THE DETERMINATION OF DIRECTION OF MOTION STEREOTYPES FOR AUTOMOBILE CONTROLS

by

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(ABSTRACT)

This experiment examined the directional relationships for six types of automobile controls: power mirrors, power windows, manual windows, stalks, generic controls, and power door locks. Two hundred driver-subjects participated in the research. Participants were divided into 4 groups of 50 each, and distributed according to age, gender, and type of vehicle they drove (domestic or foreign).

During data collection subjects were instructed to perform various types of control tasks. For each task the direction of control activation chosen by the subject was observed and recorded. Frequencies of occurrence were then tabulated to grade the strength of directional stereotypes. In addition, statistical tests were conducted to determine the effects of age, gender, type of vehicle driven, and handedness on subject behavior. Confidence limits were also calculated and tabulated.

In general, results showed that most control designs and configurations tested displayed moderate to strong stereotypes. However, weak directional stereotypes did occur whenever a control was angled away from the driver. Weak directional stereotypes were also prominent for manual window and power door lock conditions.

For the power window the two controls mounted flush with the driver's door resulted in control selection problems (i.e., which control goes with which window), while the push-pull power window control resulted in weak directional stereotypes. The most salient result from the Chi-square statistical tests indicate that foreign car drivers utilize their stalk controls differently than domestic car drivers.

Based on the overall results a list of design recommendations and direction for future research is offered.

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TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS iv

INTRODUCTION 1

LITERATURE REVIEW 3

RESEARCH OBJECTIVE 15

METHOD 17

Apparatus 17

Test Equipment 17

Controls 20

Experimental Design 25

Study 1 — Power Mirrors 25

Study 2 — Power Windows 29

Study 3 — Manual Windows 29

Study 4 — Stalk Controls 29

Study 5 — Generic Controls 49

Study 6 — Power Door Lock 59

Grouping of Conditions 59

Subjects 64

Procedure 66

RESULTS 68

Frequencies of Occurrence and Stereotype Grades 71

Study 1 — Power Mirrors 71

Study 2 — Power Windows 84

Study 3 — Manual Windows 128

Study 4 — Stalk Controls 132

Study 5 — Generic Controls 138

Study 6 — Power Door Locks 153

Statistical Tests for Age, Type of Car Driven, Gender, and Handedness 158

Significant Age Differences for Directional Stereotypes 158

Significant Vehicle Type Differences for Directional Stereotypes 160

Significant Gender Differences for Directional Stereotypes 162

Significant Handedness Differences for Directional Stereotypes 163

DISCUSSION 164

Power Mirrors 164

Power Windows 166

Manual Windows 167

Stalk Controls 168

Generic Controls 169

Power Door Locks 171

Chi-Square Analysis 172

Age Differences 172

Vehicle Differences 173

Gender Differences 175

Handedness Differences 175

CONCLUSIONS 176

Power Mirrors 176

Power Windows 177

Manual Windows 178

Stalk Controls 178

Generic Controls 179

Power Door Locks 179

Recommendations 179

Further Research 180

REFERENCES 181

Appendix A. Sample Command Script Used in Experiment 183

Appendix B. Background Information, Questionnaire, and Informed Consent 191

LIST OF ILLUSTRATIONS

Page

Figure 1. SAE recommended movements for "On" or "Increase" 12

Figure 2. View of buck from the right side 18

Figure 3. Control mounting area on driver door panel shown with typical control being removed 19

Figure 4. Manual window control mounted on "passenger" side of buck 21

Figure 5. Center console shown with control mounted 45° below the horizontal 22

Figure 6. Wedge attachment being added to center console 23

Figure 7. Three positions for an adjustable power window control 24

Figure 8. Vehicle axis system 26

Figure 9. Power mirror controls 27

Figure 10. Front view of buck and roadscene 28

Figure 11. Mirror with experimenter's handle 30

Figure 12. Power mirror Conditions A, B, C, and D for pad switch mounted on adjustable bracket affixed to flat carrier plate 31

Figure 13. Power mirror Condition E for pad switch mounted flush on flat carrier plate (X-Z plane) 32

Figure 14. Power mirror Conditions F and G for pad switch mounted flush on flat carrier plate, used on the console 33

Figure 15. Power mirror Condition H for joystick extending from flat carrier plate (X-Z plane) 34

Figure 16. Power mirror Conditions I and J for joystick mounted on bracket affixed to flat carrier plate 35
Figure 17. Power window controls 36
Figure 18. Power window Conditions, A, B, C, and D for 2 × 2 adjustable toggle switch 37
Figure 19. Power window Condition E for 2 × 2 toggle switch (X-Z plane) 38
Figure 20. Power window Condition F, G, and H for 2 × 2 adjustable rocker switch 39
Figure 21. Power window Condition I for 1 × 4 lateral toggle switch (X-Z plane) 40
Figure 22. Power window Conditions J and K for 2 × 2 adjustable push-pull switch 41
Figure 23. Driver and passenger side locations for manual window control 42
Figure 24. Manual window Conditions A and B on driver side 43
Figure 25. Manual window Conditions C and D on passenger side 44
Figure 26. View of stalks mounted on steering column 45
Figure 27. Left side stalk 46
Figure 28. Right side stalk 47
Figure 29. Generic controls 50
Figure 30. Thumbwheel control cube 51
Figure 31. Toggle switch control cube 52
Figure 32. Linear slide control cube 53
Figure 33. Rotary control cube 54
Figure 34. Rocker switch control cube 55

Figure 35. Left instrument panel shown with rocker and toggle switch cubes and right instrument panel shown with slide control and thumbwheel cubes 57

Figure 36. Power door lock controls with angle bracket 60

LIST OF TABLES

Page

Table 1. Recommended control movements 11

Table 2. Generic control conditions 58

Table 3. Power door lock conditions 61

Table 4. Grouping of conditions 63

Table 5. Subject distribution 65

Table 6. Confidence limits for specific values of $\hat{p}$, given that N = 50 and that 90% confidence is desired 70

INTRODUCTION

In the past two decades many changes have been made in the design of automobiles. Advancements in aerodynamics, lightweight materials, computers, and engine design now make it possible to drive a fuel efficient, yet surprisingly powerful, automobile. Features that make the interior environment of the automobile more appealing also have become standard fare. Cruise control, power windows, power mirrors, electronic sun roofs, multi-adjustable seats, and ultra-modern sound systems are some items now available in many automobiles. These new and advanced options produce instrument panels that are more intricate and crowded. Thus, the issue of control design and placement presents a formidable challenge to engineers and designers of automobiles.

Turner and Green (1987) pointed out that since 1969 approximately 48 non-proprietary reports and papers had been written on automobile controls and related topics. With all this research one might be led to believe that the human factors problems associated with designing automobile controls would be resolved by now. According to Turner and Green this is not the case. The principal reason is that much of the previous research is not applicable to contemporary design problems.

The research described herein is concerned with expectancies drivers have for the operation of various automobile controls. The preferred *direction* of control operation is the primary point of interest for the study. When expectancies are found to be the same in a large percentage of people, although there is no agreement about what constitutes a large percentage, the expectancies can be termed population stereotypes. For example, in this research if the directional relationship between a control movement

and its effect is expected by a large percentage of people, it can be called a direction-of-motion stereotype. Human factors professionals realize the importance of including population stereotypes when considering control design alternatives. In designing automobile controls, it is important to take into account direction-of-motion stereotypes because faulty expectations of control movements by drivers can induce actuation errors and lead to increased driver confusion and workload.

Determining the strength of direction-of-motion stereotypes is not a straightforward task. Since control designs evolve constantly as new cars are introduced, empirical data must be updated to ascertain the strength of the stereotype. In addition, there are cultural differences. In the United Kingdom, for example, light switches are switched down for turning on the light, which is the opposite direction of switches in the United States.

LITERATURE REVIEW

The scope of the literature pertaining to automobile control design is quite extensive. Some research addresses specific automotive functions, and how they should be controlled. For example, Mortimer and Post (1973) conducted an experiment examining different switching modes for a 3-beam headlight system. Other reports investigate a wider range of controls. Anacapa Sciences, Inc. (1976) issued surveys to determine driver expectancies in locating various automobile controls. Studies also exist on issues such as driver performance, driver preference, and control evaluation. The research topic described in this report is concerned with driver preference for direction-of-control operation, and therefore, this review will only elaborate on the literature germane to this topic.

One of the first steps taken in the study was the effort to secure all recent citations relevant to direction-of-motion stereotypes for automotive controls. At Virginia Polytechnic Institute and State University a computerized search was conducted on automobile control stereotypes using the DIALOG Information Retrieval Service. An on-line search was carried out using the Compendex database. Compendex reviews the abstracted information from engineering and technical literature found in the *Engineering Index*. In addition, three indices accessed through CD-ROM were searched: NTIS (a version of the printed index *Government Reports Announcements and Index*), PsychLIT (a version of the printed index *Psychological Abstracts*), and GDCS (*Government Documents Cataloging Service*). Key words were identified and used in different combinations to search each index for relevant articles. Although many articles were cited, most were not on directional stereotypes per se. Recent journals such as

Human Factors and *Ergonomics* were searched manually for pertinent studies. Letters were also sent to 35 individuals at organizations where related research was likely to have been carried out. The letters requested abstracts and, if possible, reprints of the relevant work. In addition, interviews were conducted with personnel from NHTSA (National Highway Traffic Safety Administration) to obtain information on applicable research.

In the general discussion of direction-of-motion stereotypes, Gibbs (1951) outlines two sources of stereotypes. Some stereotypes stem from normal spatial relationships, and, thus, may be called "natural." For example, when drivers turn a steering wheel to the right, it is expected that the vehicle will move to the right. Gibbs points out that this type of stereotype is related to eye-hand coordination practiced from birth. Other stereotypes may stem from manifestations of customs inherent to different cultures. Gibbs terms these latter stereotypes "expected," "preferred," or "dominant." The example of "down-for-on" light switch in the United Kingdom and "up-for-on" in the United States illustrates this stereotype. In complex control environments of automobiles it is important to consider both stereotypes (natural and expected) to ensure a well human factored design.

The amount of research that *directly* addresses direction-of-motion stereotypes with regard to automobile drivers is limited. The most recent work appears to be that carried out by Jack (1985). In this research, a series of direction-of-motion stereotype studies was conducted to determine how tactile coding schemes, switch orientation, and labeling influenced drivers' choices of initial control movement direction with rocker switches. The results of Jack's studies indicate that tactile coding such as bump/dimples

and serrations influence which side of a rocker switch is pushed to obtain a desired action. Not surprisingly, by adding on/off labeling the likelihood of driver's success in actuating the correct side of the switch is increased. Combined cues (up is on and push raised side for action) and adding cues appear to enhance the chance of success and strengthen the desired response, respectively. Finally, Jack points out that if a decision on control design is made based on the direction-of-motion research, the population used in the study should be the same as the end users to ensure consistent behavior. Jack's study, however, is limited in that only one type of automobile control, the rocker switch, was studied.

An investigation by Black, Woodson, and Selby (1977), collected driver expectancy data with regard to control location and operability for 10 functions. Functions analyzed were: windshield washer, windshield wiper, cruise control, headlights on/off, headlights high/low beam, hazard, interior fan, temperature controls, defrost/defog, and radio volume. Approximately 900 drivers were shown a two-sided sandwich board containing 20 panel mounted controls on one side, and 10 steering column mounted controls, or stalk controls, on the other side. Drivers were asked to select a control which they felt matched a function. Once selected, subjects then were asked to indicate perceived control location and method of operation. Accompanying the hardware and instructions was an exterior picture of a car in which the hypothesized controls were to be found. This was done to determine if the drivers were influenced in their expectancies by the kind of car they were visualizing. Subjects tended to associate chromed controls with domestic vehicles and dull black controls with foreign vehicles.

Location and operational expectancies were considerably stronger for panel mounted controls than for stalk controls. The salient results indicate that subjects expected the headlights on/off and windshield wiper/washer controls to be panel mounted (approximately 3:1). When mounted on the panel, a round knob that is pulled was expected for the headlight on/off switch. When the headlight on/off was located on a stalk control there was no strong agreement on the location (left or right column mounted) and mode of operation. For both the windshield wiper and washer, use of a panel mounted round knob had the highest expectancy. The knob was to be turned clockwise for the wiper and pushed in for the washer.

In analyzing high-low beam controls, only stalk controls were considered. However, it was indicated that most subjects expected the beam control to be located on the floor left of the brake pedal. When using a stalk for the high-low beam control, subjects preferred the left over the right, and pulled the stalk towards the driver for high-beam activation.

In general for the climate functions such as fan, temperature, and defog, slide controls were expected by most subjects. To increase or turn on the climate controls, subjects preferred moving the slide either up or to the right. The radio volume was expected to be controlled by a round or irregular round knob, and it was rotated clockwise to increase the volume.

An advantage of the Black et al. study is that expectancy feedback is obtained on three criteria: type of control, location, and method of operation. However, Turner and Green (1987) have pointed out that a weakness in the research was that final assignment of the control type, control location, and method of operation did not involve the

instrument panel as a whole. This is best illustrated by the fact that the data show a button on the left stalk had the highest expectancy percentages for both washer and cruise controls, even though a combination of these controls on a single stalk is probably not feasible.

Other studies on driver expectancies for controls do exist. However, the primary concern for each is *where* drivers expect controls to be located, with little or no data on control operability. The most comprehensive research in this area was conducted by Anacapa Sciences, Inc. The results are detailed in three technical reports. The first is an early progress report (Anacapa Sciences, Inc., 1974), that indicates how expectancy data should be collected. Two methods were tested. In one condition, subjects placed adhesive backed controls in expected locations on a blank instrument panel mounted in an unfamiliar full-size American car. In the second condition, subjects marked a sketch indicating their location expectancies with the same controls used during the in-car phase. The results from the survey showed that the expectancy distributions obtained from both methods (paper and pencil, in-car) were quite similar; thus, the simpler and less expensive paper and pencil method could be used for test purposes.

The study conducted by McGrath (1974) for Anacapa Sciences, Inc., reports control expectancies from a survey of 219 European and Japanese drivers. In general, McGrath found that European expectancies did not depend on whether the vehicle was European or American made. In addition, while most differences between left-hand and right-hand drive cars showed mirror image location reversal, some control locations were not reversed. For example, drivers expected the cigarette lighter on the right panel of a left-hand drive car and the left panel of a right-hand drive car, while they expected to find

the defroster on the right panel of both types of cars. Lastly, McGrath showed that each nationality had its own set of distinct expectancies concerning locations of certain controls. Thus, no single design could be perfectly-suited for world wide sales.

The last report by Anacapa Sciences, Inc. (1976) was a continuation of the progress report mentioned earlier. Expected locations were marked for 14 controls on a mail-back questionnaire by 1,708 drivers. Five versions of the questionnaire were distributed. Two were for full-size American sedans, one for compacts, one was for light weight trucks and vans, and one was for smaller foreign cars. An important finding from the surveys was that the vehicle a person drives does indeed have an influence on expectancies.

Driver preferences for controls is another area in which several studies have been conducted. Unfortunately, most of the driver preference research is concerned with preferred control configurations or preferred type of control. In these studies different controls are utilized for the decision making process by the driver. However, the driver does not have the option to choose how the control is operated, or that information is already given. Thus, no data are available on preferred direction. A recent report by Green, Kerst, Otters, Goldstein, and Adams (1987), does however take preferred direction of motion into account. In their study, 103 participants designed instrument panels by placing the controls they preferred for 24 functions where they *wanted* them, not *expected* them. There were 255 control designs (i.e., stalks, push-buttons, switches, etc.) from which to choose. In addition to control selection and placement, drivers identified control motion, and when the design was completed, reached for each control while operating an elementary driving simulator.

The Green et al. (1987) study is reasonably comprehensive in its examination of driver preferences for control type and location. Graphical illustrations and response percentages make the document easy for designers to read and use. In addition, participants in the study were told to design a dashboard for cars of the 1990's. This future-oriented frame of reference is applauded. However, the data for preferred motion are limited. For any given function, the subjects first chose both control type and location before indicating the method of operation. This technique reduces the significance of the directional percentages because the "sample size" for each configuration is reduced as more control type and control location choices are made. In addition, for some functions such as power door locks, power seat, power windows, and climate controls, data regarding method of operation was not collected.

Despite the limited volume of direction-of-motion stereotype data concerning *automotive* controls, ample research exists on the effects of directional relationships between common controls and displays. Loveless (1962) conducted a review of the literature to assess the relative strength of various stereotypes. One effect considered was body position. According to Loveless, when direction-of-motion is described it may be related to some standard frame of reference or to the orientation of an operator's body, and the two do not necessarily coincide. If a discrepancy exists between these two frames of reference it may affect direction-of-motion stereotypes. Humphries (1958) illustrates this point with an experiment in which a vertical joystick, mounted in a horizontal plane, is used to control vertical and horizontal movements of a display mounted in a vertical plane. Results of the experiment showed that stereotypes were altered when operators moved from a normal frontal position to positions which required viewing the

display over the right or left shoulder. Note that the control and display movement reference planes do not coincide in the above example. In a second part of his study, Humphries changed the presentation of the joystick so that both the control and the display plane were vertical. For this case, stereotypes were not altered for different operator positions (i.e., frontal view, side view).

The compatibility between controls and displays has also been documented in classical human factors texts geared towards equipment design. Salvendy (1987) points out that if movement and perception stereotypes are taken into account, decoding steps and mental processing work will be minimized for the operator. Thus the safety of the system is increased due to a reduction of the response time and learning phase. Salvendy lists some recommendations for the direction of controls and the function or response of the technical system. This table is reprinted and shown in Table 1. Control movement recommendations have also been documented for specific types of controls. Figure 1 shows the guidelines listed by SAE (1977) for "on" or "increase." The two sets of recommendations given above are similar to those outlined by other authors (McCormickand Sanders, 1982; Woodson, 1981). Research by Warrick (1947) presented guidelines for rotary controls and linear displays in the same plane. *Warrick's Principle* can be described as the expectation that the pointer on the display will move in the same direction as that side of the control which is nearest to it. This principle applies only when the control is located to the side of the display. One of the main questions of interest for this research is whether the recommendations above should be modified for controls utilized in an automotive environment.

Table 1

Recommended control movements (Salvendy, 1987).

Function	Control Action
On	Up, right, forward, pull (switch knobs)
Off	Down, left, rearward, push (switch knobs)
Right	Clockwise, right
Left	Counterclockwise, left
Up	Up, rearward
Down	Down, forward
Retract	Rearward, pull, counterclockwise, up
Extend	Forward, push, clockwise, down
Increase	Right, up, forward
Decrease	Left, down, rearward

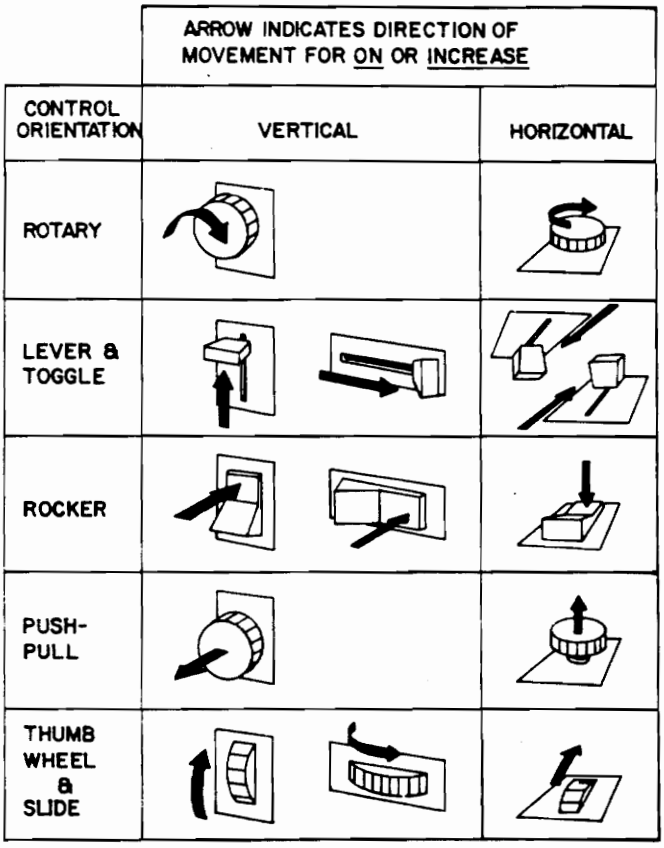


Figure 1. SAE recommended movements for "on" or "increase" (SAE, 1977).

