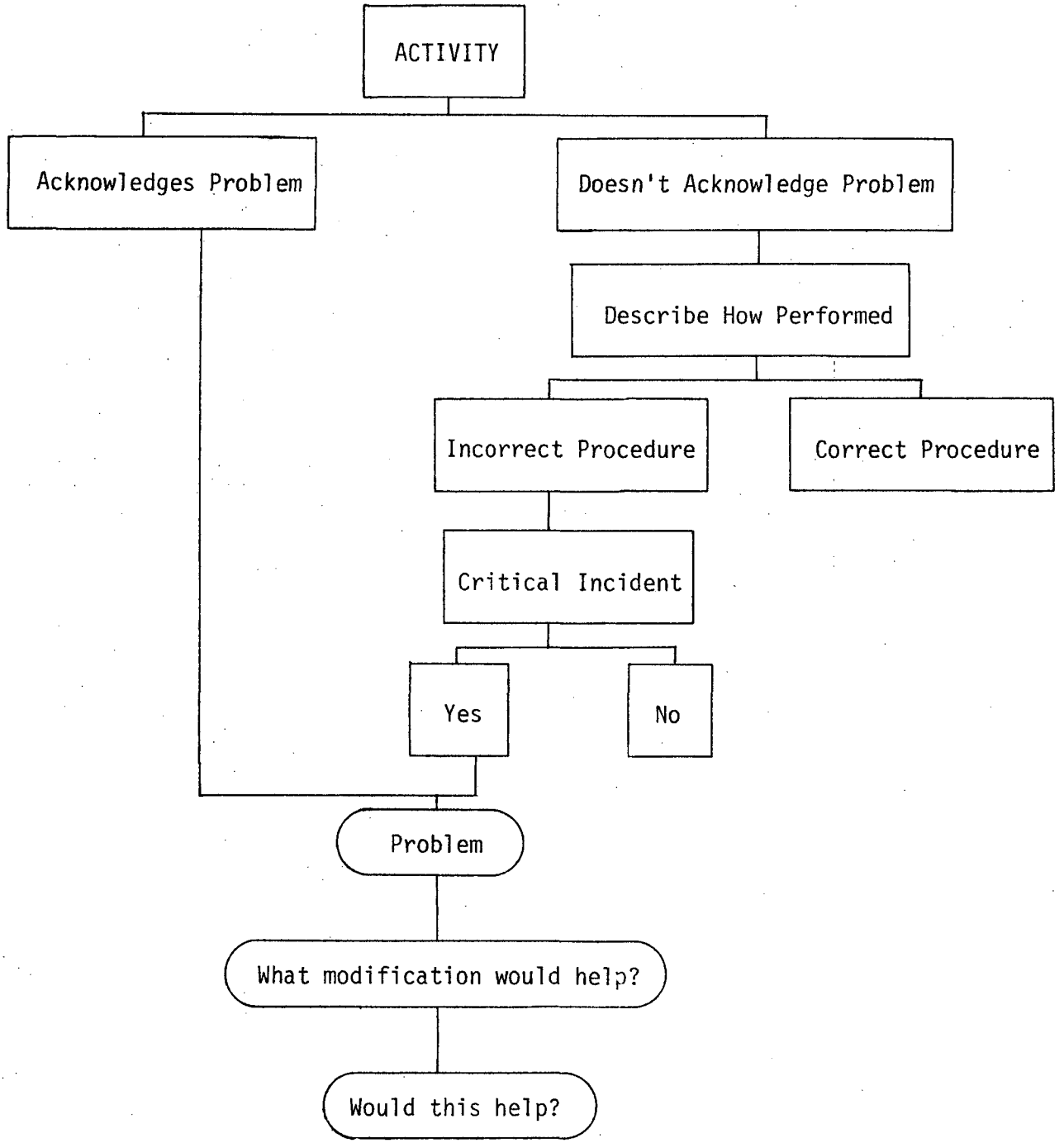
   - A detailed description of the problem and any specific incidents resulting from the problem.
   - Any modifications to the automobile that would alleviate or eliminate the problem.
   - The individual's reaction to specific modifications suggested by the instructor.

   When the description is completed, the interviewer will ask if the individual has any additional problems.

   If the individual fails to identify a problem, or cannot identify any additional problems, the interviewer will proceed to the prompting phase.

3. Prompting -- Unless the available interview time is completely consumed by descriptions of problems furnished spontaneously by the individual, the interviewer will proceed to the list of prompts.

PROMPTING PROCESS



To determine which prompt will be used for a particular individual, the interviewer will refer to the Prompt Reference Sheet (attachment E) to identify those problems that are appropriate to each functional disability of the individual.

The prompting process is presented in schematic form on the opposite page.

The prompt begins with a question concerning the activity known to be affected with a particular disability.

If an individual acknowledges a problem, the problem is described in the manner outlined above.

If the individual does not acknowledge a problem, the interviewer will ask the individual to describe how the activity is performed.

If the individual performs the activity correctly, the prompting is terminated.

If the individual performs the activity incorrectly, the interviewer asks if the individual has ever encountered specific incidents known to result from improper performance of the activity.

If the individual acknowledges encountering an incident, the incident and the problem leading to it will be described in the manner outlined.

If the individual does not acknowledge encountering an incident, the prompting is terminated.

The final items on the prompt list apply only to drivers whose vehicles have adaptive equipment. Any problems identified through these prompts would be recorded on the problem description. The individual's recommendations and reactions to suggestions concerning modifications to the adaptive equipment would also be recorded on the Problem Description Sheet.