Another issue of concern in directional stereotypes is that of handedness. Depending on the situation, such as operator position or control location, operators may not be able to use their preferred or dominant hand for control operation. This is especially true in automotive design where controls are located on both sides of the driver. Chapanis and Gropper (1968) comment that most population stereotypes reported are right-handed relationships. With this in mind, is there an effect on direction-of-motion stereotypes between use of the preferred on non-preferred hand? The review by Loveless (1962) does not disclose concrete evidence documenting there is an effect. In fact, Loveless states, "*on the present evidence, it would seem that as long as well marked stereotypes are used, there is little risk in assigning controls to the left hand.*" Since left-handed individuals live in a predominantly right-handed world they are subject to right-handed biases, and, therefore, respond in a right-handed manner. This conclusion is supported in a study by Boles and Dewar (1986). In their experiment, individual differences in movement stereotypes for controls on common household appliances were examined. Samples of both right- and left-handed subjects from three countries (Canada, United States, Australia) were used. In general, results showed that directional stereotypes were stronger for right-handers. However, in no instance were stereotypes for left-handed subjects in the opposite direction of those for right-handers. Boles and Dewar concluded that there was no need for special consideration of left-handed people in the design of the appliances tested.

The research by Chapanis and Gropper (1968) is not consistent with the findings above. Their study utilized an apparatus with a scale that could be oriented horizontally or vertically with scale values that could be made to increase in either direction for both

the horizontal and vertical layouts. In addition, the linkage between the control knob and hairline was reversible so that a clockwise rotation of the knobs could be made to move the hairline toward either end of the scale. Results showed that the performance of right-handed and left-handed operators was significantly different for some control-display (C-D) arrangements. The results also suggest that the effects of a given C-D arrangement on response time, reversal movements, and initial direction of movement should be considered independently. A possible shortcoming of the Chapanis and Gropper study is that the significant arrangements were "far-fetched," in that they violated commonly accepted C-D relationships. This may have had an adverse effect on subject performance, thus reducing the applicability of the results.

RESEARCH OBJECTIVE

It has already been stated that the research literature is dated, incomplete, or not applicable to many current automotive designs. Thus, a new experimental investigation was undertaken with the objective of providing as much information as could be obtained from one project. The specific purpose was to determine the nature and strength of automobile direction-of-motion stereotypes for as many present-day controls as possible.

The selection of controls, their locations, and their orientations was based on current usage, prevalence, and feasibility of incorporation in the study. To determine prevalence and location of various types of controls a survey of recent model automobiles was reviewed (Moore and Wierwille, 1990). After reviewing the results of the survey and discussions with the SAE Displays and Controls Committee, it was decided that six studies would be performed, one involving each of the following: power mirrors, power windows, manual windows, stalk controls, generic controls, and power door locks.

In each of the above six studies, various types of controls and control configurations were tested to determine those factors that affect the strength of directional stereotypes In addition, analyses were conducted to determine if subjects responded differently due to age, gender, handedness, or the type of vehicle they drove. In the sections that follow the methodology of the experiment is outlined in greater detail. Results are then summarized and discussed, conclusions are drawn and recommendations made.

The manner of presentation for this thesis was chosen with designers in mind. The reader can refer to a specific control configuration, and then review the results to

see how research subjects behaved for that condition. In addition, the recommendations made explain why certain design characteristics should or should not be utilized. Designers can then make design decisions based on empirical data available from the experiment, or by following the guidelines extrapolated from the overall results of the research.

METHOD

Apparatus

Test equipment. During data collection, subjects were seated in a stationary apparatus similar to a fixed base simulator. This apparatus, or buck, contained a contemporary automotive bucket seat mounted on a 3 × 4.5 foot wooden platform. A 2.5 foot high base was positioned at the front of the buck. The base, which simulated the front hood area of a vehicle, contained a steering column, steering wheel, and foot pedals for the accelerator, brake, and clutch.

To accommodate the different control fixtures used during the experiment, many hardware additions were made to the buck. Two multi-function stalks were mounted on the steering column, one on the left side, the other on the right side. To simulate the location of an instrument panel, angle brackets were mounted on the left- and right-side of the steering wheel. The surfaces of the angle brackets were covered with hook and loop self-gripping fastener tape. All of the mounting surfaces and each of the interchangeable controls used in the experiment were affixed with fastener tape. This tape, popularly known as Velcro, was extremely effective in securing the controls for actuation. However, since the hold wasn't permanent, changes in control configuration could be made quickly and easily. Figure 2 shows a view of the buck from the right side. (Note controls mounted on left- and right-side instrument panels).

To simulate the driver's door, a panel was attached to the front base and platform on the left side of the buck. A square mounting area was created on the door where controls could be fastened. Figure 3 shows the mounting area on the door panel, and one of the power window controls used in the experiment. On the right side of the buck

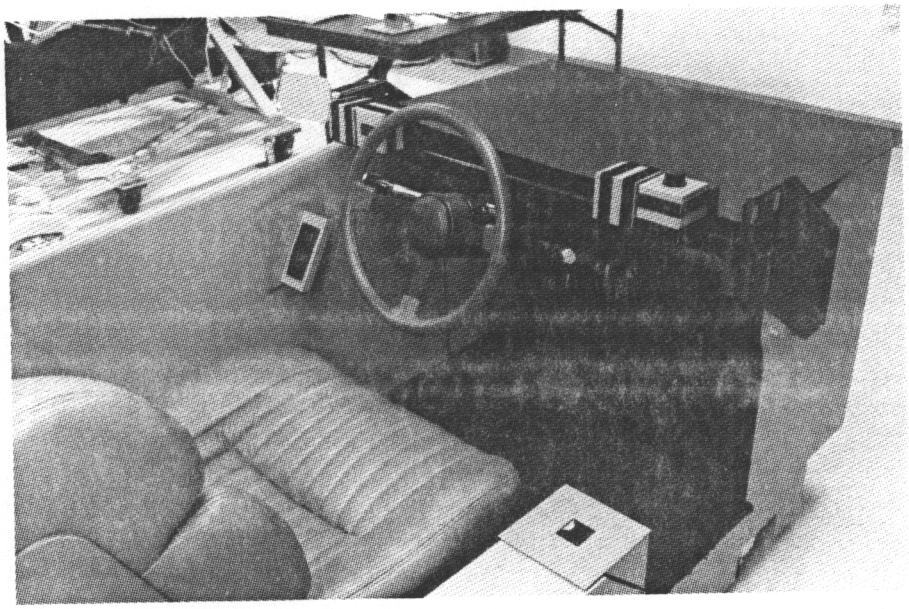


Figure 2. View of buck from the right side.

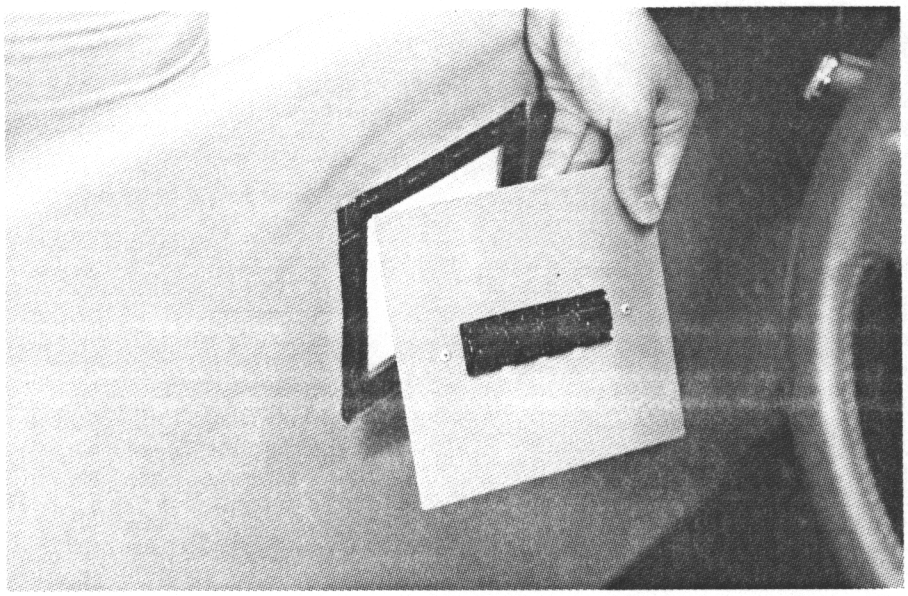


Figure 3. Control mounting area on driver door panel shown with typical control being removed.

a bracket was configured to accommodate the passenger side manual window control (Figure 4). Use of the window crank on the right side was the only situation where subjects were instructed to perform as if they were "passengers."

Next to the bucket seat, on the lower right side of the buck, a narrow wooden base was used as a center console. The console was designed to allow attachment of controls at two different angles. Figure 5 shows a pad switch mounted on the console at an angle 45° below the horizontal. In Figure 6 a wedge attachment is being added to the console so that controls may be mounted in the horizontal plane. A pad switch mounted in the horizontal plane on the center console is shown near the bottom of Figure 2.

Controls. A collection of 26 controls was used for the experiment. Controls mounted on flat carrier plates constituted 14 of the 26 controls. In addition, there were 10 controls mounted in control cubes and two were permanently mounted on multi-function stalks. An angle bracket mounted on a flat carrier plate (used in power door lock study) and a panel section for the passenger side "door" (used in manual window study, Figure 4) completed the control hardware.

Certain steps were taken to prepare the controls for the research. Many of the power mirror and power window controls were modified and mounted on adjustable brackets so that changes in presentation angle could be made quickly and easily. Figure 7 shows an adjustable power window control mounted on the driver's door panel at three different angles. Labels and any tactile coding (such as "bumps and dimples") were also removed to prevent feedback that might indicate "correct" movement direction. This was done to obtain the driver's unbiased preferred direction of activation. Turning

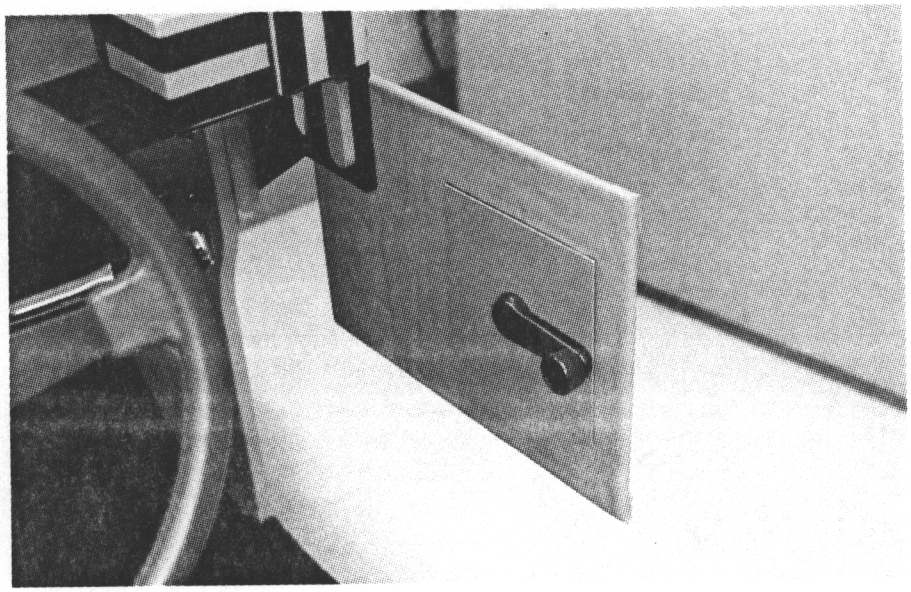


Figure 4. Manual window control mounted on "passenger" side of buck.

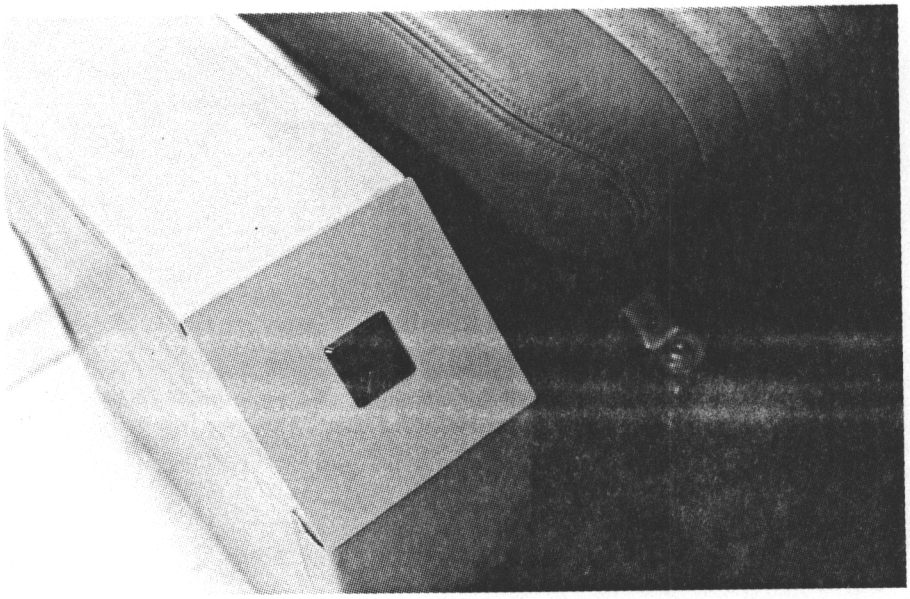


Figure 5. Center console shown with control mounted 45° below the horizontal.

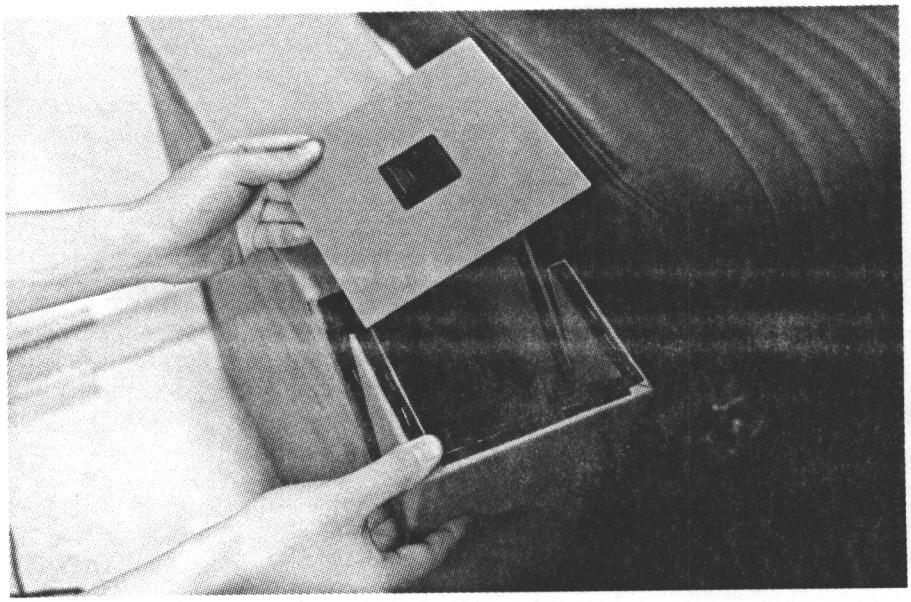


Figure 6. Wedge attachment being added to center console.

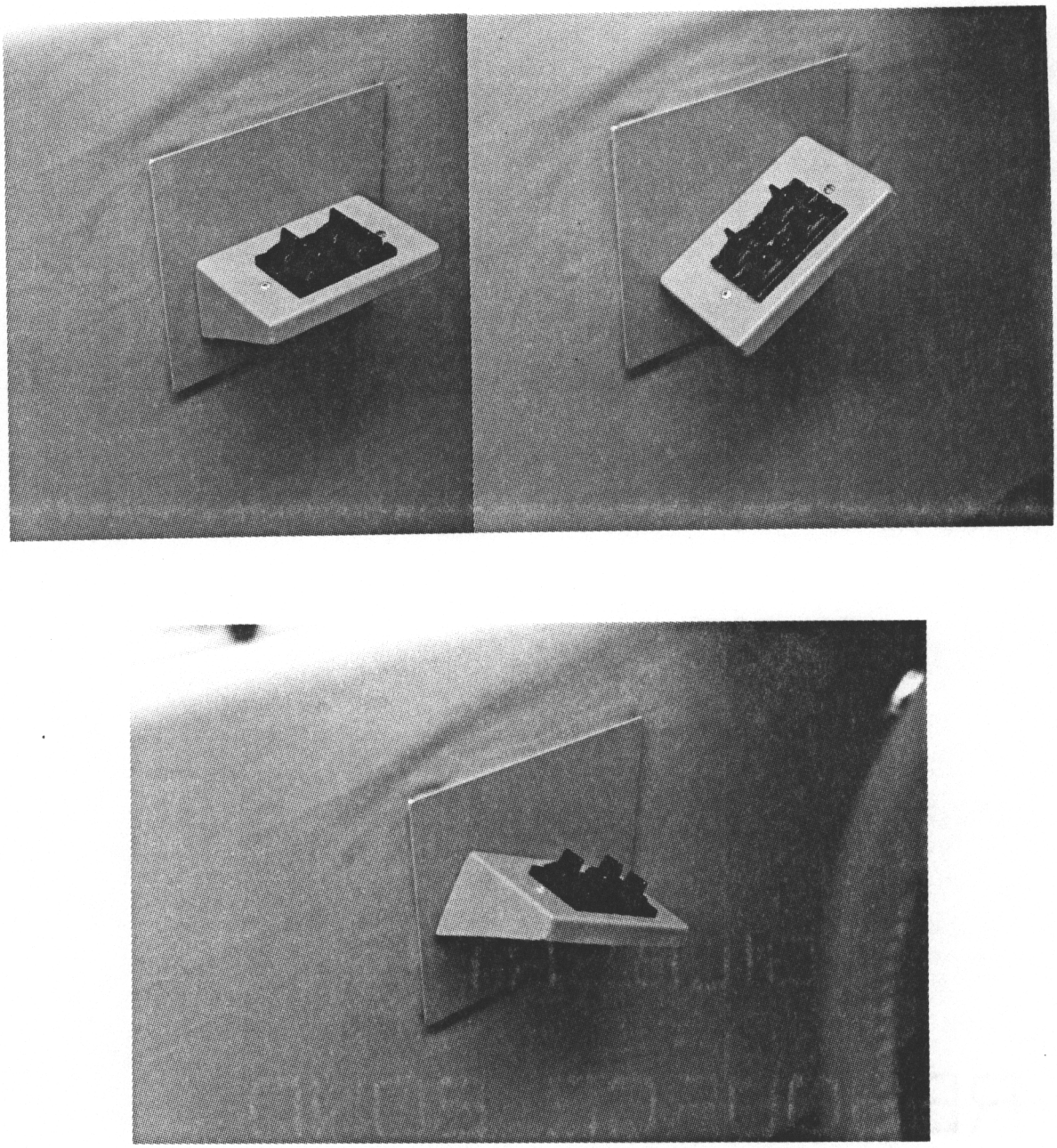


Figure 7. Three positions for an adjustable power window control.

friction on the manual window cranks was carefully set to present the right "feel" for the control. In addition, all controls were prepared with functionality and durability in mind, such that the rigors of a multi-subject experiment could be withstood. Each of the controls used for the six studies is described in greater detail in the experimental design section that follows.

Experimental Design

Keeping with the format outlined earlier, the test plan for the research will be discussed separately for each of the six studies. Many of the control configurations are described using an angle relative to a pair of axes. Unless otherwise noted the (X, Y, Z) vehicle axis system used is X = fore-aft, Y = right-left, and Z = up-down (see Figure 8). The various conditions for each control configuration are designated by capital letter abbreviations.

Study 1 — Power Mirror. The power mirror study incorporated four types of controls: a pad switch mounted flush on a flat carrier plate, a joystick extending from a flat carrier plate at 90°, a joystick mounted on a bracket affixed to a flat carrier plate, and a pad switch mounted on an adjustable bracket affixed to a flat carrier plate. The four power mirror controls are shown in Figure 9. For each power mirror condition, subjects received four commands. They were instructed to activate the designated mirror control to initiate mirror movement of up, down, right, or left. This was accomplished by first "centering" the mirror for the subjects. A road scene was placed behind the buck (Figure 10), and subjects were instructed to manually adjust the mirror to a position they would normally use when operating their own car. The experimenter then showed the subjects the appropriate mirror movement by grasping and moving a handle attached to

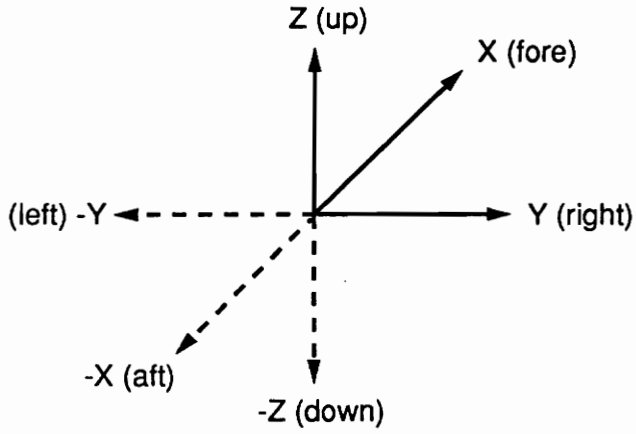


Figure 8. Vehicle axis system.