4. Closing the Interview -- As the end of the scheduled interview approaches or whenever the individual is unable to describe any more problems, the interviewer will close the interview with the remaining questions on the Biographical Information Sheet.

The interviewer will thank the individual for his or her participation and provide a telephone number at which the interviewer can be reached for any questions or additional information.

If the interviewee's car is accessible, the interviewer will ask to see it in order to observe the following:

- The nature and installation of adaptive control and visibility enhancing equipment.
- The location and configuration of turn signals, horn, and accessories.
- The existence and location of visibility obstructing features, e.g., door posts.
- Other vehicle design characteristics not sufficiently common to warrant inclusion among the Accessories and Adaptive Equipment list.

Where vehicle characteristics are difficult to describe in verbal terms, the interviewer will ask to take a photograph of the particular item, e.g., a homemade adaptive control system. If the driver shows any reluctance to have the vehicle seen or photographed, the request will be dropped.

DISABILITY CODES

Disease or Disability

AR - Arthritis

HP - Hemiplegia

PP - Paraplegia

QP - Quadriplegia

PO - Polio

AM - Amputee

CP - Cerebral Palsy

CD - Congenitally Deformed

SP - Spondylitis

Part of Body Affected

N - Neck

UT - Upper Torso

LT - Lower Torso

SH - Shoulder

EL - Elbow

HA - Hands

HP - Hips

KN - Knees

FT - Ankle and Foot

L - Left

R - Right

BI - Bilateral

Functional Difficulty

CO - Coordination

RM - Range of Motion

SM - Strength of Motion

LL - Loss, Lack or Insufficiency of Limb

ACCESSORIES AND ADAPTIVE EQUIPMENT CODES

ACCESSORIES

BS - Bench Seat - split
ES - Electric powered Seat
SS - Swivel Seats
AR - Arm Rests
AT - Automatic Transmission
PS - Power Steering
PB - Power Brakes
ICM - Inside Control for outside mirror

PW - Power Windows
AC - Air Conditioning
CC - Cruise Control
PL - Power door Locks
TW - Tilting steering Wheel
RD - Rear window Defroster
LS - Luggage compartment Switch
CB - 2 way radio

ADAPTIVE EQUIPMENT

HC - Hand Controls
LA - Left foot Accelerator

THC - Turn signal on Hand Controls
TR - Turn signal on Right
TEX - Turn signal Extension

DF - Dimmer switch - Foot operated
DH - Dimmer switch - Hand operated
DMC - Dimmer switch on Hand Controls
DC - Dimmer - Courtesy

HP - Headlight switch under instrument panel
WC - Windshield wiper control on steering Column
HF - Horn on Floor

SA - Steering Assists
SK - Spinner Knob
SL - Steering - Left foot operated

SBD - Starter Button on Dash
IE - Ignition key Extensions
IP - Ignition underneath instrument panel
MW - Modified steering Wheel (angle or size)

GL - Gear selection on Left
GF - Gear selection on Floor

BH - parking Brake and release - Hand operated
BF - parking Brake and release - Foot operated
BE - parking Brake and release - Extensions

LIM - Large Inside rearview Mirror
LOM - Large Outside rearview Mirror

CH - Chest Harness

Attachment D

PROMPTS

Head Checks to the Side and Scanning at Intersections and Over the Shoulder Checks

1.1 DO YOU LOOK BOTH WAYS AT INTERSECTIONS?

Have you had any problems:

a. because you pulled out when you didn't know someone was already there?

1.2 DO YOU LOOK OVER YOUR SHOULDER WHEN CHANGING LANES?

Have you had any problems:

a. because you started to change to a lane when somebody was already there?
b. by coming to a quick stop because you couldn't tell if the adjacent lane was clear?
c. because you made a quick lane change without checking to see if the lane was clear?

1.3 DO YOU LOOK OVER YOUR SHOULDER WHEN BACKING UP OR PARKING?

1.4 HAVE YOU EVER ALMOST RUN INTO THE CAR AHEAD BECAUSE YOU WERE MAKING A HEAD CHECK OR LOOKING IN YOUR MIRROR?

Detecting Changing Traffic Lights

2.1 DO YOU HAVE TROUBLE SEEING TRAFFIC LIGHTS WHEN YOU ARE STOPPED CLOSE TO AN INTERSECTION?

Have you had any problems:

a. because you pulled away from a traffic light without being able to see if it had changed?

Backing Up and Parking

3.1 DO YOU HAVE ANY PROBLEMS PARKING?

3.2 DO YOU HAVE ANY PROBLEMS BACKING UP?

Have you had any problems:

a. such as running into anything while backing up?

   a pedestrian run out from behind you? _____
   a pedestrian call to you? _____
   a vehicle honk its horn at you? _____

b. such as forcing someone coming from the side to stop for you?
c. when you were parallel parking?

Use of Accessories

4.1 DO YOU HAVE TROUBLE REACHING ANY OF YOUR ACCESSORIES?

Windshield Wipers?
Headlight Switch?
Dimmer Switch?
Heater and Air Conditioner Switches?
Radio?
Lighter?

Have you had any problems:

a. such as not being able to see through your windshield because it was difficult to turn on the windshield wipers?
b. because you were driving without your lights on when it was too dark to see?
c. such as approaching a car with its bright lights on and not flashing your lights because it was too difficult?
d. such as slowing way down or running off the road because you couldn't see due to darkness or light rain?
e. because you didn't turn on your air conditioning or heater when you wanted to?
f. operating the car because you were trying to work an accessory?
g. because you reached for one accessory and accidently activated another one?

Remaining Upright

5.1 DO YOU HAVE ANY PROBLEMS STAYING BEHIND THE WHEEL?

Have you had any problems;

a. because you were seated in a position that made it difficult to control the car?
b. because you had trouble staying behind the wheel?

Have you had any problems:

c. because you were seated in a position that made it difficult to see?
d. because you slid across the seat in a swerve or a turn?
e. because your position made it difficult to see to the front or rear of the car?

Steering

6.1 DO YOU HAVE TROUBLE STEERING?

Have you had any problems:

a. either in a straightaway or curve, because you couldn't turn properly (too fast, not fast enough, too far, not far enough)?

run off the road?
hit another car?
gone into another lane?

b. maintaining control of your car because of wind gusts or bumpy roads?

6.2 DO YOU EVER TAKE BOTH YOUR HANDS OFF YOUR STEERING CONTROL TO OPERATE A CONTROL OR ACCESSORY?

Have you had any problems:

a. because you were operating a control or accessory?

Pre-Drive Functions--Adjusting mirrors, adjusting seat, parking brake

7.1 DO YOU ADJUST YOUR OUTSIDE AND INSIDE REARVIEW MIRRORS BEFORE YOU START TO DRIVE?

Have you had any problems:

a. with a car you didn't see because your mirrors weren't adjusted properly?

7.2 DO YOU ADJUST YOUR SEAT?

Have you had any problems:

a. with a car you had trouble seeing because you didn't adjust your seat properly?

7.3 DO YOU USE YOUR PARKING BRAKE?

Have you had any problems:

a. because the parking brake wasn't set?

Changing Gears

8.1 DO YOU HAVE ANY PROBLEMS CHANGING GEARS?

Have you had any problems:

a. such as going up a hill so slowly that you stalled?
b. when operating on a slick surface because you couldn't upshift to keep the wheels from spinning? (keep traction)

Signalling--Using Horn

9.1 DO YOU USE YOUR TURN SIGNALS EVERY TIME YOU CHANGE LANES OR TURN?

Have you had any problems:

a. that using your signals might have prevented?

9.2 IS SIGNALLING A PROBLEM?

Have you had any problems:

a. because you didn't use your turn signal when you should have?
b. because you signalled too early to too late?

9.3 DO YOU HAVE ANY PROBLEMS USING YOUR HORN WHEN YOU WANT TO?

Have you had any problems:

a. because you couldn't use your horn when you wanted to?
b. because you wanted to alert somebody with your horn but couldn't?

   a pedestrian?
   a bicyclist?
   a car backing out?

c. that you think could have been avoided if you'd been able to use your horn?

Windows

10.1 CAN YOU OPEN AND CLOSE YOUR WINDOWS WHILE DRIVING?

Have you had any problems:

a. while trying to open or close your windows (in order to see better or be more comfortable)?

in the rain?
when hot?

10.2 IF THE WINDSHIELD IS FOGGED UP HOW DO YOU CLEAN IT?

Have you had any problems:

a. because you couldn't see due to fog or snow on your rear window?

Seat Belts and Shoulder Harnesses

11.1 DO YOU HAVE A SEAT BELT, SHOULDER HARNESS OR BOTH?

11.2 DO YOU USE EITHER OR BOTH?

a. have you ever injured yourself in a collision or quick stop because you weren't using your seat belt or shoulder harness?
b. have you had any problems such as sliding away from the wheel when you weren't wearing your seat belt?

swerving to avoid someone? _____
turning sharply? _____

11.3 HAVE YOU EVER SUFFERED SEVERE IRRITATION FROM WEARING A SEAT BELT OR SHOULDER HARNESS?

Emergency Signals

12.1 CAN YOU REACH YOUR EMERGENCY FLASHERS?

Have you had any problems:

a. when you pulled off the road or stopped in the road because you didn't turn your emergency flashers on?

12.2 HAVE YOU EVER SAT BY THE SIDE OF THE ROAD AND HAD TO WAIT BECAUSE YOU COULDN'T SIGNAL FOR HELP?

12.3 DO YOU CARRY SOME KIND OF HELP SIGNAL?

Headlight Dimmer

13.1 DO YOU USE YOUR BRIGHT LIGHTS AT NIGHT WHEN THERE ARE NO CARS IN FRONT OF YOU OR APPROACHING YOU?

Have you had any problems:

a. at night because you couldn't see well enough?

13.2 CAN YOU REACH AND OPERATE YOUR DIMMER EASILY?

Have you had any problems:

a. because you almost lost control of your car while trying to use the headlight dimmer?

13.3 DO YOU DIM YOUR HEADLIGHTS WHEN ANOTHER CAR APPROACHES YOU?

Have you had any problems:

a. because another driver was blinded by your headlights?

13.4 DO YOU FLASH YOUR HEADLIGHTS AT AN ONCOMING CAR THAT HAS ITS BRIGHT LIGHTS ON?

Have you had any problems:

a. because you were blinded by the lights of another car?
b. if so, was it because you didn't flash your lights?

Acceleration

14.1 DO YOU HAVE ANY PROBLEMS ACCELERATING?

Have you had any problems:

a. because you had to accelerate and couldn't do it or couldn't do it fast enough?
b. because you accelerated accidently or accelerated more than you wanted to?