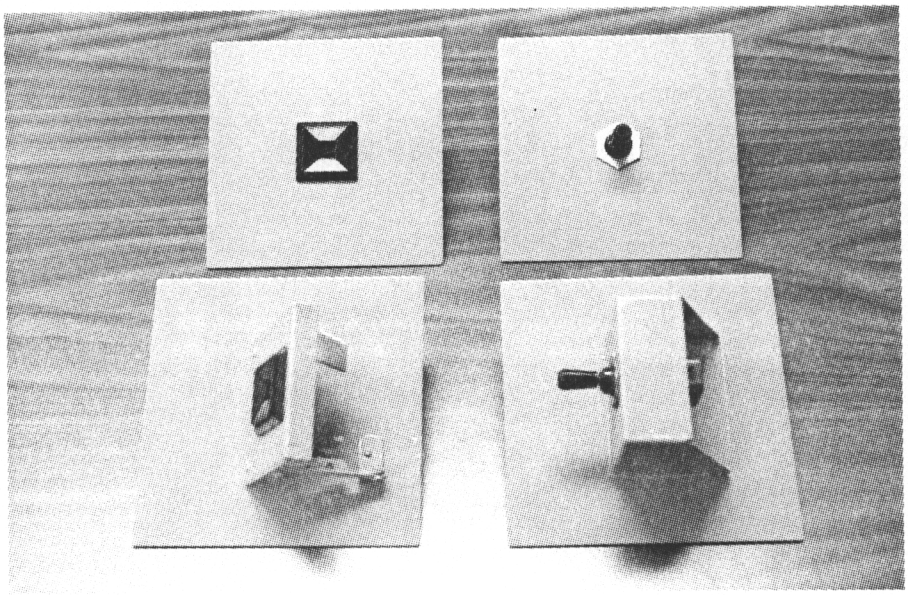


Figure 9. Power mirror controls.

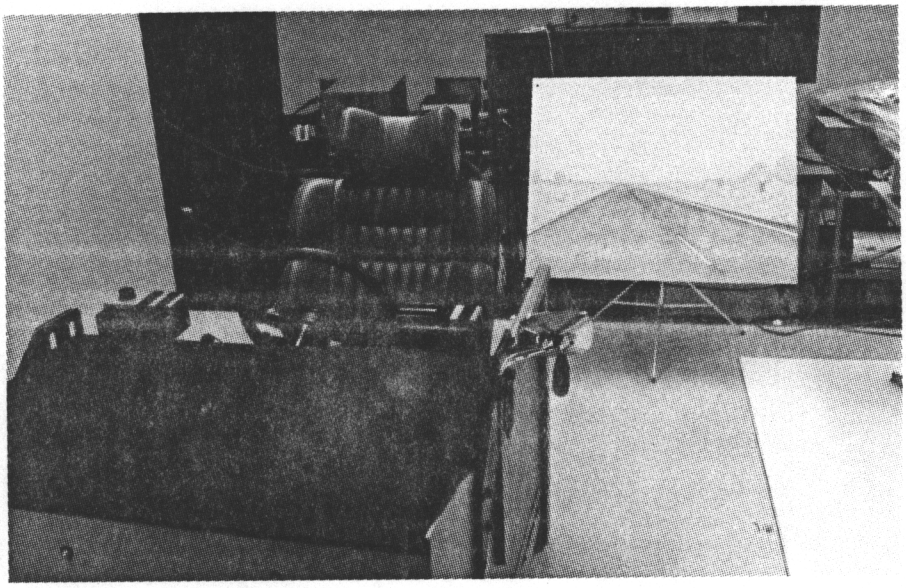


Figure 10. Front view of buck and roadscene.

the rear of the mirror (Figure 11). Subject's were instructed to watch the mirror movement, using the road scene as a reference, and then actuate the control to make the mirror move in the *same* direction as that initiated by the experimenter. The 10 conditions for the power mirror study are shown in Figures 12 through 16.

Study 2 — Power Windows. The power window study used five types of switch arrays: 2 × 2 adjustable toggle, 2 × 2 adjustable rocker, 2 × 2 adjustable push-pull, 1 × 4 lateral toggle, and 2 × 2 toggle. Figure 17 shows the power window controls. The three adjustable controls are in the back row of the picture. Subjects were instructed to either raise or lower the front or rear window on the driver or passenger side. A given subject received raise commands only or lower commands only. Thus, four commands per condition were issued. The 11 conditions for this phase, all configured on the driver's door panel are shown in Figures 18 through 22.

Study 3 — Manual Windows. The manual window study utilized a crank that could be mounted in two locations: driver's side door and passenger's side door (Figure 23). For each location there were two crank positions. These were mirror images of one another for the two doors. The four conditions are illustrated in Figures 24 and 25. Each subject received only one condition and was instructed to turn the crank to raise the window, and at another time, to lower the window.

Study 4 — Stalk Controls. Two multi-function stalks were used in this study, one on each side of the steering column. Figure 26 shows the two stalks, which were identical. Each stalk was capable of moving up-down and fore-aft, with a barrel that could rotate over the top away from the subject or under the bottom. Figures 27 and 28

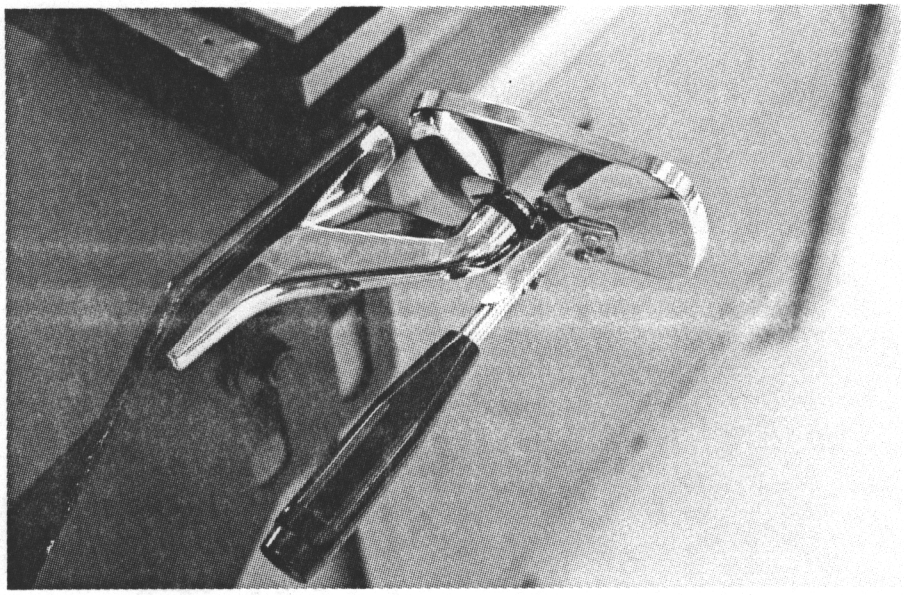
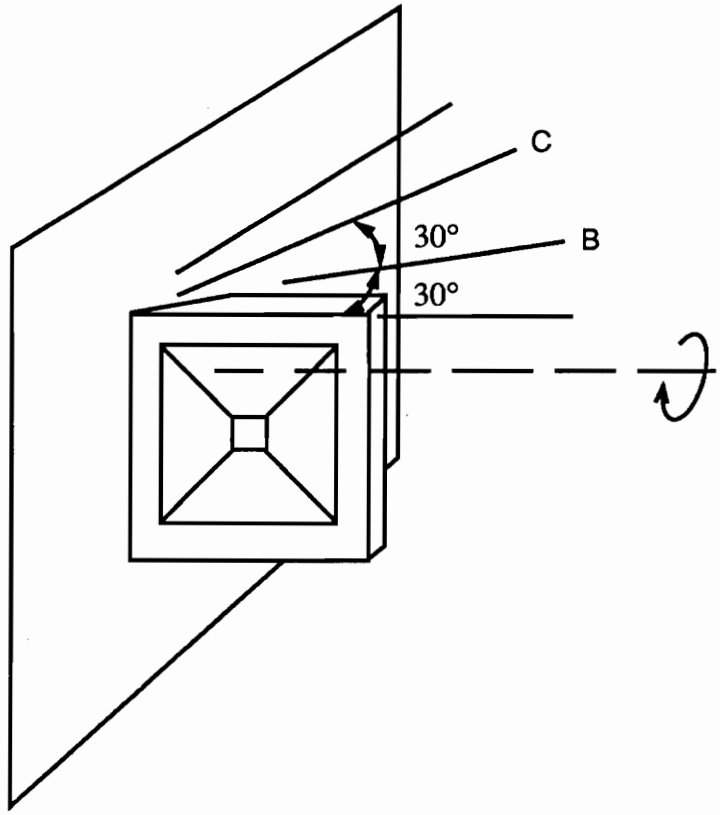


Figure 11. Mirror with experimenter's handle.



Condition	Configuration
A	Shown (extending from door panel in the vertical (Y-Z) plane)
B	Angled away from subject 30°
C	Angled away from subject 60°
D	Extending from door panel in horizontal (X-Y) plane

Figure 12. Power mirror Conditions A, B, C, and D for pad switch mounted on adjustable bracket affixed to flat carrier plate.

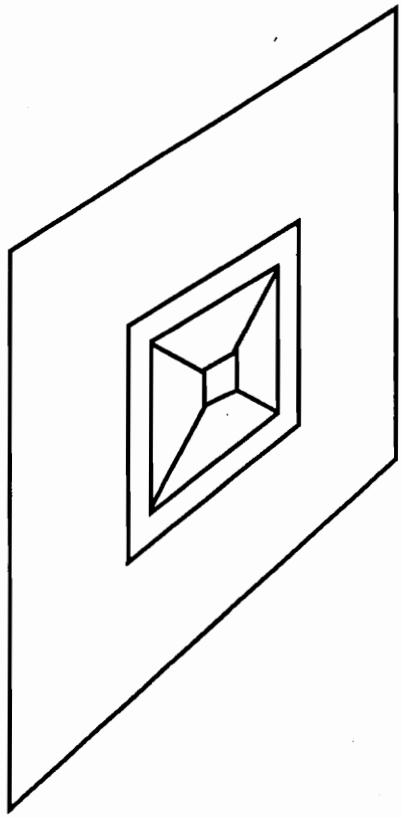
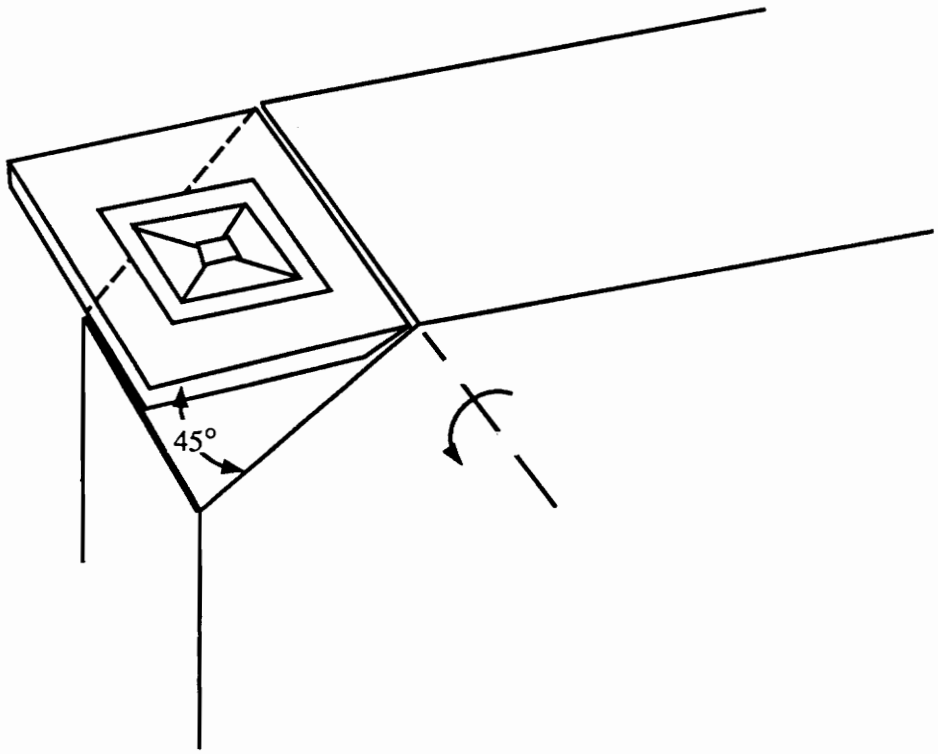


Figure 13. Power mirror Condition E for pad switch mounted flush on flat carrier plate (X-Z plane).



Condition	Configuration
F	Shown (mounted in horizontal (X-Y) plane on center console)
G	Mounted 45° below horizontal plane on center console

Figure 14. Power mirror Conditions F and G for pad switch mounted flush on flat carrier plate, used on the console.

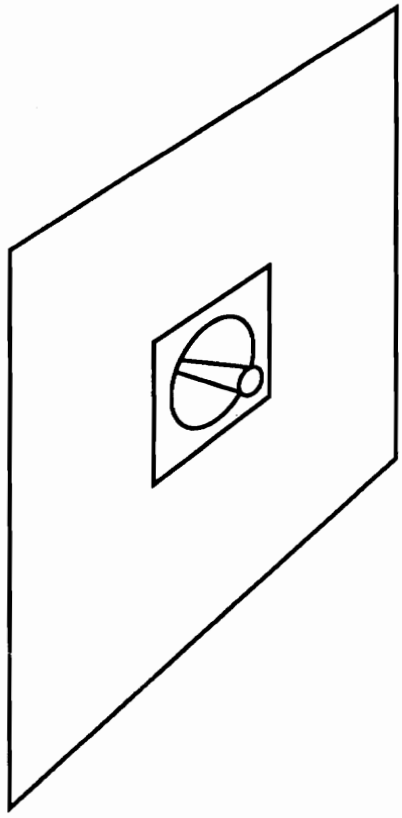
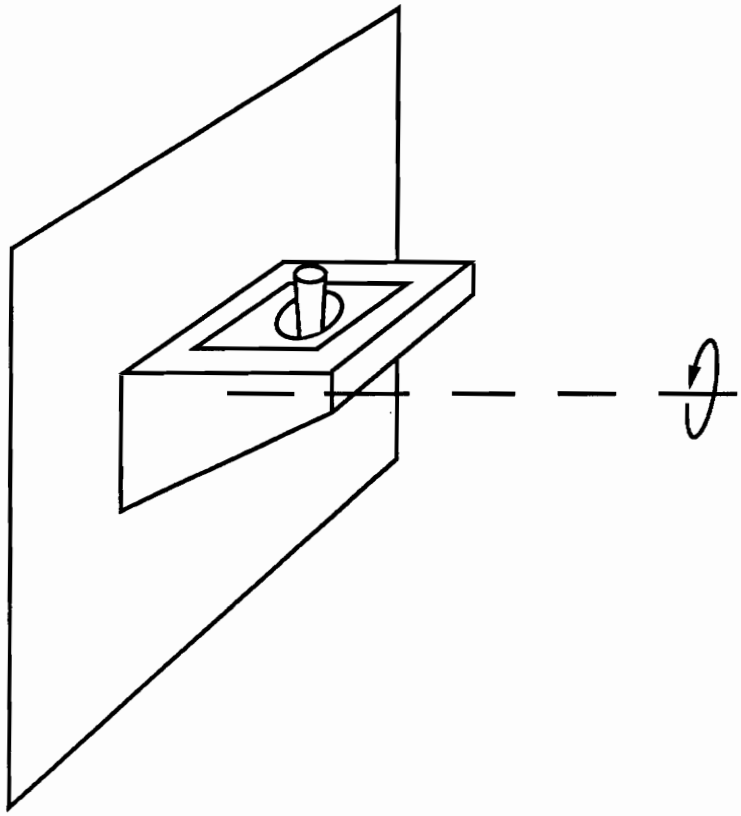


Figure 15. Power mirror Condition H for joystick extending from flat carrier plate (X-Z plane).



Condition	Configuration
I	Shown (face of bracket extending in horizontal (X-Y) plane)
J	Face of bracket extending in vertical (Y-Z) plane

Figure 16. Power mirror Conditions I and J for joystick mounted on bracket affixed to flat carrier plate.

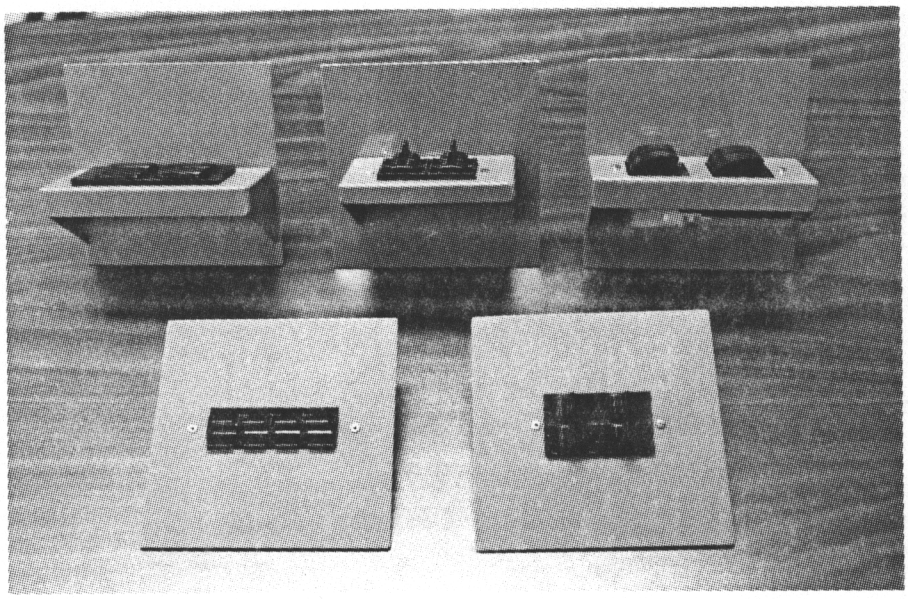
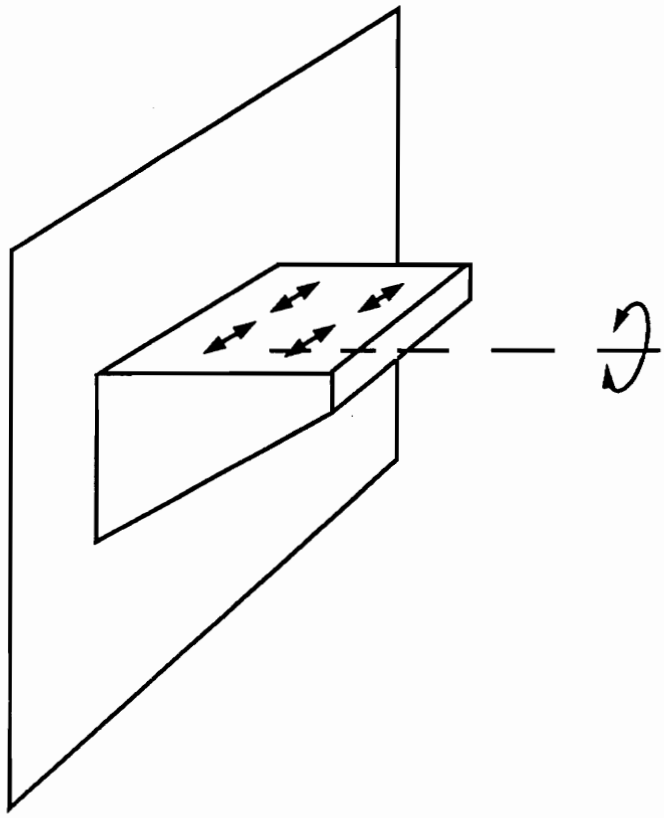


Figure 17. Power window controls.



Condition	Configuration
A	Shown (control mounted in horizontal (X-Y) plane)
B	Control angled towards driver 30°
C	Control angled towards driver 60°
D	Control angled away from driver 30°

Figure 18. Power window Conditions A, B, C, and D for 2 × 2 adjustable toggle switch.