14.2 DO YOU HAVE TROUBLE MAINTAINING A STEADY SPEED?

14.3 DO YOU FIND THAT OPERATION OF THE ACCELERATOR MAKES YOU TIRED?

14.4 DO YOU HAVE TROUBLE KEEPING YOUR WHEELS FROM SPINNING ON SLIPPERY SURFACES?

Have you had any problems:

a. because you lost control by spinning your wheels on a slippery surface?

Braking

15.1 DO YOU HAVE ANY PROBLEMS BRAKING?

Have you had any problems:

a. because you tried to brake and couldn't?
b. because you inadvertently locked the wheels or put the car into a skid by applying the brakes too hard?
c. because you hit the brake accidently?
d. because you had to stop on a hill and had difficulty going from brake to accelerator quickly?

Entry and Exit of Vehicle

16.1 DO YOU HAVE ANY PROBLEMS GETTING IN AND OUT OF YOUR CAR?

Have you had any problems:

a. getting in or out of your car? (e.g., driver had to stop suddenly or swerve to avoid you)

Position of Limbs

17.1 DO YOU HAVE DIFFICULTY KEEPING YOUR LIMBS FROM GETTING IN THE WAY OF YOUR CONTROLS?

Have you had any problems:

a. because your foot slipped under the brake pedal?
b. because your foot slipped onto the accelerator?
c. because your knee got in the way of your controls when you went to brake or accelerate?

18.1 HAS YOUR ENGINE EVER DIED WHILE YOU WERE DRIVING?

Have you had any problems:

a. steering the car because your engine died while you were turning?
b. slowing or stopping the car because your engine died?

ADAPTIVE EQUIPMENT

19. Describe your present adaptive equipment. (to be accompanied by photo)

20. How long have you been using adaptive equipment?

21. Have you ever changed types or manufacturers of adaptive equipment?

22. If so, what kind did you have?

23. Why did you change?

24. What specific incidents arose with the old equipment? Good and Bad?

25. Have you ever had an accident or almost had an accident because of your present equipment?

26. Have you ever had an accident or almost had an accident because of malfunctioning equipment? (other than normal automobile failures)

27. What changes in your controls do you think could have helped you avoid this incident?

28. What changes would you like to see in adaptive equipment?

29. What kinds of adaptive equipment that you don't have now would help you?

30. What would you tell someone who is just beginning to drive with your type of adaptive equipment?

31. How much and what kind of maintenance is spent on adaptive controls, and other disability-related characteristics of the vehicle?

32. How much and what kind of training did you receive in the use of hand controls?

33. What kinds of problems with your equipment did you have initially?

34. Do you still have any problems with your adaptive equipment?

PROMPT REFERENCES

Attachment F

Part of Body Affected	Coordination	Strength of Motion	Range of Motion	Loss, Lack or Insufficiency of Limb
NECK	-	-	1,2,3	-
UPPER TORSO	1,4,5	-	1,4	-
LOWER TORSO	5	-	5	-
SHOULDERS	-	-	-	-
Bilateral	4,5,6,7,8,9,10, 11,12	4,6,7,8,11	4,6,7,8,11	4,5,6,7,8,9,10, 11,13
Left	4,6,7,9,10,11	4,6,7,9,10,11	4,6,7,10,11	4,6,7,9,10,11 13
Right	4,6,7,8,11,12	4,6,7,8,11,12	4,6,7,8,11	4,6,7,8,9,11 13
ELBOWS	-	-	-	-
Bilateral	4,6,7,8,9,10,11 12	6,10	6,10	4,6,7,9,10, 11, 12
Left	4,6,7,10,11,12	6,10	6,10	4,6,7,9,10, 11,12
Right	4,6,7,8,9,10,11 12	6	6	4,6,7,8,9,10 12
WRISTS	-	-	-	-
Bilateral	4,6,7,8,9,10,11 12	-	-	4,6,7,8,9,10, 11,12
Left	4,6,7,9,10,11	-	-	4,6,7,9,10,11 12
Right	4,6,7,8,9,11,12	4,6,7,10,11	4,6,7,10,11	4,6,7,8,9,10 11
HANDS	-	-	-	-
Bilateral	4,6,7,8,9,10,11, 12	-	-	4,6,7,8,9,10 11,12
Left	4,6,7,9,10,11	-	-	4,6,7,9,10,11 12
Right	4,6,7,8,9,11,12	4,6,7,10,11	4,6,7,10,11	4,6,7,8,9,10,11
HIPS	-	-	-	-
Bilateral	13,14,15,16,17	14,15	13,14,15,16,17	1,5,13,14,15 16,17
Left	13,17	13	13	13,17
Right	14,17	14	14	14,17
KNEES	-	-	-	-
Bilateral	13,14,15,16,17	13,14,15,16	13,14,15,16	13,14,15,16,17
Left	13,17	13	-	13,17
Right	14,17	14	14	14,17
ANKLES	-	-	-	-
Bilateral	13,14,15,16,17	13,14,15,16	13,14,15,16	13,14,15,16,17
Left	13,17	13	-	13,17
Right	14,17	14	14	14,17
FEET	-	-	-	-
Bilateral	13,14,15,16,17	13,14,15,16	13,14,15,16	13,14,15,16,17
Left	13,17	13	-	13,17
Right	14,17	14	14	14,17

PROBLEM DESCRIPTIONS

MODIFICATIONS

PHYSICALLY LIMITED NON-DRIVERS

INTERVIEW GUIDE

SPECIAL DRIVING POPULATIONS

Purpose of Guide

The purpose of this guide is to assist interviewers in obtaining information concerning driving problems encountered by physically disabled individuals who are capable of driving but no longer do so. Results will be compared with those obtained by interviewing physically disabled individuals who are still driving.