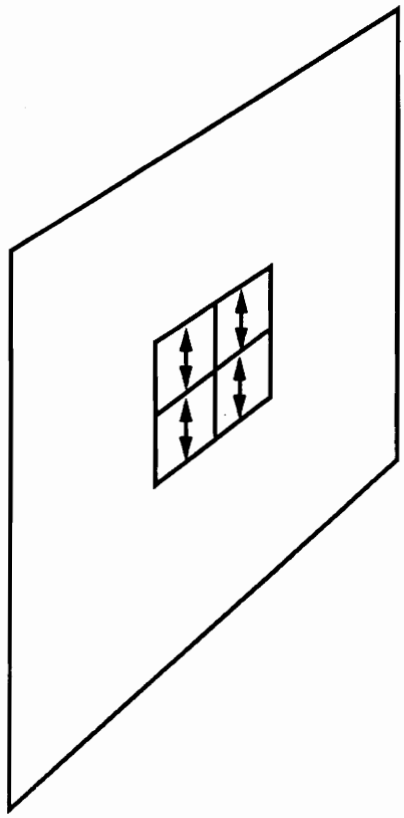
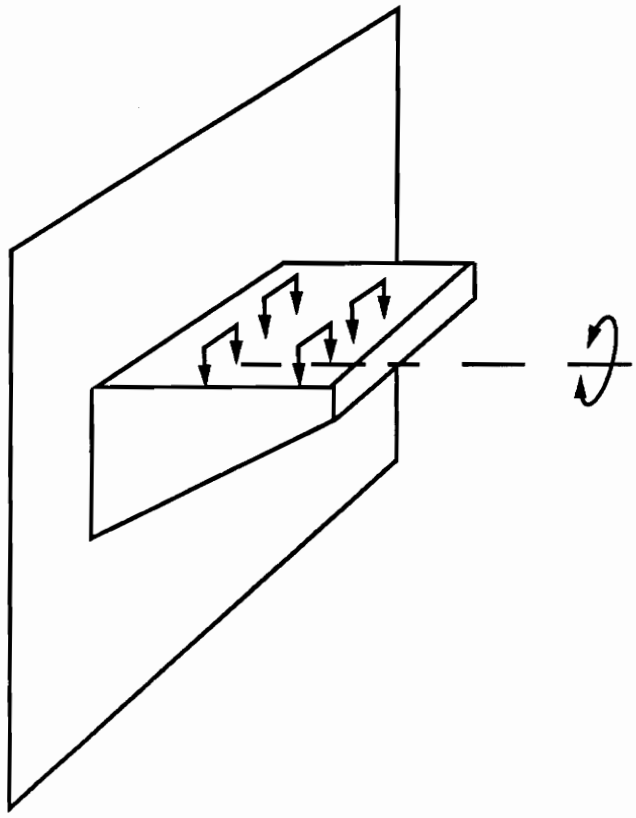


Figure 19. Power window Condition E for 2 × 2 toggle switch (X-Z) plane.



Condition	Configuration
F	Shown (control mounted in horizontal (X-Y) plane)
G	Control angled towards driver 60°
H	Control angled away from driver 30°

Figure 20. Power window Conditions F, G, and H for 2 × 2 adjustable rocker switch.

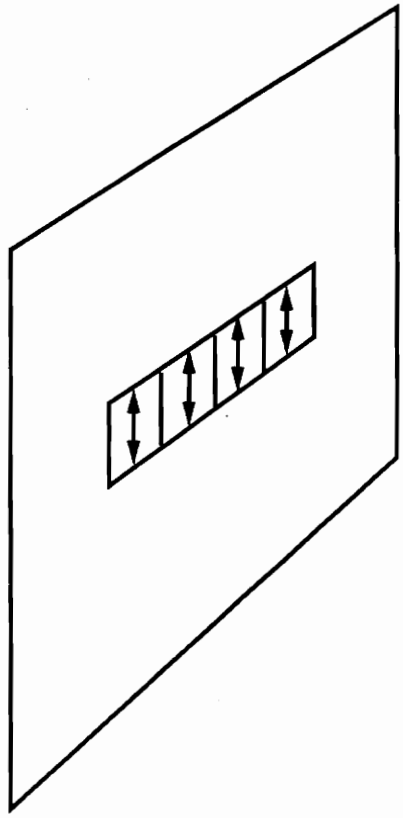
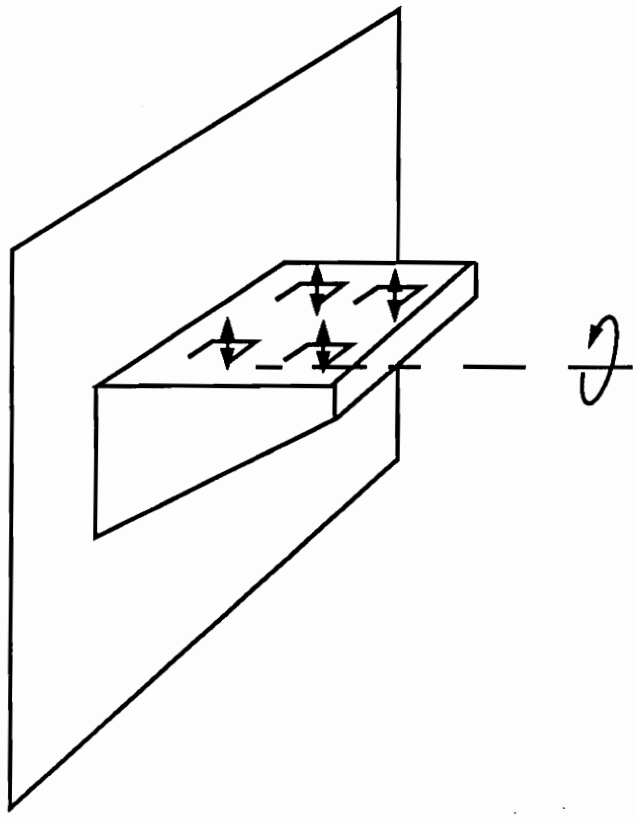
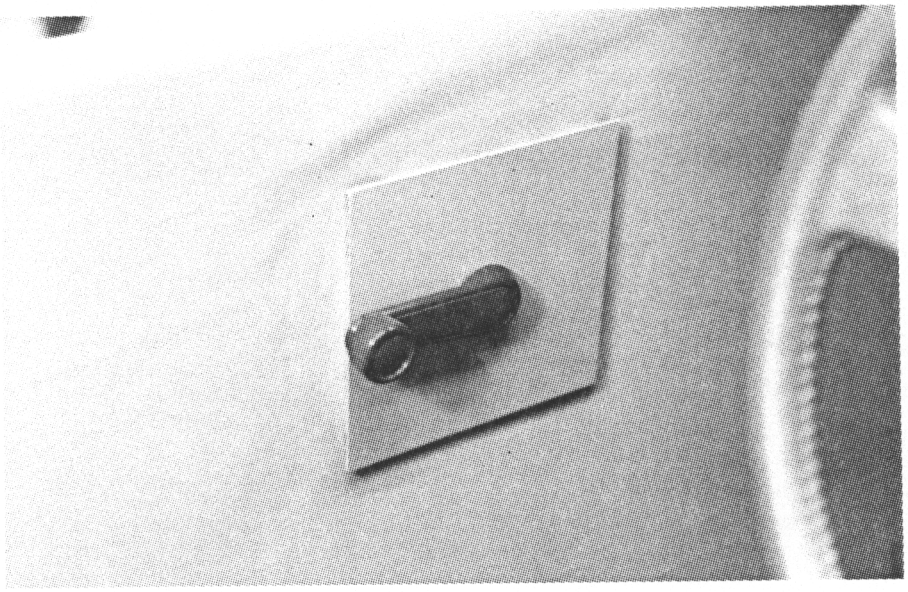


Figure 21. Power window Condition I for 1 × 4 lateral toggle switch (X-Z plane).



Condition	Configuration
J	Shown (control mounted in horizontal (X-Y) plane)
K	Control angled towards driver 45°

Figure 22. Power window Conditions J and K for 2 × 2 adjustable push-pull switch.



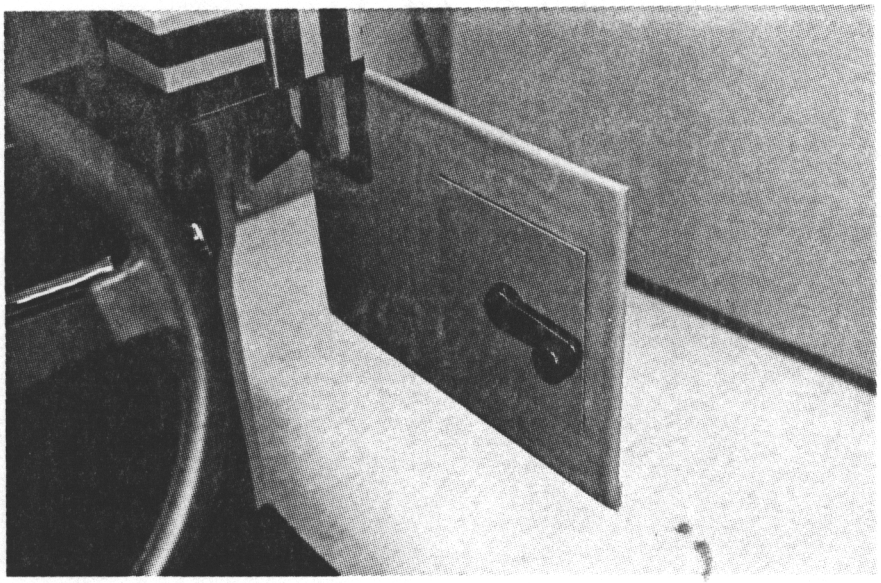
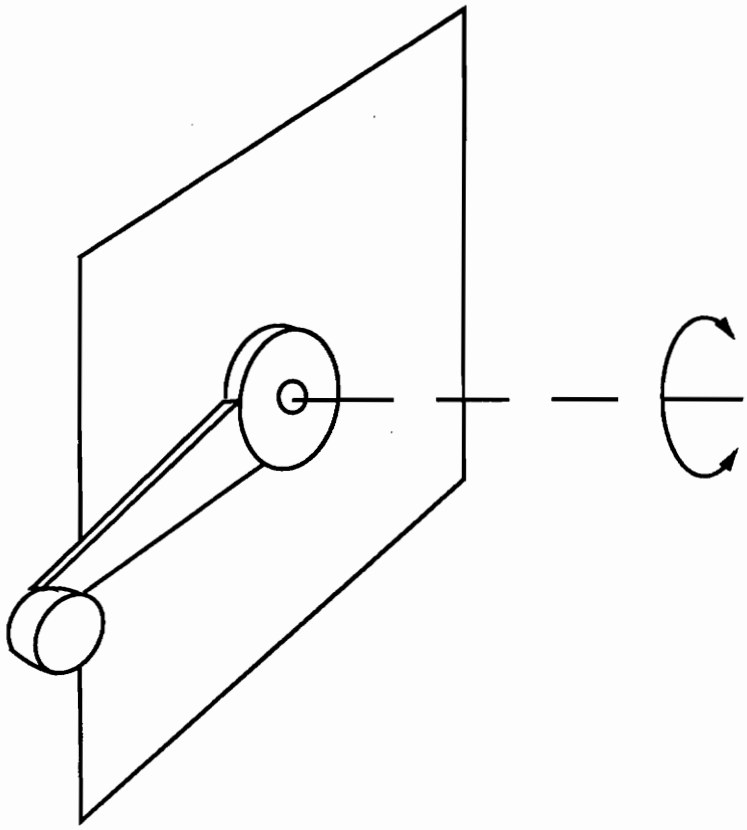
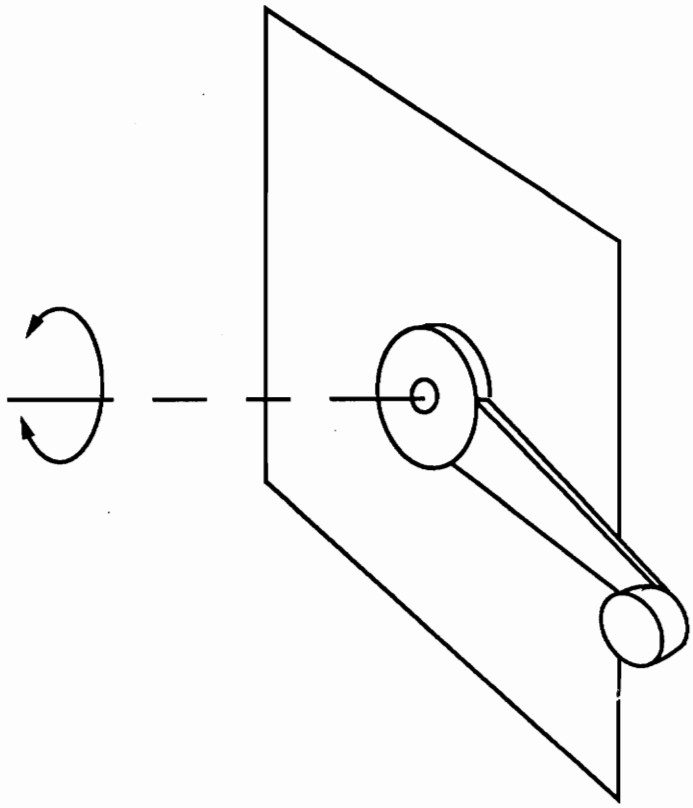


Figure 23. Driver and passenger side locations for manual window control.



Condition	Configuration
A	Shown (X-Z plane, handle facing rear of buck)
B	Handle facing front of buck (X-Z plane)

Figure 24. Manual window Conditions A and B on driver side.



Condition	Configuration
C	Shown (X-Z plane, handle facing rear of buck)
D	Handle facing front of buck (X-Z plane)

Figure 25. Manual window Conditions C and D on passenger side.

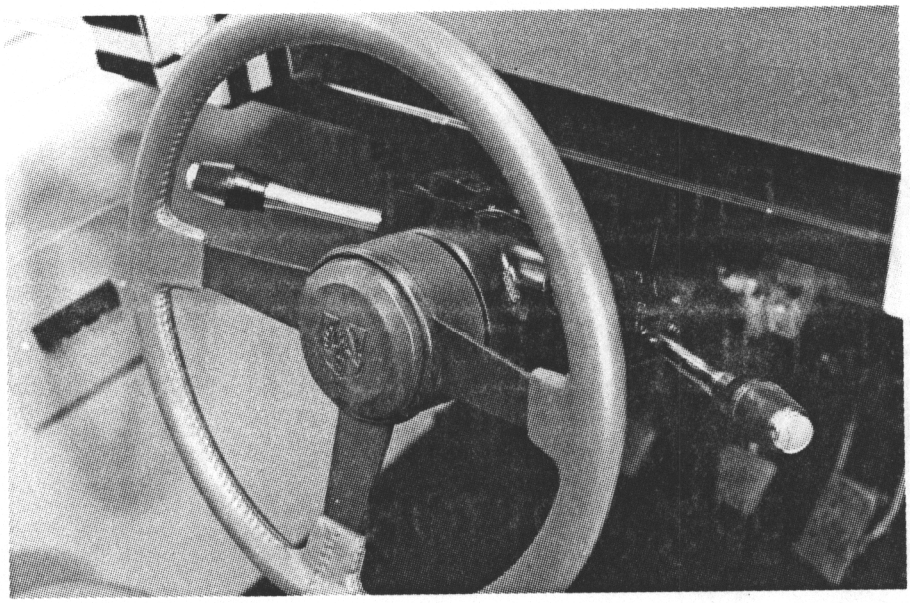


Figure 26. View of stalks mounted on steering column.

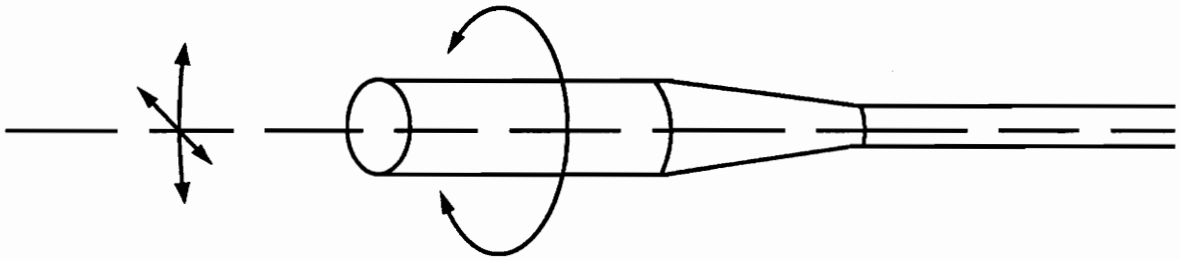


Figure 27. Left side stalk.

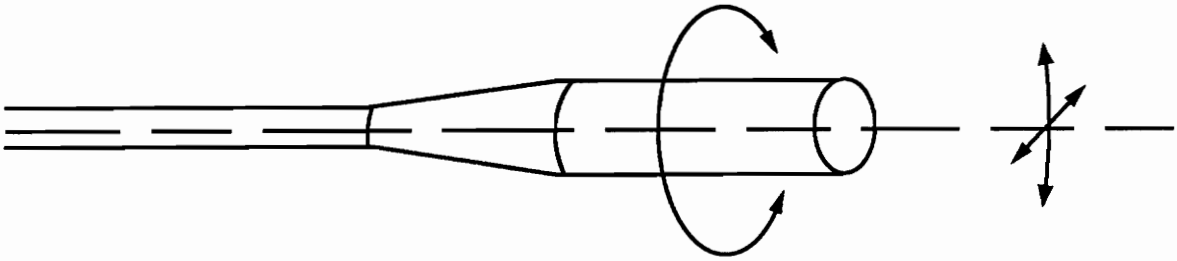


Figure 28. Right side stalk.

illustrate the stalk movement capabilities. The 15 conditions for stalk actuation were dependent on the specificity of the instructions. For example subjects could be given a nonspecific command to rotate the left stalk to turn something on, or specifically told to turn on the wipers by raising or lowering the right stalk. The instructions for each of the 15 conditions are given below. When a pair of conditions is given, the first condition in each pair corresponds to the left stalk, and the second corresponds to the right stalk.

1. Nonspecific

   Conditions:

   A,B. For the left/right stalk, raise or lower the stalk to turn something on.

   C,D. For the left/right stalk, push or pull on the stalk to turn something on.

   E,F. For the left/right stalk, rotate the barrel of the stalk to turn something on.

2. Specific Unconstrained Conditions:

   G,H. Given that the wipers are on the left/right stalk, turn the wipers on.

   I. Given that the headlight high beam is on the left stalk, turn the high beams on.

3. Specific Constrained Conditions:

   J,K. Given that the wipers are on the left/right stalk, and that they are turned on by raising or lowering the stalk, turn the wipers on.

N. Given that the headlight high beams are on the left stalk, and that they are turned on by pushing or pulling the stalk, turn the high beams on.

O. Given that the headlight on/off switch is on the left stalk, and the headlights are turned on by rotating the barrel, turn the headlights on.

Study 5 — Generic Controls. Five types of generic controls were used in this study: thumbwheel, toggle switch, linear slide control, rotary knob, and rocker switch. All five types of controls were mounted in pairs in control cubes. In addition the toggle, slide, and rocker were also mounted on flat carrier plates (Figure 29). The control cubes were always situated on either the right or left instrument panels, while the carrier plates were always mounted on the center console. The purpose of using generic controls was that the configurations are much the same as several functions found in current automobiles. The slide control, for example, can be thought of as a temperature or fan adjustment. The rotary knob is similar to the volume control on a conventional radio or perhaps a rotary fan control. Figures 30 through 34 show detailed diagrams of the generic controls mounted in the control cubes. Many conditions were possible with the control cubes. Not only could the cubes be moved to different positions, but they could be oriented to face up, front (facing the subject), left side, or right side. In addition, if the control cubes were rotated 90°, the direction of the control movement could be changed (e.g., right-left to fore-aft, up-down to right-left).

Conditions are distinguished by capital letter abbreviations. When conditions are described by pairs of letters, the first letter indicates a position on the left side of the

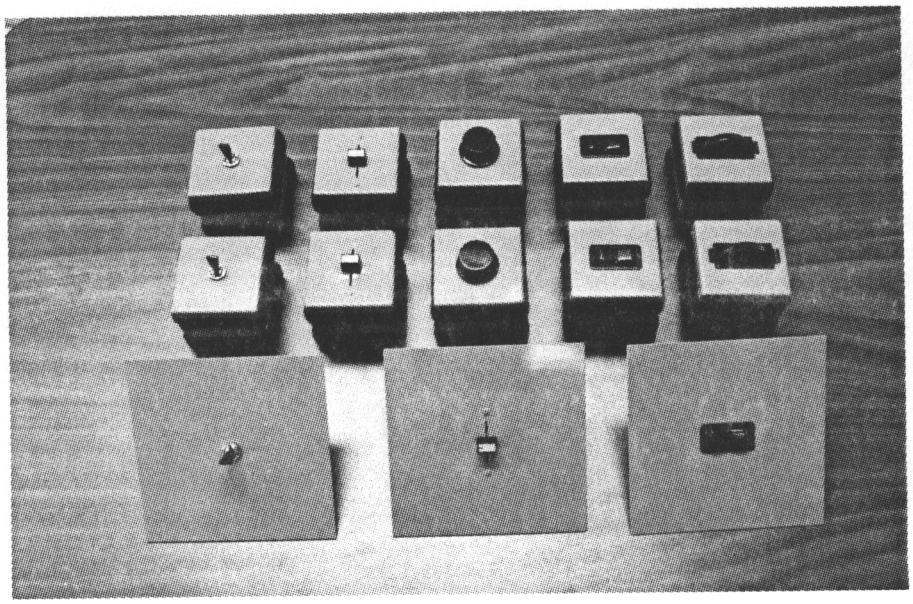


Figure 29. Generic controls.

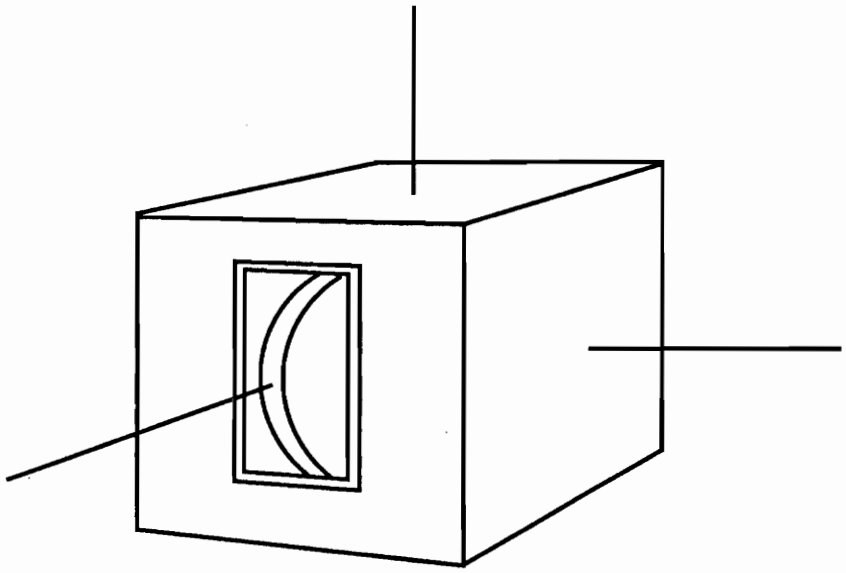


Figure 30. Thumbwheel control cube.

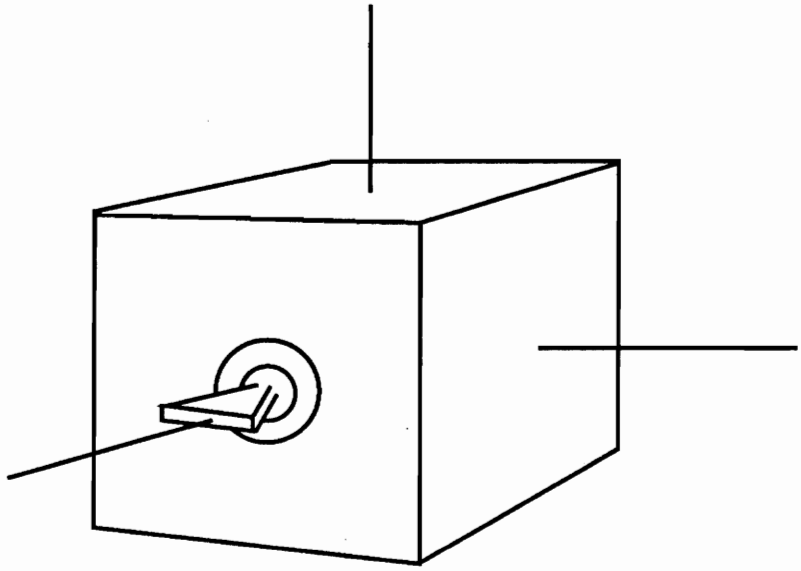


Figure 31. Toggle switch control cube.

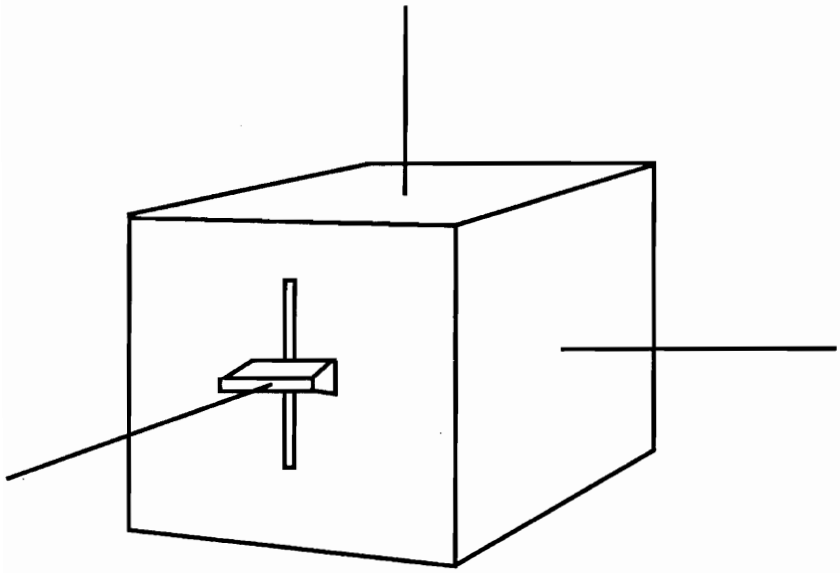


Figure 32. Linear slide control cube.

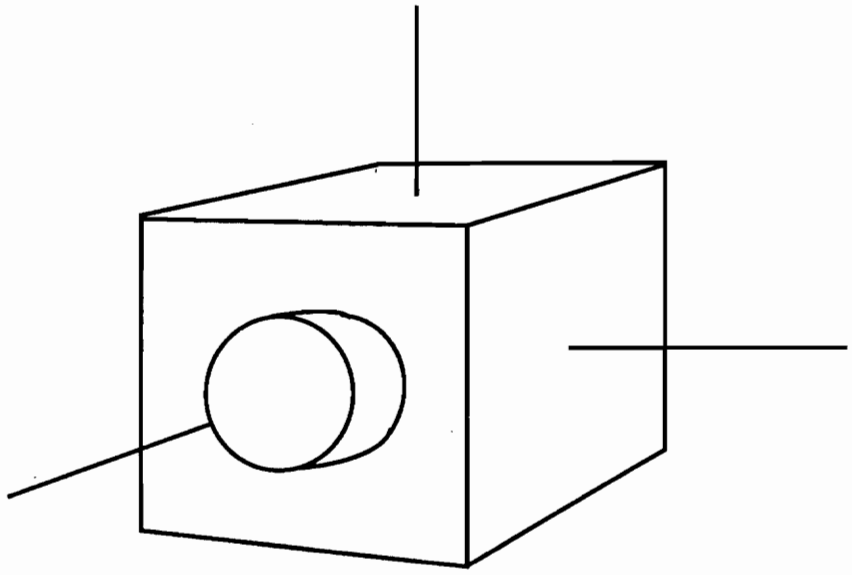


Figure 33. Rotary control cube.

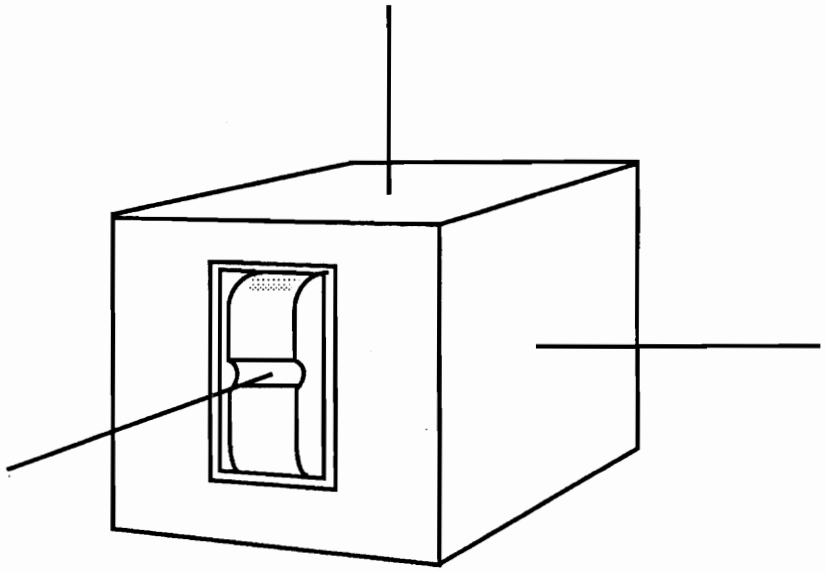


Figure 34. Rocker switch control cube.

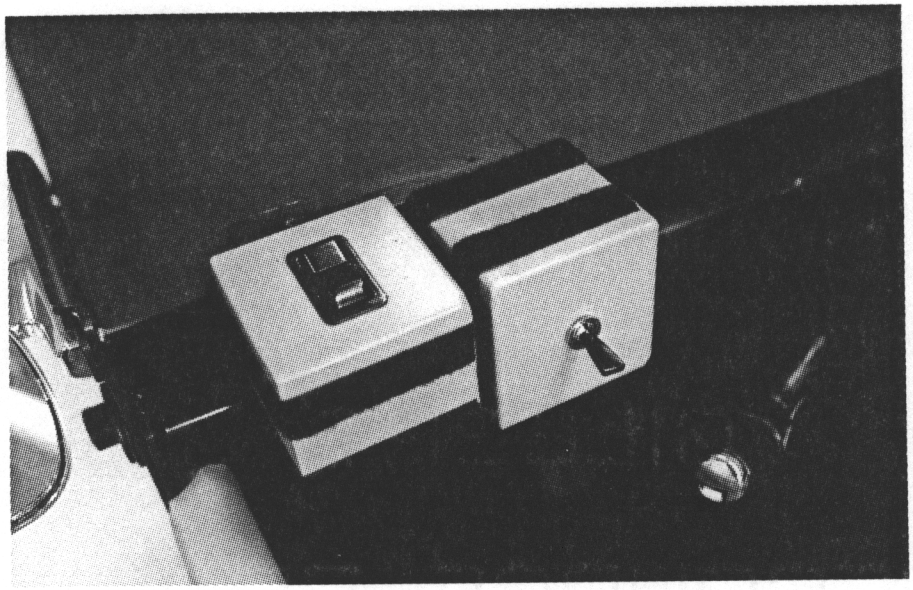
steering wheel, and the second letter designates a right-side position. If the condition is presented singularly, it indicates location on the center console. In addition to the condition, the control orientation (i.e., facing up, front, right, left) and control movement/ alignment is designated. Since the two angle brackets (one on each side of the steering wheel) could each accommodate two cubes, cube orientation sometimes makes it necessary to situate a cube on the outside or inside portion of the bracket. This situation arises for left and right orientations. For example, in Figure 35 since the thumbwheel has a right orientation it must be mounted on the outside of the right instrument panel. For cases such as this, the cube position on the angle bracket is also noted.

The *thumbwheel* was used only on the angle brackets located to the left and right side of the steering wheel. The instructions for all conditions were to move the thumbwheel to increase something. The 10 conditions are listed in Table 2.

The *toggle switch* had configurations on the left and right side of the steering wheel, and on the center console panel. Subjects were instructed to move the toggle switch to turn something on. See Table 2 for the 16 conditions.

The *slide control* was also positioned to the left and right of the steering wheel and on the center console panel. The slide control was centered before each command and subjects were directed to increase something using the slide. The 13 conditions are shown in Table 2.

The *rotary control*, like the thumbwheel, was only incorporated on the left and right angle brackets. For the six conditions shown in Table 2 subjects were instructed to turn the rotary knob to increase something.



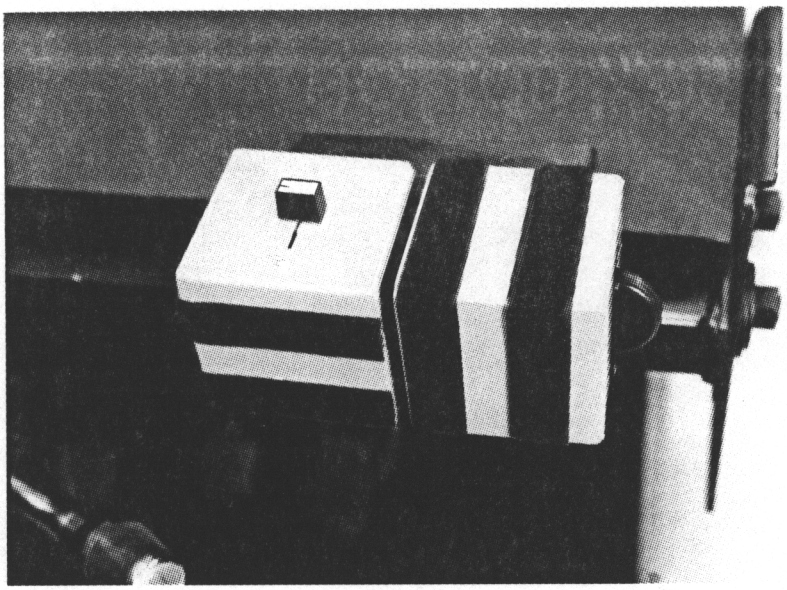


Figure 35. Left instrument panel shown with rocker and toggle switch cubes (top), and right instrument panel shown with slide control and thumbwheel cubes (bottom).

Table 2

Generic control conditions.

	CONDITION	ORIENTATION†	CONTROL MOVEMENT	POSITION
Thumbwheel				
	A, B	Up	Right-Left	----
	C, D	Up	Fore-Aft	----
	E, F	Front	Right-Left	----
	G, H	Front	Up-Down	----
	I, J*	Left,Right	Up-Down	Outside
Toggle Switch				
	A, B	Up	Right-Left	----
	C, D	Up	Fore-Aft	----
	E, F	Front	Right-Left	----
	G*, H	Front	Up-Down	----
	I, J	Right	Up-Down	Inside, Outside
	K, N	Left,Right	Fore-Aft	Outside
	L, M	Left	Up-Down	Outside, Inside
	O	Up	Fore-Aft	----
	P	Up	Right-Left	----
Slide Control				
	A, B	Up	Right-Left	----
	C, D*	Up	Fore-Aft	----
	E, F	Front	Right-Left	----
	G, H	Front	Up-Down	----
	I, J	Left	Up-Down	Outside, Inside
	K, L	Right	Up-Down	Inside, Outside
	M	Up	Fore-Aft	----
Rotary Control				
	A, B	Up	Rotated	----
	C, D	Front	Rotated	----
	E, F	Left,Right	Rotated	----
Rocker Switch				
	A, B	Up	Right-Left	----
	C*, D	Up	Fore-Aft	----
	E, F	Front	Right-Left	----
	G, H	Front	Up-Down	----
	I, J	Left	Up-Down	Outside, Inside
	K, L	Right	Up-Down	Inside, Outside
	M	Up	Right-Left	----
	N	Up	Fore-Aft	----
	O	45° Away from driver‡	Right-Left	----
	P	45° Away from driver‡	Fore-Aft	----

† All "up" orientations are in the X-Y plane; all "front" are in the Y-Z plane; and, all "left" or "right" are in the X-Z plane.

* This condition appears in Figure 35.

‡ See Figure 5 for a view of this orientation, but with a different control.

The *rocker switch* was used on the two angle brackets and the center console. Instructions to the subjects were to actuate the rocker to turn something on. This segment had 16 conditions, and they are outlined in Table 2.

Study 6 — Power Door Lock. There were two controls used in the power door lock study. A rocker switch on a flat carrier plate and a rocker switch in a control cube that was mounted on a second carrier plate with an angle bracket. The carrier plate was mounted flush with the driver's door, while the control cube was mounted on the door with the second carrier plate and angle bracket. Figure 36 shows the power door lock control hardware. Subjects were instructed to lock or unlock the doors for each of the six conditions outlined in Table 3.

Groupings of Conditions

There were 107 conditions for the six studies in this experiment, with many of the conditions calling for multiple commands. For example, for power door lock conditions subjects locked and unlocked the doors for each control configuration. Similarly, for each power mirror condition, subjects adjusted the mirror in four ways (up, down, right, and left). Hence, 170 commands were needed for the 107 conditions. With a study of this magnitude it was considered unfeasible to collect all the data using one group of subjects. It was also imperative to take into account transfer effects caused by previous exposure or learning. With control configurations that were similar in nature (e.g., toggle switch power window control at 30° or 60°), it could not be assumed that when a subject was exposed to one set of controls, and then to a second set, that the two responses were independent.

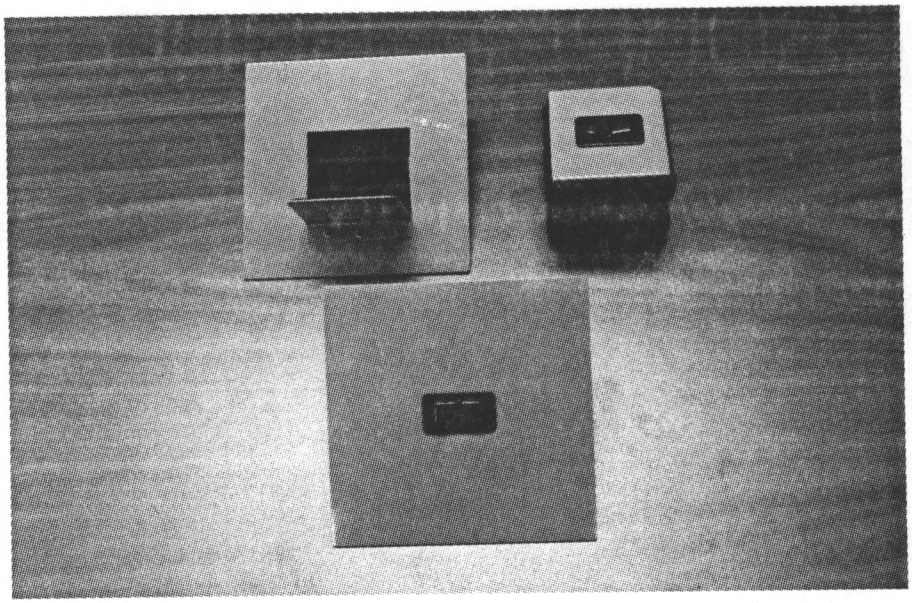


Figure 36. Power door lock controls with angle bracket.

Table 3

Power door lock conditions.*

	CONDITION	ORIENTATION	SWITCH ALIGNMENT
Carrier Plate			
	A	Flush on Door (X-Z plane)	Fore-Aft
	B	Flush on Door (X-Z plane)	Up-Down
Control Cube with Carrier Plate and Angle Bracket			
	C, D	Up (X-Y plane)	Fore-Aft, Right-Left
	E, F	Front (Y-Z plane)	Up-Down, Right-Left

* All conditions for the power door lock study were on the driver's door.

It was decided that the conditions would be separated into four groups. Each of the four groups of conditions would have a separate set of subjects. It was believed that four groups would be more manageable because the data collection from each subject would not be a marathon effort, and, additionally, conditions similar in nature could be placed in separate groups to control for transfer effects. The groupings used for the research are shown in Table 4. The letters correspond to the conditions given earlier, and each study is listed separately for ease of reference. In this design, on the average, each subject received 26.75 conditions and a total of 45 commands.

Additional precautions were taken to control for learning and fatigue effects within each group of commands (composed of approximately 45 commands). The commands within each group were randomized using a computerized random number generator. Any related commands (for example the four power mirror directions) which fell near one another after randomization were manually separated by removal and re-insertion at another point in the sequence. Similarly a check was made to insure that the first few commands and the last few were not closely related. If any were found, the same removal and re-insertion procedure was used.