The guide is intended to provide the interviewer with information that will assist in conducting the interview. It is not intended to identify specific questions to be asked; it is not a questionnaire. Nor is it intended to tell the interviewer how to interview; such instruction will be provided as part of an interviewer training program.

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   The interviewer will ask those questions on the Biographical Information Sheet needed to provide the interviewer insight into the types of problems the individual may have. These questions include the following:

   1. Whether or not the individual drives.
   2. Why the individual gave up driving.
   3. The nature of the individual's disability.
   4. What parts of the body are affected by the disability.
   5. If the individual ever drove after becoming disabled.
   6. What standard or optional accessories the individual's car was equipped with.
   7. What items of adaptive equipment the individual added.

The remaining questions in the Biographical Information Sheet will be deferred until the end of the interview in order to avoid a question-and-answer pattern and maintain an informal atmosphere.

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   If the individual acknowledges a problem the interviewer will obtain the following:

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   - Any modifications to the automobile that would alleviate or eliminate the problem.
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   If an individual acknowledges a problem the problem is described in the manner outlined above.

   If the individual does not acknowledge a problem, the interviewer will ask the individual to describe how the activity was performed.

If the individual performed the activity correctly, the prompting is terminated.

If the individual performed the activity incorrectly, the interviewer asks if the individual ever encountered specific incidents known to result from improper performance of the activity.

If the individual acknowledges encountering an incident, the incident and the problem leading to it will be described in the manner outlined.

If the individual does not acknowledge encountering an incident, the prompting is terminated.

The final items on the prompt list apply only to drivers whose vehicles had adaptive equipment. Any problems identified through these prompts would be recorded on the Problem Decription Sheet. The individual's recommendations and reactions to suggestions concerning modifications to the adaptive equipment would also be recorded on the Problem Description Sheet.

4. Closing the Interview--As the end of the scheduled interview approaches or whenever the individual is unable to describe any more problems, the interviewer will close the interview with the remaining questions on the Biographical Information Sheet.

The interviewer will thank the individual for his or her participation and provide a telephone number at which the interviewer can be reached for any questions or additional information.

If the driver reports any modification of the vehicle, the interviewer will ask to see the vehicle. If the vehicle is accessible and permission is granted, the interviewer will record the following information:

(1) A description of the nature of the modification.

(2) The manufacturer and manufacturer's designation, if applicable.

(3) Any design defects (e.g. inadequate clearance).

(4) Any evidence of breakdown or disrepair (e.g., loose screws).

Sketches may be made or photographs taken where it will help in communicating the nature of the modification. Photographs will not be taken if the interviewee shows any hesitance in permitting them.

DISABILITY CODES

Disease or Disability

AR - Arthritis

HP - Hemiplegia

PP - Paraplegia

QP - Quadriplegia

PO - Polio

AM - Amputee

CP - Cerebral Palsy

CD - Congenitally Deformed

SP - Spondylitis

Part of Body Affected

N - Neck

UT - Upper Torso

LT - Lower Torso

SH - Shoulder

EL - Elbow

HA - Hands

HP - Hips

KN - Knees

FT - Ankle and Foot

L - Left

R - Right

BI - Bilateral

Functional Difficulty

CO - Coordination

RM - Range of Motion

SM - Strength of Motion

LL - Loss, Lack or Insufficiency of Limb

ACCESSORIES AND ADAPTIVE EQUIPMENT CODES

ACCESSORIES

BS - Bench Seat - split
ES - Electric powered Seat
SS - Swivel Seats
AR - Arm Rests
AT - Automatic Transmission
PS - Power Steering
PB - Power Brakes
ICM - Inside Control for outside mirror

PW - Power Windows
AC - Air Conditioning
CC - Cruise Control
PL - Power door Locks
TW - Tilting steering Wheel
RD - Rear window Defroster
LS - Luggage compartment Switch
CB - 2 way radio

ADAPTIVE EQUIPMENT

HC - Hand Controls
LA - Left foot Accelerator

THC - Turn signal on Hand Controls
TR - Turn signal on Right
TEX - Turn signal Extension

DF - Dimmer switch - Foot operated
DH - Dimmer switch - Hand operated
DMC - Dimmer switch on Hand Controls
DC - Dimmer - Courtesy

HP - Headlight switch under instrument panel
WC - Windshield wiper control on steering Column
HF - Horn on Floor

SA - Steering Assists
SK - Spinner Knob
SL - Steering - Left foot operated

SBD - Starter Button on Dash
IE - Ignition key Extensions
IP - Ignition underneath instrument panel
MW - Modified steering Wheel (angle or size)

GL - Gear selection on Left
GF - Gear selection on Floor

BH - parking Brake and release - Hand operated
BF - parking Brake and release - Foot operated
BE - parking Brake and release - Extensions

LIM - Large Inside rearview Mirror
LOM - Large Outside rearview Mirror

CH - Chest Harness

PROMPTS

Head Checks to the Side and Scanning at Intersections and Over the Shoulder Checks

1.1 DID YOU LOOK BOTH WAYS AT INTERSECTIONS?

Did you have any problems:

a. because you pulled out when you didn't know someone was already there?