Subsequently, the command group was subdivided into three ordered blocks, each containing approximately 15 commands. A given subject then received one of three orders of command blocks, as follows: I, II, III; II, III, I; or III, I, II. In effect this meant that a given subject entered the command sequence at one of three points in the 45-command cycle. It was believed that this procedure was sufficient to control for learning and fatigue while at the same time not overly complicating the experimenter's

Table 4

Grouping of conditions.

	Study	Group 1	Group 2	Group 3	Group 4
GENERIC	Power Mirror	A G I	B H	C F J	D E
	Power Window	A I K	B H J	C F	D E G
	Manual Window	A	B	C	D
	Stalk Controls	A D E K O	G B M N	H C L	I F J
	Thumbwheel	A D J	B C I	E H	F G
	Toggle	B G O M	D E J P	C F I N	A H K L
	Slide	C F I	A H K	B G M L	D E J
	Rotary	D	C	A F	B E
	Rocker	I M H P	D F K O	A J G N	C L E B
	Power Door Locks	A	B	C F	D E
	Number of Conditions	28	26	27	26
	Number of Commands	48	43	45	44

workload and paper handling problem. A sample copy of a script is shown in Appendix A.

Subjects

As indicated, the experimental design required four groups of participants (subjects). From a statistical standpoint it was felt that four groups of 50 individuals each was sufficient to achieve stable estimates of mean values, based on confidence limit calculations (to be described later). This resulted in a total sample size of 200 subjects.

During recruitment, efforts were made to insure that subjects met specific demographic requirements. Three factors given consideration were age, type of primary vehicle driven (domestic, foreign), and gender. Each of the four subject groups consisted of 25 individuals in a younger age category (18 to 45 years) and 25 in an older age category (46 to 86 years)* Additionally, each age category had 18 members who drove domestic vehicles and 7 who drove foreign cars. The number of males and females was almost the same for each age category and vehicle type. Table 5 shows a breakdown of the subject distribution.

One of the main goals during recruitment was to obtain a subject sample representative of a new car buying population in the U.S. While the data were collected in a university laboratory, the great majority of the participants were not students. Care was taken to obtain subjects other than students so that the population would not be unusually skewed.

*Individuals age 80 and above were queried to insure that they drove regularly. There were two such individuals in the subject sample.

Table 5

Subject distribution.

	Younger				Older				
	Domestic		Foreign		Domestic		Foreign		
	Males	Females	Males	Females	Males	Females	Males	Females	Totals
Group 1	9	9	4	3	9	9	3	4	50
Group 2	9	9	4	3	9	9	3	4	50
Group 3	9	9	4	3	9	9	3	4	50
Group 4	9	9	3	4	9	9	2	5	50
Totals	36	36	15	13	36	36	11	17	200

Procedure

When participants first entered the laboratory they were required to fill out a short questionnaire. They then read and signed an informed consent form. The questionnaire was used to provide general information about the experiment and to obtain data on the subject's driving background. The informed consent form indicated the subject's agreement to participate in the study. These documents are shown in Appendix B. To assure that all potential participants were licensed, each subject was required to present a valid driver's license. If subjects passed all the screening requirements they were scheduled for the experiment. Most participants began the session immediately upon completion of the above prerequisites.

When the session began, the subject was first seated in a comfortable position in the buck (using the power seat controls, which were operational) and instructed on the experimental protocol. During the instructions the experimenter stressed that the *direction* of control activation was the important issue in the study. The subject was told to respond in a natural manner, and to move the control in the direction that felt right. The experimenter showed the subject each control to be used during the session. Explanation was provided on how the control operated, and what its function was. However, no feedback was given on "correct" direction for control operation.

Once the subject understood all of the instructions, data collection began. The experimenter issued the commands and observed and recorded the subject's selection (where appropriate) and initial direction of control movement. Once the data collection was completed, participants were paid $5, debriefed, and dismissed. The entire session including all preliminaries took about one hour.

Occasionally a subject would deflect or move a control and then recognize immediately that he or she had made an "error." In such instances the subject was permitted to make a "correction," and the corrected response was recorded. It is estimated that this occurred about once for every three subjects, or one for every 135 commands issued. With 200 subjects a grand total of approximately 9000 commands were issued, therefore, "corrected" responses represent about 0.75% of the commands.

RESULTS

The frequency of occurrence for each response possibility was tabulated for every control condition. These results are presented in symbolic manner to better indicate preferred direction. Since the 200 subject pool was partitioned into four groups of 50, most conditions have an N value, or sample size, of 50. In all cases, actual response frequencies are listed. From these frequencies sample proportions are calculated. For example, suppose subjects were asked to move a slide control either right or left to increase something. If 42 of the 50 research subjects polled preferred the right direction, then the sample proportion, $\hat{p}$, equals 42/50 = 0.84.

To assess the relative strength of directional stereotypes a grading system was incorporated in the results. If sample proportions are greater than 0.85 the stereotype was graded as an A, indicating a strong directional stereotype. If the proportion is greater than 0.70, but less than or equal to 0.85, then its grading was a B, indicating a medium strength directional stereotype. Finally, any sample proportion less than or equal to 0.70 was graded as a C, for weak stereotypes. The gradings are only presented for the response with the highest sample proportion in each condition.

One might ask how accurate the sample proportions are in representing the population. One way to determine the "accuracy" of the sample is by computing confidence limits. Confidence limits specify the bounds on either side of $\hat{p}$ within which the population proportion, p, would fall with a certain degree of confidence (e.g., 80%, 90%, 95%). Confidence limits can be easily calculated for all of the sample proportions given. To prevent clutter and repetitiveness the reader is referred to the report by Wierwille

(1990) for a complete discussion and examples on how to calculate confidence limits, and for the appropriate tables from which to draw values.

Because the results of each condition can be represented as a sample drawn from a binomial distribution, the associated confidence limits can be computed from $\hat{p}$, N, and the percent confidence desired. Representative examples are given in Table 6. The reader is again referred to Wierwille's report for a full explanation and complete tables.

Table 6

Confidence limits for specific values of $\hat{p}$, given that N = 50 and that 90% confidence is desired.

$\hat{p}$	Lower Limit	Upper Limit
.50	.387	.613
.60	.484	.706
.70	.585	.794
.80	.693	.887
.90	.808	.950
1.00	.949	1.000

FREQUENCIES OF OCCURRENCE AND STEREOTYPE GRADES

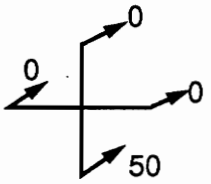
Study 1 — Power Mirror

Condition A (See Figure 12 for an illustration of this configuration.)

Pad switch mounted on driver's door panel, extending from panel in a vertical (Y-Z) plane.

Experimenter moves mirror **down** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror down response results:

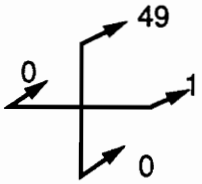


$\hat{p}$ = 50/50 = 1.00

Grade = A

Experimenter moves mirror **up** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror up response results:

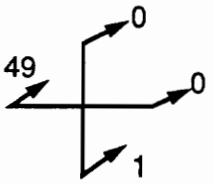


$\hat{p}$ = 49/50 = 0.98

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror left response results:

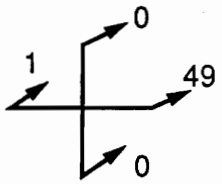


$\hat{p}$ = 49/50 = 0.98

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p} = 49/50 = 0.98$

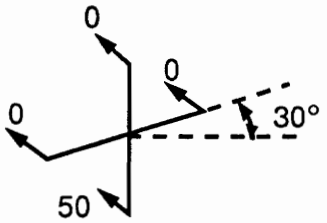
Grade = A

Condition B (See Figure 12 for an illustration of this configuration.)

Pad switch mounted on driver's door panel at 30° relative to y axis and 60° relative to x axis.

Experimenter moves mirror **down** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror down response results:

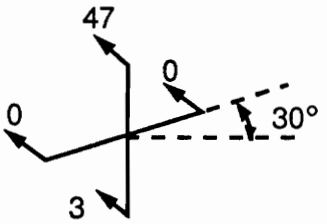


$\hat{p} = 50/50 = 1.00$

Grade = A

Experimenter moves mirror **up** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror up response results:

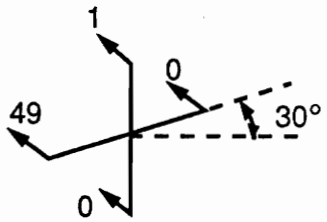


$\hat{p} = 47/50 = 0.94$

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror left response results:

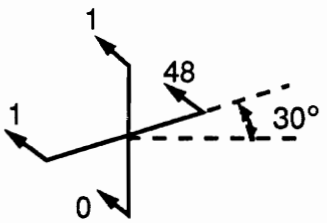


$\hat{p}$ = 49/50 = 0.98

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p}$ = 48/50 = 0.96

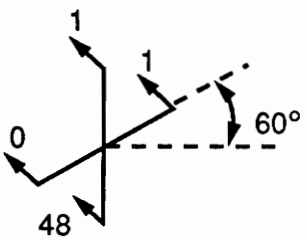
Grade = A

Condition C (See Figure 12 for an illustration of this configuration.)

Pad switch mounted on driver's door panel at 60° relative to y axis and 30° relative to x axis.

Experimenter moves mirror **down** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror down response results:

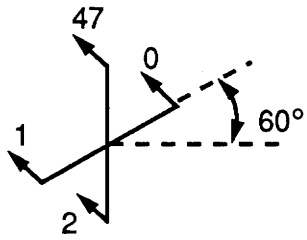


$\hat{p}$ = 48/50 = 0.96

Grade = A

Experimenter moves mirror **up** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror up response results:

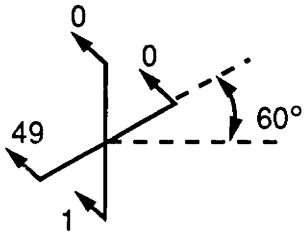


$\hat{p} = 47/50 = 0.94$

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror left response results:

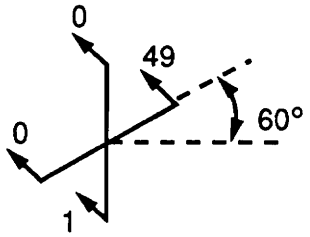


$\hat{p} = 49/50 = 0.98$

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p} = 49/50 = 0.98$

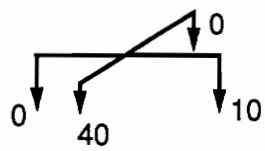
Grade = A

Condition D (See Figure 12 for an illustration of this configuration.)

Pad switch, facing up, mounted on driver's door panel, extending from panel in a horizontal (X-Y) plane.

Experimenter moves mirror **down** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror down response results:

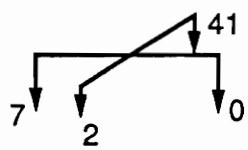


$\hat{p} = 40/50 = 0.80$

Grade = B

Experimenter moves mirror **up** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror up response results:

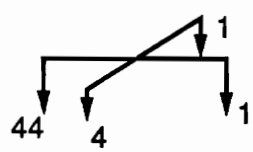


$\hat{p} = 41/50 = 0.82$

Grade = B

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror left response results:

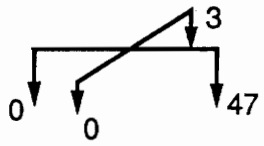


$\hat{p} = 44/50 = 0.88$

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p} = 47/50 = 0.94$

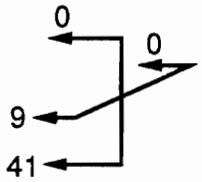
Grade = A

Condition E (See Figure 13 for an illustration of this configuration.)

Pad switch mounted flush with driver's door panel (X-Z plane).

Experimenter moves mirror **down** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror down response results:

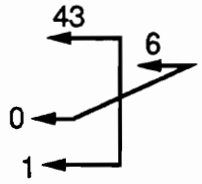


$\hat{p} = 41/50 = 0.82$

Grade = B

Experimenter moves mirror **up** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror up response results:

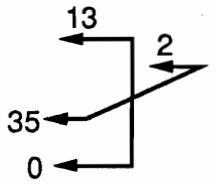


$\hat{p} = 43/50 = 0.86$

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror left response results:

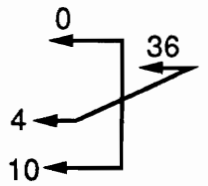


$\hat{p} = 35/50 = 0.70$

Grade = C

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror right response results:

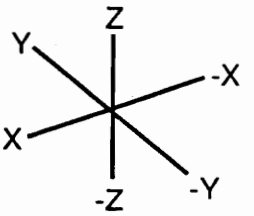


$\hat{p} = 36/50 = 0.72$

Grade = B

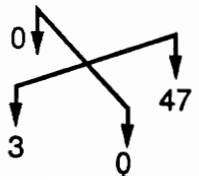
Condition F (See Figure 14 for an illustration of this configuration.)

Pad switch mounted on horizontal plane of center console.
Note different orientation of axis system for this configuration.
Vantage point is that shown in Figure 14.



Experimenter moves mirror **down** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror down response results:

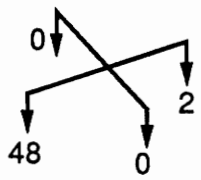


$\hat{p} = 47/50 = 0.94$

Grade = A

Experimenter moves mirror **up** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror up response results:

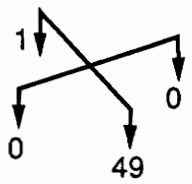


$\hat{p}$ = 48/50 = 0.96

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror left response results:

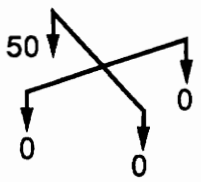


$\hat{p}$ = 49/50 = 0.98

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror right response results:

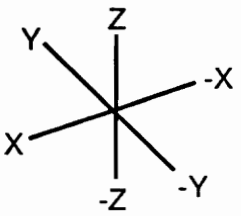


$\hat{p}$ = 50/50 = 1.00

Grade = A

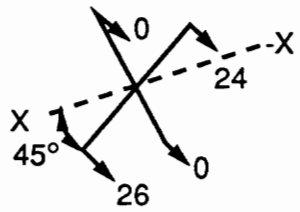
Condition G (See Figure 14 for an illustration of this configuration.)

Pad switch angled 45° **below** the horizontal plane on the center console.
Note different orientation of axis system for this configuration.
Vantage point is that shown in Figure 14.



Experimenter moves mirror **down** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror down response results:

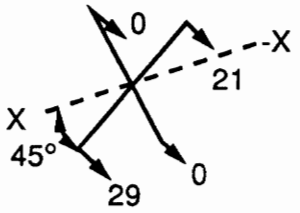


$\hat{p} = 26/50 = 0.52$

Grade = C

Experimenter moves mirror **up** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror up response results:

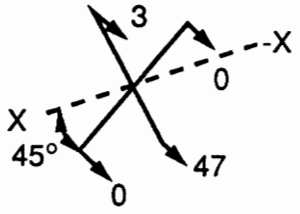


$\hat{p} = 29/50 = 0.58$

Grade = C

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror left response results:

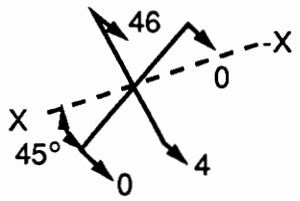


$\hat{p} = 47/50 = 0.94$

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please press the portion of the pad switch to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p} = 46/50 = 0.92$

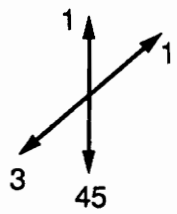
Grade = A

Condition H (See Figure 15 for an illustration of this configuration.)

Joystick mounted flush with driver's door panel (X-Z plane).

Experimenter moves mirror **down** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror down response results:

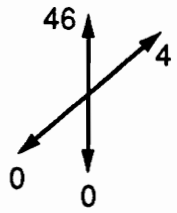


$\hat{p} = 45/50 = 0.90$

Grade = A

Experimenter moves mirror **up** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror up response results:

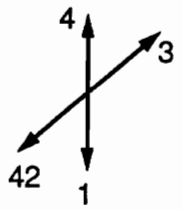


$\hat{p} = 46/50 = 0.92$

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror left response results:

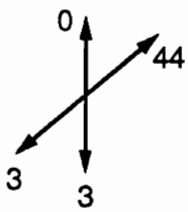


$\hat{p} = 42/50 = 0.84$

Grade = B

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p} = 44/50 = 0.88$

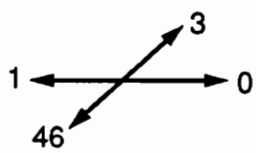
Grade = A

Condition I (See Figure 16 for an illustration of this configuration.)

Joystick, facing up, mounted on driver's door panel, extending from panel in a horizontal (X-Y) plane.

Experimenter moves mirror **down** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror down response results:

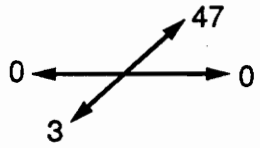


$\hat{p} = 46/50 = 0.92$

Grade = A

Experimenter moves mirror **up** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror up response results:

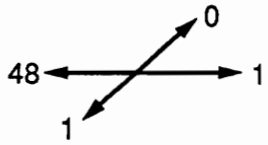


$\hat{p} = 47/50 = 0.94$

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror left response results:

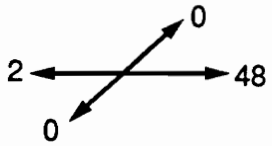


$\hat{p} = 48/50 = 0.96$

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p} = 48/50 = 0.96$

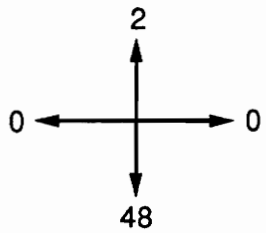
Grade = A

Condition J (See Figure 16 for an illustration of this configuration.)

Joystick mounted on driver's door panel, extending from panel in a vertical (Y-Z) plane.

Experimenter moves mirror **down** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror down response results:

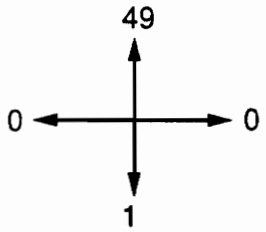


$\hat{p} = 48/50 = 0.96$

Grade = A

Experimenter moves mirror **up** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror up response results:

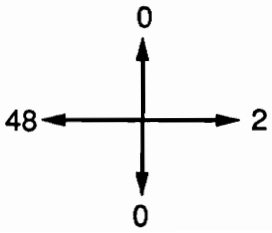


$\hat{p} = 49/50 = 0.98$

Grade = A

Experimenter moves mirror **left (away from subject)** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror left response results:

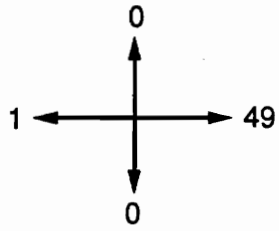


$\hat{p} = 48/50 = 0.96$

Grade = A

Experimenter moves mirror **right (towards subject)** and asks subject to: *"Please activate the joystick to make the mirror move in this direction."* (N = 50)

Mirror right response results:



$\hat{p} = 49/50 = 0.98$

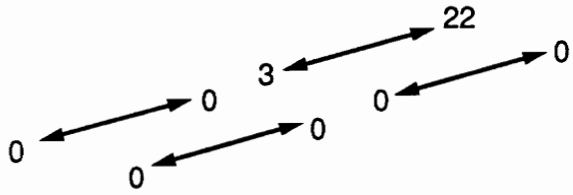
Grade = A

Study 2 — Power windows

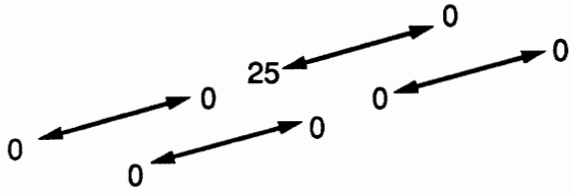
Condition A (See Figure 18 for an illustration of this configuration.)

2 × 2 toggle switch array extending from driver's door panel in a horizontal (X-Y) plane.

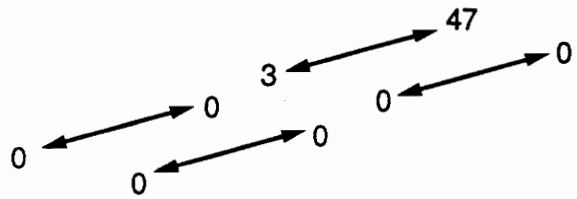
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

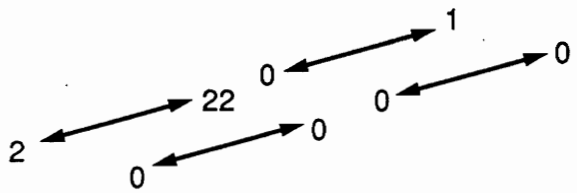


$\hat{p} = 47/50 = 0.94$

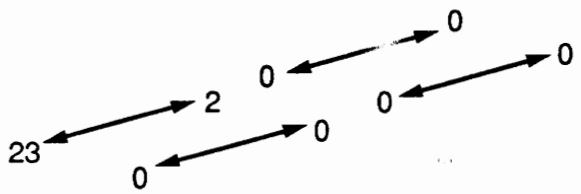
Grade = A

Condition A

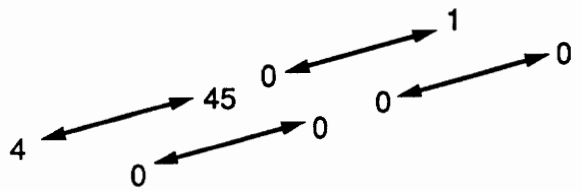
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

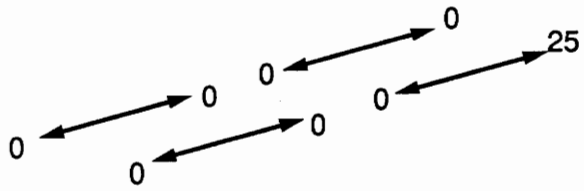


$\hat{p} = 45/50 = 0.90$

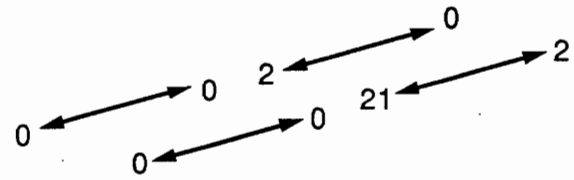
Grade = A

Condition A

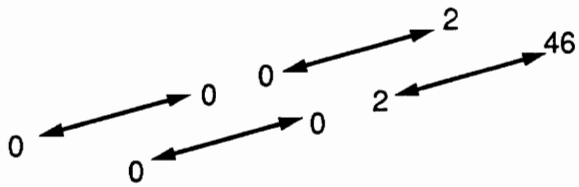
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

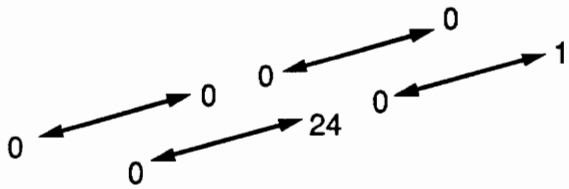


$\hat{p} = 46/50 = 0.92$

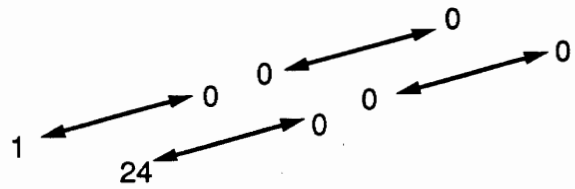
Grade = A

Condition A

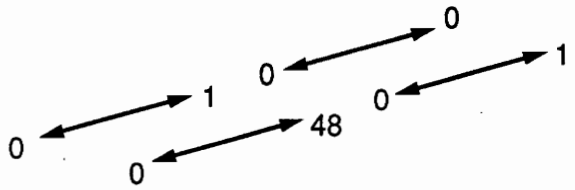
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



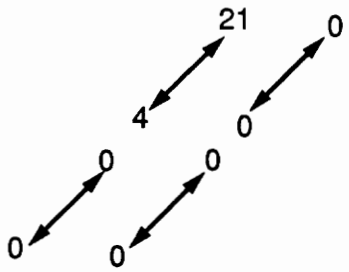
$\hat{p} = 48/50 = 0.96$

Grade = A

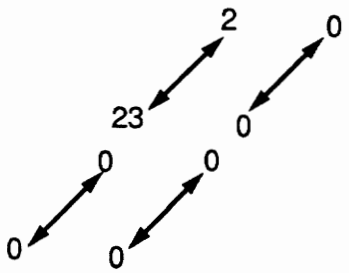
Condition B (See Figure 18 for an illustration of this configuration.)

2 × 2 toggle switch array extending from driver's panel angled **towards** the driver 30°.

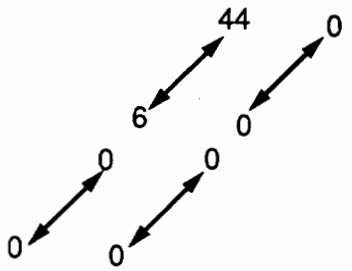
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

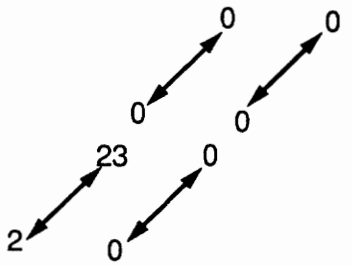


$\hat{p} = 44/50 = 0.88$

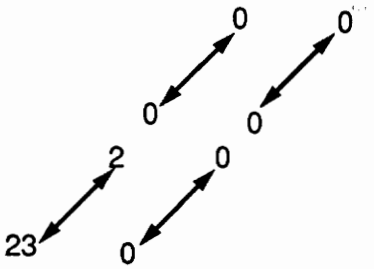
Grade = A

Condition B

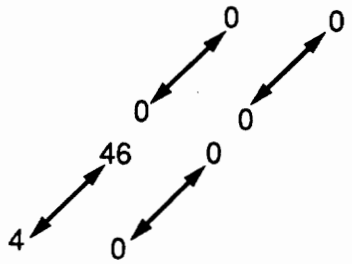
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

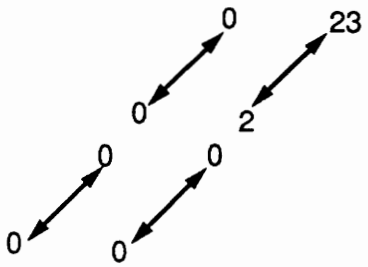


$\hat{p} = 46/50 = 0.92$

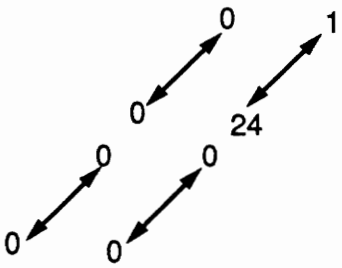
Grade = A

Condition B

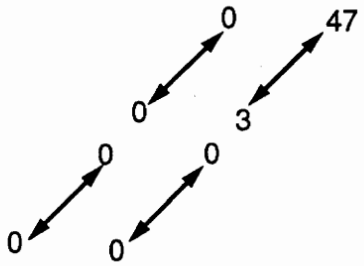
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

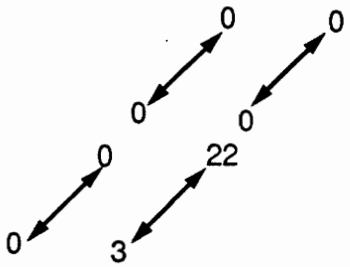


$\hat{p} = 47/50 = 0.94$

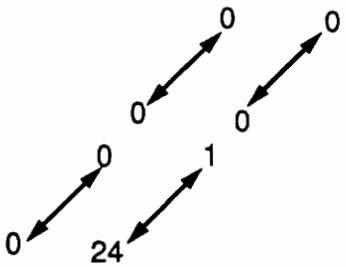
Grade = A

Condition B

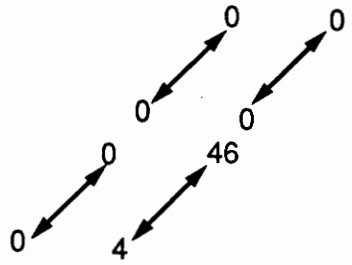
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



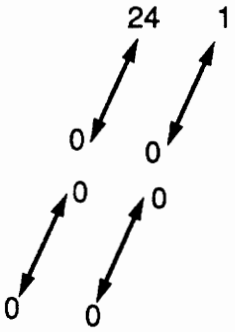
$\hat{p} = 46/50 = 0.92$

Grade = A

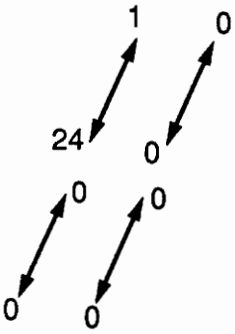
Condition C (See Figure 18 for an illustration of this configuration.)

2 × 2 toggle switch array extending from driver door panel angled **towards** the driver 60° above the horizontal plane.

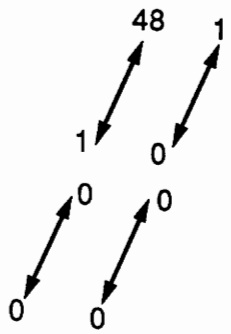
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

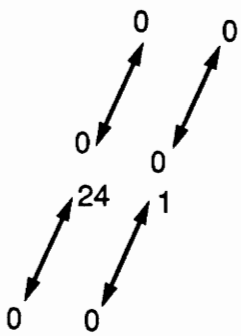


$\hat{p} = 48/50 = 0.96$

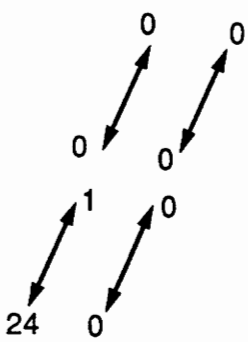
Grade = A

Condition C

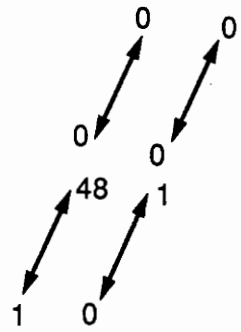
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

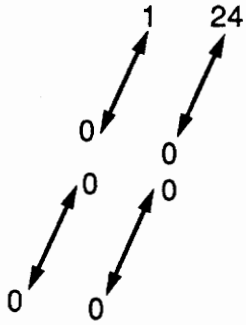


$\hat{p} = 48/50 = 0.96$

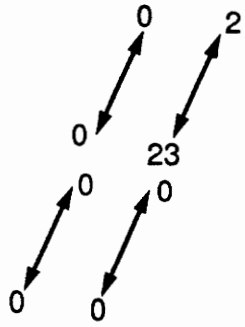
Grade = A

Condition C

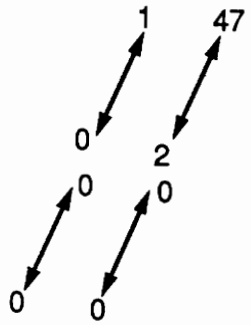
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

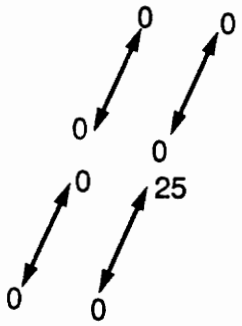


$\hat{p} = 47/50 = 0.94$

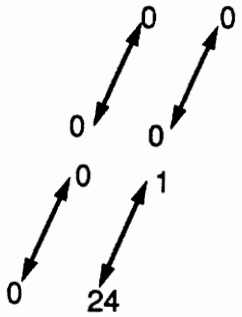
Grade = A

Condition C

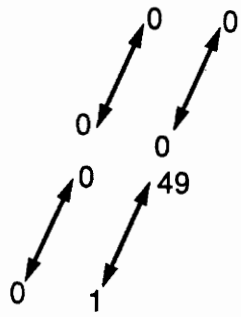
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

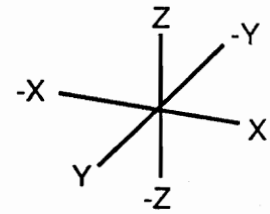


$\hat{p} = 49/50 = 0.98$

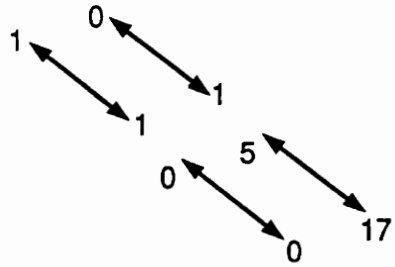
Grade = A

Condition D (See Figure 18 for an illustration of this configuration.)

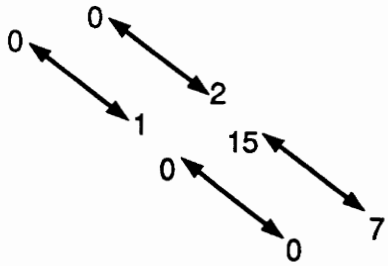
2 × 2 toggle switch array extending from driver's door panel angled **away** from the driver 30°
Note different orientation of axis system for this configuration. For clarity of presentation, vantage point is **not** that shown in Figure 18. Vantage point **Is** at the center of the instrument panel, looking toward the driver's door.



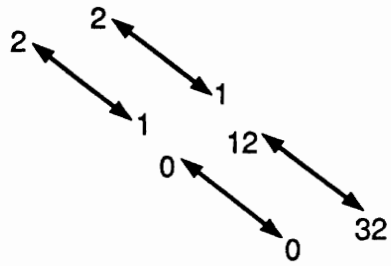
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

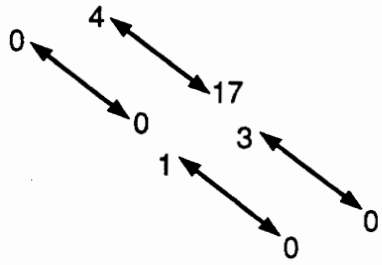


$\hat{p} = 32/50 = 0.64$

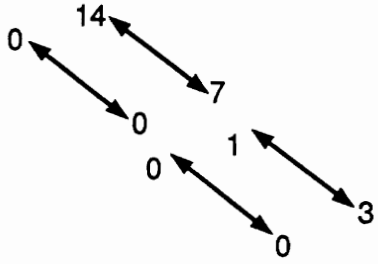
Grade = C

Condition D

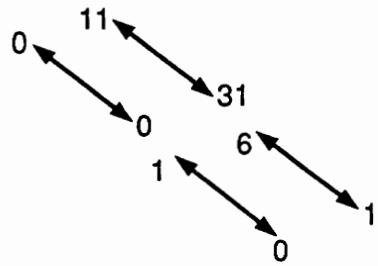
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

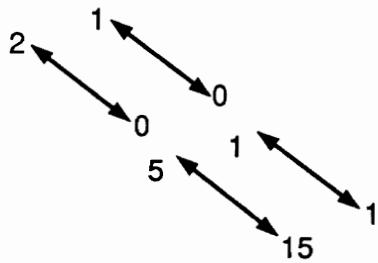


$\hat{p} = 31/50 = 0.62$

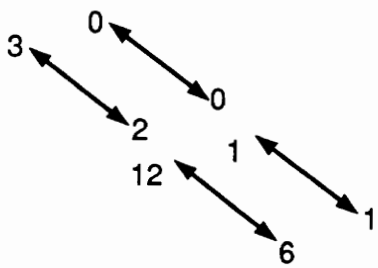
Grade = C

Condition D

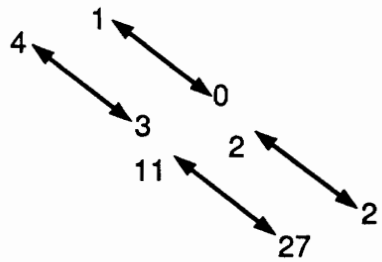
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

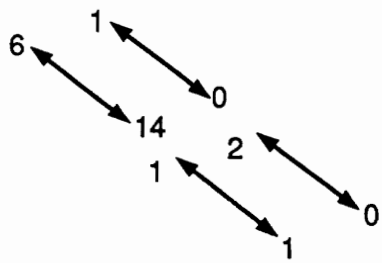


$\hat{p} = 27/50 = 0.54$

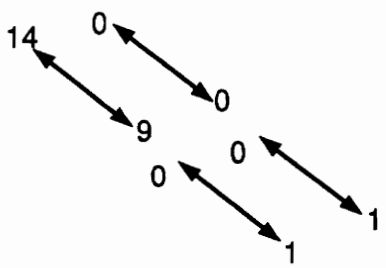
Grade = C

Condition D

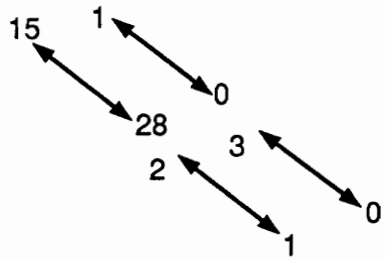
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



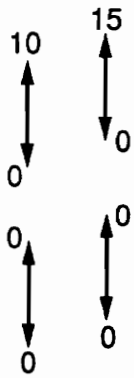
$\hat{p} = 28/50 = 0.56$

Grade = C

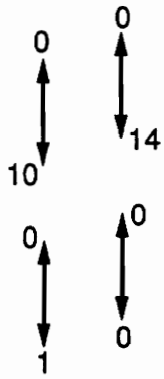
Condition E (See Figure 19 for an illustration of this configuration.)

2 × 2 toggle switch array mounted flush with driver's door panel (X-Z plane).

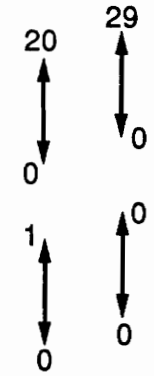
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

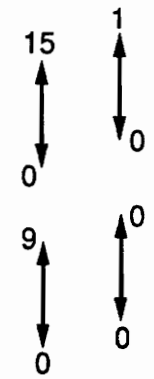


$\hat{p} = 29/50 = 0.58$

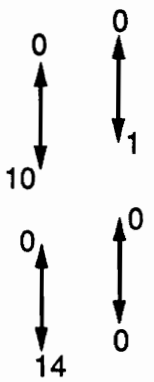
Grade = C

Condition E

"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

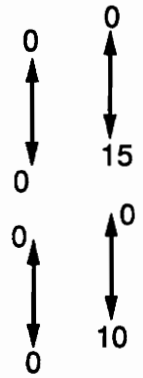
$\hat{p} = 25/50 = 0.50$

Grade = C

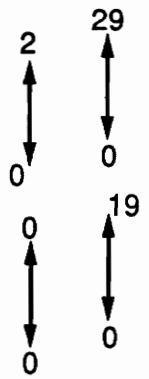
Condition E

"Raise the passenger side front window"

"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

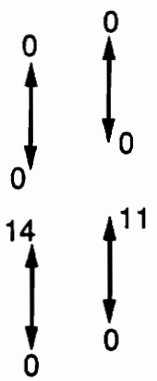


$\hat{p} = 29/50 = 0.58$

Grade = C

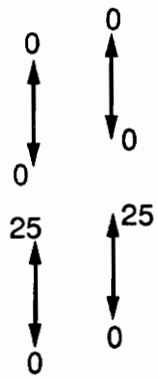
Condition E

"Raise the passenger side rear window"



"Lower the passenger side rear window"

"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



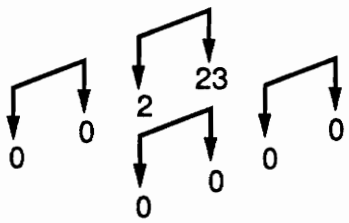
$\hat{p} = 25/50 = 0.50$

Grade = C

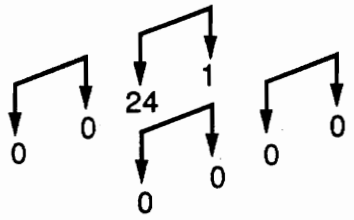
Condition F (See Figure 20 for an illustration of this configuration.)

2 × 2 rocker switch array extending from driver's door panel in a horizontal (X-Y) plane.