1.2 DID YOU LOOK OVER YOUR SHOULDER WHEN CHANGING LANES?

Did you have any problems:

a. because you started to change to a lane when somebody was already there?
b. by coming to a quick stop because you couldn't tell if the adjacent lane was clear?
c. because you made a quick lane change without checking to see if the lane was clear?

1.3 DID YOU LOOK OVER YOUR SHOULDER WHEN BACKING UP OR PARKING?

1.4 DID YOU EVER ALMOST RUN INTO THE CAR AHEAD BECAUSE YOU WERE MAKING A HEAD CHECK OR LOOKING IN YOUR MIRROR?

Detecting Changing Traffic Lights

2.1 DID YOU HAVE TROUBLE SEEING TRAFFIC LIGHTS WHEN YOU WERE STOPPED CLOSE TO AN INTERSECTION?

Did you have any problems:

a. because you pulled away from a traffic light without being able to see if it had changed?

Backing Up and Parking

3.1 DID YOU HAVE ANY PROBLEMS PARKING?

3.2 DID YOU HAVE ANY PROBLEMS BACKING UP?

Did you have any problems:

a. such as running into anything while backing up?

   a pedestrian ran out from behind you? _____
   a pedestrian called to you? _____
   a vehicle honked its horn at you? _____

b. such as forcing someone coming from the side to stop for you?
c. when you were parallel parking?

Use of Accessories

4.1 DID YOU HAVE TROUBLE REACHING ANY OF YOUR ACCESSORIES?

Windshield Wipers?
Headlight Switch?
Dimmer Switch?
Heater and Air Conditioner Switches?
Radio?
Lighter?

Did you have any problems:

a. such as not being able to see through your windshield because it was difficult to turn on the windshield wipers?
b. because you were driving without your lights on when it was too dark to see?
c. such as approaching a car with its bright lights on and not flashing your lights because it was too difficult?
d. such as slowing way down or running off the road because you couldn't see due to darkness or light rain?
e. because you didn't turn on your air conditioning or heater when you wanted to?
f. operating the car because you were trying to work an accessory?
g. because you reached for one accessory and accidentally activated another one?

Remaining Upright

5.1 DID YOU HAVE ANY PROBLEMS STAYING BEHIND THE WHEEL?

Did you have any problems:

a. because you were seated in a position that made it difficult to control the car?
b. because you had trouble staying behind the wheel?

Did you have any problems:

c. because you were seated in a position that made it difficult to see?
d. because you slid across the seat in a swerve or a turn?
e. because your position made it difficult to see to the front or rear of the car?

Steering

6.1 DID YOU HAVE TROUBLE STEERING?

Did you have any problems:

a. either in a straightaway or curve, because you couldn't turn properly (too fast, not fast enough, too far, not far enough)?

ran off the road?
hit another car?
went into another lane?

b. maintaining control of your car because of wind gusts or bumpy roads?

6.2 DID YOU EVER TAKE BOTH YOUR HANDS OFF YOUR STEERING CONTROL TO OPERATE A CONTROL OR ACCESSORY?

Did you have any problems:

a. because you were operating a control or accessory?

Pre-Drive Functions--Adjusting Mirrors, Adjusting Seat, Parking Brake

7.1 DID YOU ADJUST YOUR OUTSIDE AND INSIDE REARVIEW MIRRORS BEFORE YOU STARTED TO DRIVE?

Did you have any problems:

a. with a car you didn't see because your mirrors weren't adjusted properly?

7.2 DID YOU ADJUST YOUR SEAT?

Did you have any problems:

a. with a car you had trouble seeing because you didn't adjust your seat properly?

7.3 DID YOU USE YOUR PARKING BRAKE?

Did you have any problems:

a. because the parking brake wasn't set?

Changing Gears

8.1 DID YOU HAVE ANY PROBLEMS CHANGING GEARS?

Did you have any problems:

a. such as going up a hill so slowly that you stalled?
b. when operating on a slick surface because you couldn't upshift to keep the wheels from spinning? (Keep traction)

Signalling--Using Horn

9.1 DID YOU USE YOUR TURN SIGNALS EVERY TIME YOU CHANGED LANES OR TURNED?

Did you have any problems:

a. that using your signals might have prevented?

9.2 WAS SIGNALLING A PROBLEM?

Did you have any problems:

a. because you didn't use your turn signal when you should have?
b. because you signalled too early or too late?

9.3 DID YOU HAVE ANY PROBLEMS USING YOUR HORN WHEN YOU WANTED TO?

Did you have any problems:

a. because you couldn't use your horn when you wanted to?
b. because you wanted to alert somebody with your horn but couldn't?

a pedestrian?
a bicyclist?
a car backing out?

c. that you think could have been avoided if you'd been able to use your horn?

Windows

10.1 COULD YOU OPEN AND CLOSE YOUR WINDOWS WHILE DRIVING?

Did you have any problems:

a. while trying to open or close your windows (in order to see better or be more comfortable)?

in the rain?
when hot?

10.2 IF THE WINDSHIELD WAS FOGGED UP HOW DID YOU CLEAN IT?

Did you have any problems:

a. because you couldn't see due to fog or snow on your rear window?

Seat Belts and Shoulder Harnesses

11.1 DID YOU HAVE A SEAT BELT, SHOULDER HARNESS, OR BOTH?

11.2 DID YOU USE EITHER OR BOTH?

a. Did you ever injure yourself in a collision or quick stop because you weren't using your seat belt or shoulder harness?
b. Did you have any problems such as sliding away from the wheel when you weren't wearing your seat belt?

swerving to avoid someone? _____
turning sharply? _____

11.3 HAVE YOU EVER SUFFERED SEVERE IRRITATION FROM WEARING A SEAT BELT OR SHOULDER HARNESS?

Emergency Signals

12.1 COULD YOU REACH YOUR EMERGENCY FLASHERS?

Did you have any problems:

a. when you pulled off the road or stopped in the road because you didn't turn your emergency flashers on?

12.2 HAVE YOU EVER SAT BY THE SIDE OF THE ROAD AND HAD TO WAIT BECAUSE YOU COULDN'T SIGNAL FOR HELP?

12.3 DID YOU CARRY SOME KIND OF HELP SIGNAL?

Headlight Dimmer

13.1 DID YOU USE YOUR BRIGHT LIGHTS AT NIGHT WHEN THERE WERE NO CARS IN FRONT OF YOU OR APPROACHING YOU?

Did you have any problems:

a. at night because you couldn't see well enough?

13.2 COULD YOU REACH AND OPERATE YOUR DIMMER EASILY?

Did you have any problems:

a. because you almost lost control of your car while trying to use the headlight dimmer?

13.3 DID YOU DIM YOUR HEADLIGHTS WHEN ANOTHER CAR APPROACHED YOU?

Did you have any problems:

a. because another driver was blinded by your headlights?

13.4 DID YOU FLASH YOUR HEADLIGHTS AT AN ONCOMING CAR THAT HAD ITS BRIGHT LIGHTS ON?

Did you have any problems:

a. because you were blinded by the lights of another car?
b. if so, was it because you didn't flash your lights?

Acceleration

14.1 DID YOU HAVE ANY PROBLEMS ACCELERATING?

Did you have any problems:

a. because you had to accelerate and couldn't do it or couldn't do it fast enough?
b. because you accelerated accidently or accelerated more than you wanted to?

14.2 DID YOU HAVE TROUBLE MAINTAINING A STEADY SPEED?

14.3 DID YOU FIND THAT OPERATION OF THE ACCELERATOR MADE YOU TIRED?

14.4 DID YOU HAVE TROUBLE KEEPING YOUR WHEELS FROM SPINNING ON SLIPPERY SURFACES?

Did you have any problems:

a. because you lost control by spinning your wheels on a slippery surface?

Braking

15.1 DID YOU HAVE ANY PROBLEMS BRAKING?

Did you have any problems:

a. because you tried to brake and couldn't?
b. because you inadvertently locked the wheels or put the car into a skid by applying the brakes too hard?
c. because you hit the brake accidently?
d. because you had to stop on a hill and had difficulty going from brake to accelerator quickly?

Entry and Exit of Vehicle

16.1 DO YOU HAVE ANY PROBLEMS GETTING IN AND OUT OF YOUR CAR?

Did you have any problems:

a. getting in or out of your car? (e.g., driver had to stop suddenly or swerve to avoid you)

Position of Limbs

17.1 DID YOU HAVE DIFFICULTY KEEPING YOUR LIMBS FROM GETTING IN THE WAY OF YOUR CONTROLS?

Did you have any problems:

a. because your foot slipped under the brake pedal?
b. because your foot slipped onto the accelerator?
c. because your knee got in the way of your controls when you went to brake or accelerate?

18.1 DID YOUR ENGINE EVER DIE WHILE YOU WERE DRIVING?

Did you have any problems:

a. steering the car because your engine died while you were turning?
b. slowing or stopping the car because your engine died?

ADAPTIVE EQUIPMENT

19. Did you use adaptive equipment?

20. How long did you use adaptive equipment?

21. Did you ever change types or manufacturers of adaptive equipment?

22. If so, what kind did you have?

23. Why did you change?

24. What specific incidents arose with the old equipment? Good and Bad?

25. Did you ever have an accident or almost have an accident because of your equipment?

26. Did you ever have an accident or almost have an accident because of malfunctioning equipment? (other than normal automobile failures?)

27. What changes in your controls do you think could have helped you avoid this incident?

28. What changes would you like to see in adaptive equipment?

29. How much and what kinds of maintenance did you spend on adaptive controls, and other disability-related characteristics of the vehicle?

30. How much and what kind of training did you receive in the use of hand controls?

31. What kinds of problems with your equipment did you have initially?

32. Did you have any recurring problems with your equipment?

PROMPT REFERENCES

Attachment E

Part of Body Affected	Coordination	Strength of Motion	Range of Motion	Loss, Lack or Insufficiency of Limb
NECK	-	-	1,2,3	-
UPPER TORSO	1,4,5	-	1,4	-
LOWER TORSO	5	-	5	-
SHOULDERS	-	-	-	-
Bilateral	4,5,6,7,8,9,10, 11,12	4,6,7,8,11	4,6,7,8,11	4,5,6,7,8,9,10, 11,13
Left	4,6,7,9,10,11	4,6,7,9,10,11	4,6,7,10,11	4,6,7,9,10,11 13
Right	4,6,7,8,11,12	4,6,7,8,11,12	4,6,7,8,11	4,6,7,8,9,11 13
ELBOWS	-	-	-	-
Bilateral	4,6,7,8,9,10,11 12	6,10	6,10	4,6,7,9,10, 11, 12
Left	4,6,7,10,11,12	6,10	6,10	4,6,7,9,10, 11,12
Right	4,6,7,8,9,10,11 12	6	6	4,6,7,8,9,10 12
WRISTS	-	-	-	-
Bilateral	4,6,7,8,9,10,11 12	-	-	4,6,7,8,9,10, 11,12
Left	4,6,7,9,10,11	-	-	4,6,7,9,10,11 12
Right	4,6,7,8,9,11,12	4,6,7,10,11	4,6,7,10,11	4,6,7,8,9,10 11
HANDS	-	-	-	-
Bilateral	4,6,7,8,9,10,11, 12	-	-	4,6,7,8,9,10 11,12
Left	4,6,7,9,10,11	-	-	4,6,7,9,10,11 12
Right	4,6,7,8,9,11,12	4,6,7,10,11	4,6,7,10,11	4,6,7,8,9,10,11
HIPS	-	-	-	-
Bilateral	13,14,15,16,17	14,15	13,14,15,16,17	1,5,13,14,15 16,17
Left	13,17	13	13	13,17
Right	14,17	14	14	14,17
KNEES	-	-	-	-
Bilateral	13,14,15,16,17	13,14,15,16	13,14,15,16	13,14,15,16,17
Left	13,17	13	-	13,17
Right	14,17	14	14	14,17
ANKLES	-	-	-	-
Bilateral	13,14,15,16,17	13,14,15,16	13,14,15,16	13,14,15,16,17
Left	13,17	13	-	13,17
Right	14,17	14	14	14,17
FEET	-	-	-	-
Bilateral	13,14,15,16,17	13,14,15,16	13,14,15,16	13,14,15,16,17
Left	13,17	13	-	13,17
Right	14,17	14	14	14,17

DISABLED NON-DRIVERS

PROBLEM DESCRIPTIONS

MODIFICATIONS

APPENDIX C

AGE/SEX QUOTAS FOR DISABILITY CATEGORIES

	AGE			
	45-	45-64	65+	Total
Range of Motion				
Upper Extremity				
Male	23%	45%	19%	87%
Female	9%	3%	1%	13%
Both Legs				
Male	33%	20%	27%	80%
Female	0%	0%	20%	20%
Right Leg				
Male				
Female				
Coordination				
Hemiplegics				
Male	11%	21%	26%	58%
Female	7%	12%	23%	42%
Paraplegics				
Male	25%	21%	13%	59%
Female	12%	21%	8%	41%
Quadriplegics				
Male	15%	20%	14%	49%
Female	2%	25%	24%	51%
CP				
Male	51%	3%	3%	57%
Female	36%	4%	3%	43%
Strength of Motion				
Arthritics				
Male	4%	13%	16%	33%
Female	6%	25%	36%	67%

Percentages are based upon unpublished statistics obtained from the U.S. Public Health Service.

Non-disabled drivers will be equally divided between males and females and between drivers under 60 and drivers over 60. This will provide 25 individuals in each age/sex category for age/sex comparison purposes.

APPENDIX D

INTERVIEWERS

Illinois

Warren P. Quensel

Missouri

Carrie Dunson
Frank Masten
Normal Patterson

Texas

Barbara Bell
Nancy Hatfield
Rodger Koppa
Martha McKennie
Donna Sexton

Washington, D. C. - Metropolitan Area

Kay Carlisle
Molly A. Green
Diane Katz
Jo Marshall
Linda Newman
Vallerie Pote
Carmella Strano
Peggy Tluszcz

APPENDIX E

ORGANIZATIONS THAT PROVIDED ASSISTANCE TO THE PROJECT

American Automobile Association
Fairfax, Virginia

American Coalition of Citizens with Disabilities
Washington, D. C.

American Red Cross
Alexandria, Virginia

Arlington Stroke Club
Arlington, Virginia

Arthritis Rehabilitation Center
Washington, D. C.

Arthritis and Rheumatism Foundation
Washington, D. C.

Center for Concerned Engineers
Washington, D. C.

Die-A-Matic
Arlington, Virginia

Disabled American Veterans
Washington, D. C.

Fairfax Hospital Stroke Unit
Home Health Services
Falls Church, Virginia

Gallaudet College
Washington, D. C.

Georgetown University Hospital
Orthopedics Department
Washington, D. C.

George Washington University Job
Development Laboratory
Bio-Medical Laboratory
Washington, D. C.

Heart Association of Northern Virginia
Annandale, Virginia

Maryland Center - Montibello Hospital
Baltimore, Maryland

Maryland United Cerebral Palsy Association
Annapolis, Maryland

National Academy of Sciences
Washington, D. C.

National Association of the Physically Handicapped
Washington, D. C.

National Orthopedic and Rehabilitation Hospital
Arlington, Virginia

National Paraplegia Foundation
Washington, D. C.

Our Way
Chevy Chase, Maryland

Paralyzed Veterans of America
Washington, D. C.

President's Commission on the Handicapped
Washington, D. C.

Rehab Group, Inc.
Alexandria, Virginia

Sharp School
Washington, D. C.

United Cerebral Palsy Associations
Washington, D. C.

United Cerebral Palsy of Prince George's County
Hyattsville, Maryland

United Cerebral Palsy of Central Maryland
Pikesville, Maryland

U. S. Department of Health, Education and Welfare
Washington, D. C.

U. S. House of Representatives
Committee of Veterans Affairs
Washington, D. C.

U. S. Veterans Administration
Washington, D. C.

Veterans Administration Hospital
Washington, D. C.

Veterans Administration Prosthetics Center
New York City, New York

Virginia Vocational Rehabilitation
- Alexandria, Virginia
- Arlington, Virginia
- Baileys Crossroads, Virginia
- Falls Church, Virginia
- Springfield, Virginia
- Woodbridge, Virginia