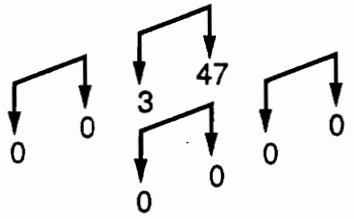
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

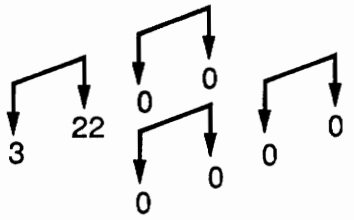


$\hat{p} = 47/50 = 0.94$

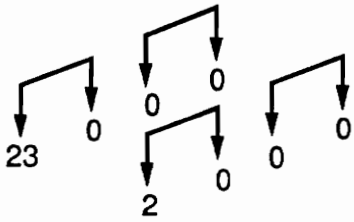
Grade = A

Condition F

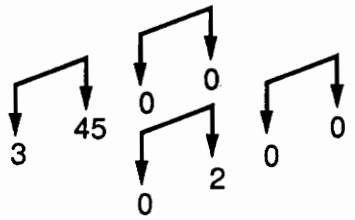
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

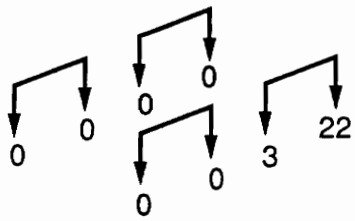


$\hat{p} = 45/50 = 0.90$

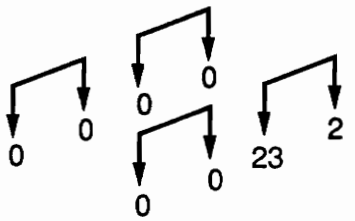
Grade = A

Condition F

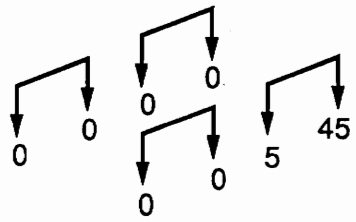
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

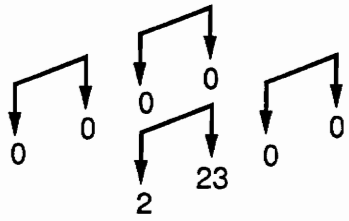


$\hat{p} = 45/50 = 0.90$

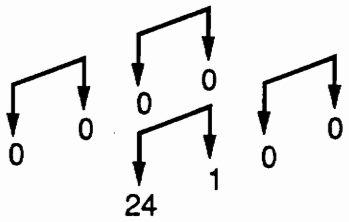
Grade = A

Condition F

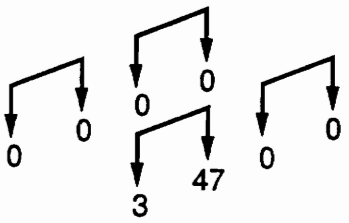
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



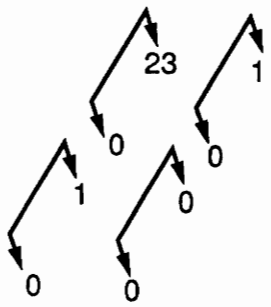
$\hat{p} = 47/50 = 0.94$

Grade = A

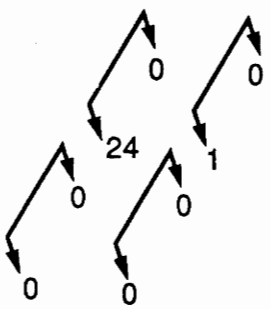
Condition G (See Figure 20 for an illustration of this configuration.)

2 × 2 rocker switch array extending from driver's door panel angled **towards** the driver 60°.

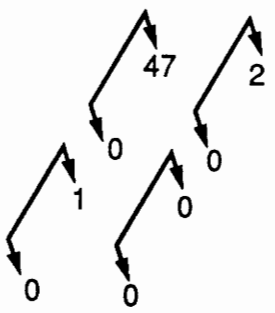
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

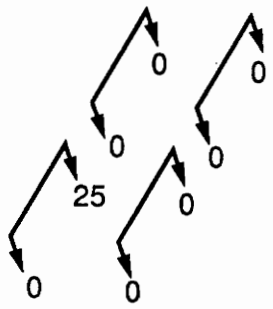


$\hat{p} = 47/50 = 0.94$

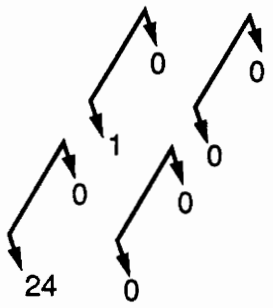
Grade = A

Condition G

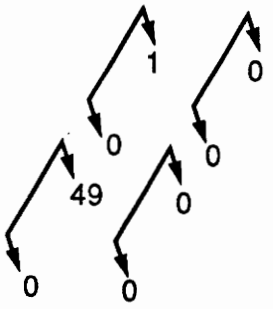
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

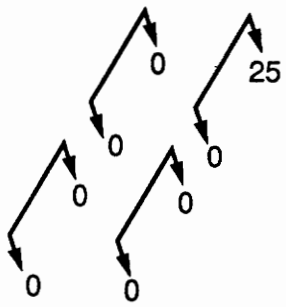


$\hat{p} = 49/50 = 0.98$

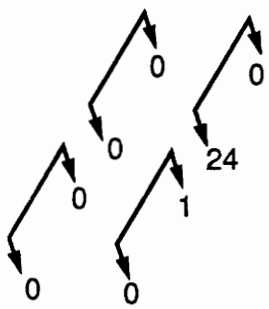
Grade = A

Condition G

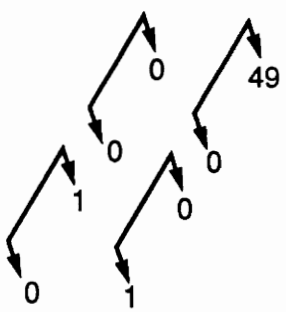
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

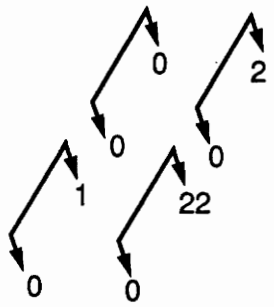


$\hat{p} = 49/50 = 0.98$

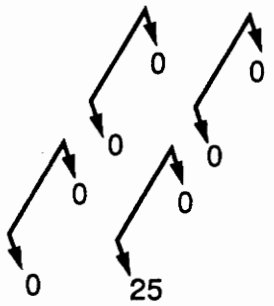
Grade = A

Condition G

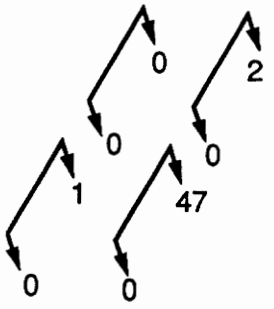
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

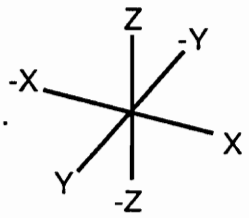


$\hat{p} = 47/50 = 0.94$

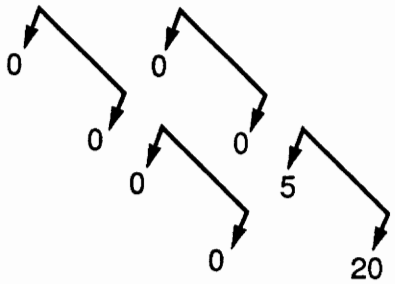
Grade = A

Condition H (See Figure 20 for an illustration of this configuration.)

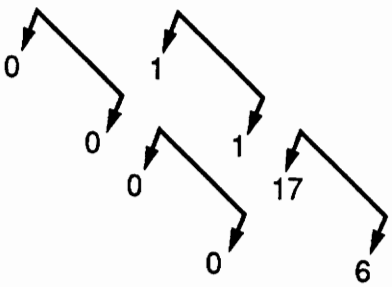
2 × 2 rocker switch array extending from driver's door panel angled **away** from the driver 30° below the horizontal plane.
Note different orientation of axis system for this configuration. For clarity of presentation, vantage point is **not** that shown in Figure 20. Vantage point **is** at the center of the instrument panel, looking toward the driver's door.



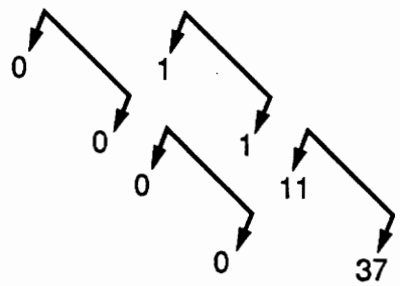
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

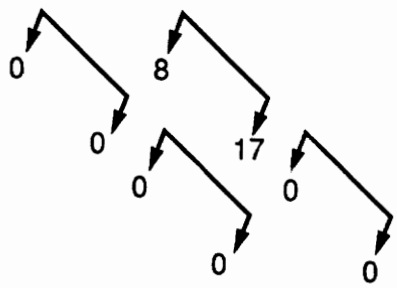


$\hat{p} = 37/50 = 0.74$

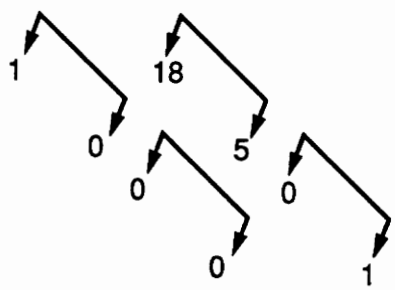
Grade = B

Condition H

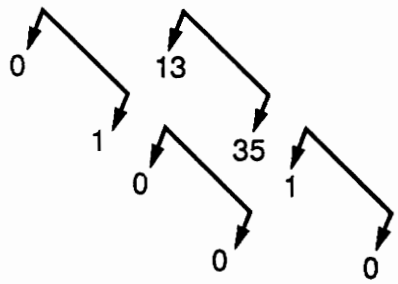
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

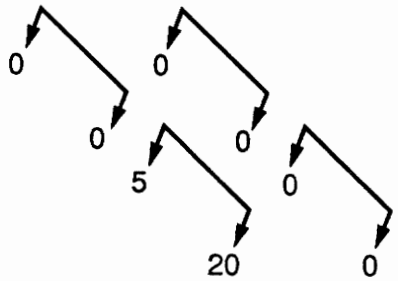


$\hat{p} = 35/50 = 0.70$

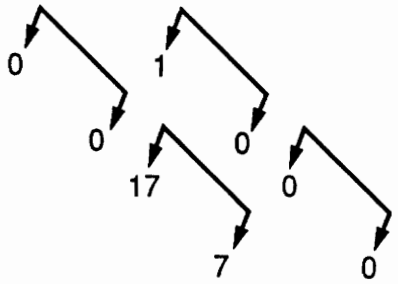
Grade = C

Condition H

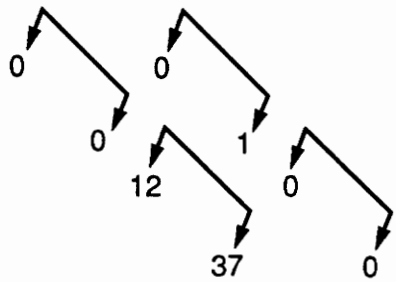
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

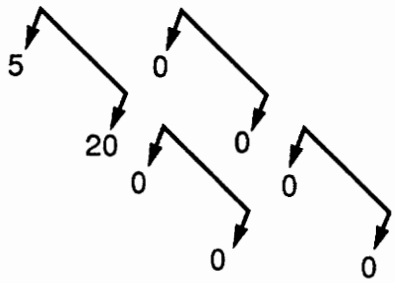


$\hat{p} = 37/50 = 0.74$

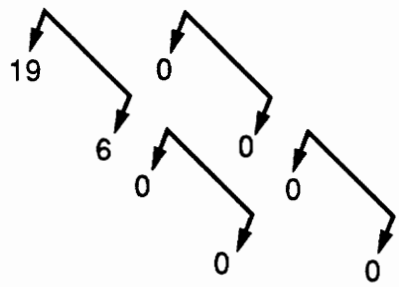
Grade = B

Condition H

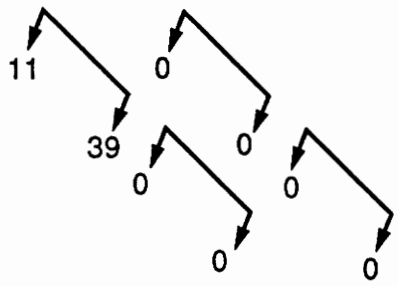
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



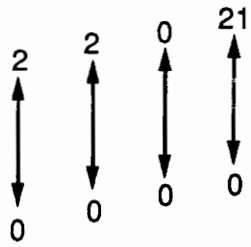
$\hat{p} = 39/50 = 0.78$

Grade = B

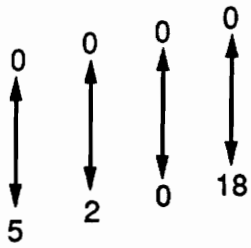
Condition I (See Figure 21 for an illustration of this configuration.)

1 × 4 lateral toggle switch array mounted flush on the driver's door panel.

"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

7	4	0	39
0	0	0	0

$\hat{p} = 39/50 = 0.78$

Grade = B

Condition I

"Raise the driver side rear window"

8	9	8	0
0	0	0	0

"Lower the driver side rear window"

0	0	0	0
4	10	10	1

"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

12	19	18	1
0	0	0	0

$\hat{p} = 19/50 = 0.38$

Grade = C

Condition I

"Raise the passenger side front window"

0	6	16	3
0	0	0	0

"Lower the passenger side front window"

0	0	0	0
1	11	12	1

"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

1	17	28	4
0	0	0	0

$\hat{p} = 28/50 = 0.56$

Grade = C

Condition I

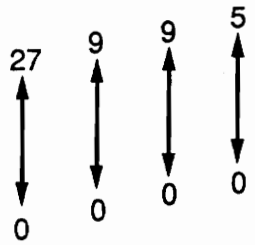
"Raise the passenger side rear window"

13	5	6	1
0	0	0	0

"Lower the passenger side rear window"

0	0	0	0
14	4	3	4

"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



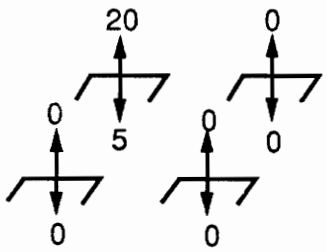
$\hat{p} = 27/50 = 0.54$

Grade = C

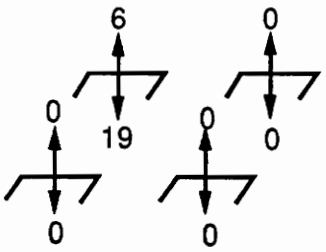
Condition J (See Figure 22 for an illustration of this configuration.)

2 × 2 push/pull switch array extending from driver's door panel in a horizontal (X-Y) plane.

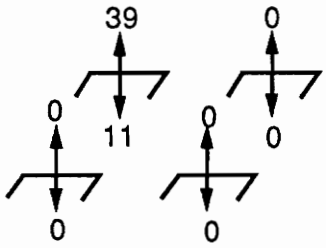
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

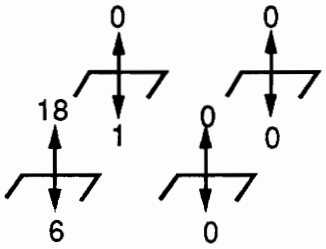


$\hat{p} = 39/50 = 0.78$

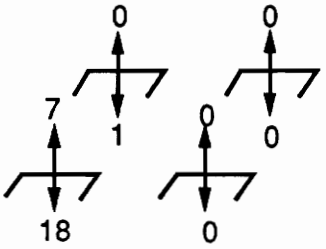
Grade = B

Condition J

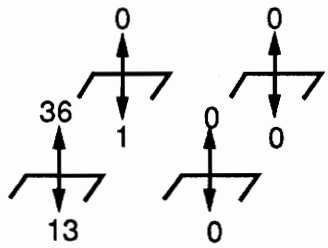
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

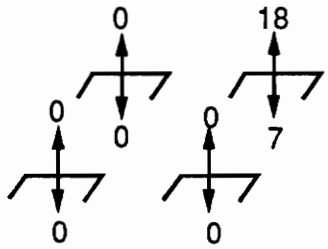


$\hat{p} = 36/50 = 0.72$

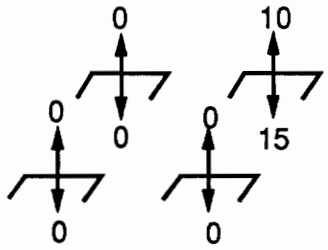
Grade = B

Condition J

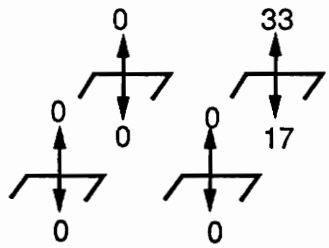
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

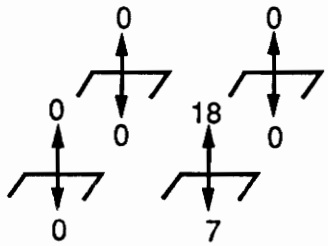


$\hat{p} = 33/50 = 0.66$

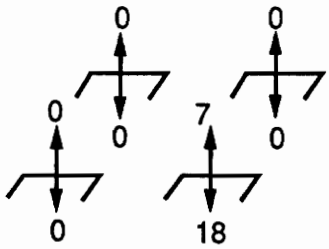
Grade = C

Condition J

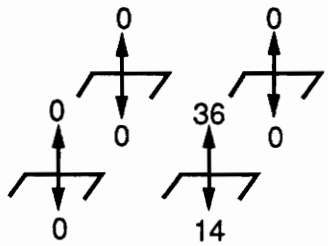
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



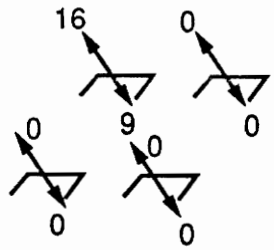
$\hat{p} = 36/50 = 0.72$

Grade = B

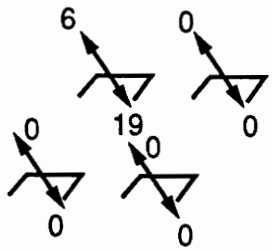
Condition K (See Figure 22 for an illustration of this configuration.)

2 × 2 push/pull switch array extending from driver's door panel angled **towards** the driver 45°.

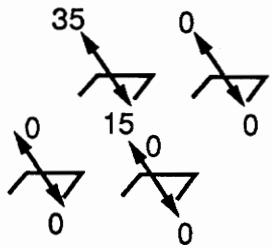
"Raise the driver side front window"



"Lower the driver side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

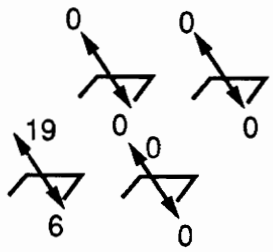


$\hat{p} = 35/50 = 0.70$

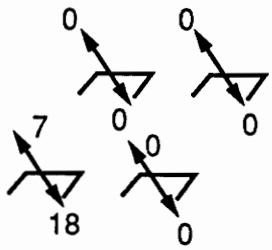
Grade = C

Condition K

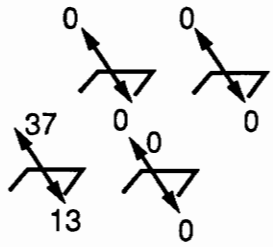
"Raise the driver side rear window"



"Lower the driver side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

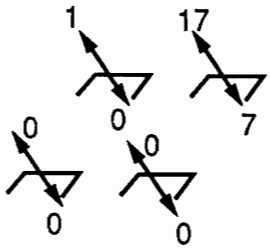


$\hat{p} = 37/50 = 0.74$

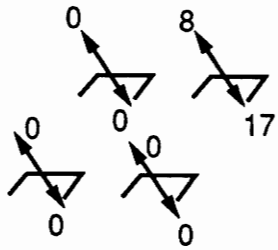
Grade = B

Condition K

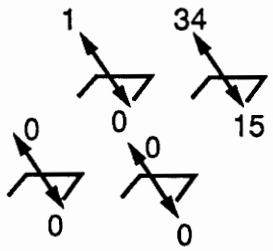
"Raise the passenger side front window"



"Lower the passenger side front window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side front window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)

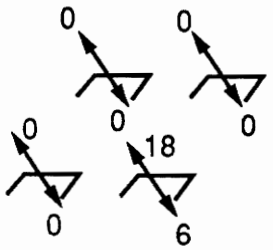


$\hat{p} = 34/50 = 0.68$

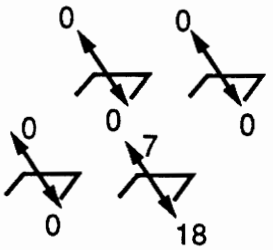
Grade = C

Condition K

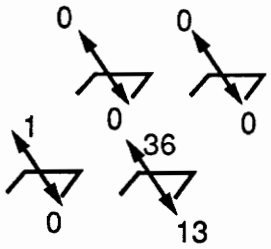
"Raise the passenger side rear window"



"Lower the passenger side rear window"



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger side rear window," with "lower" values transformed to "raise" values by reflection to opposite half of switch. (N = 50)



$\hat{p} = 36/50 = 0.72$

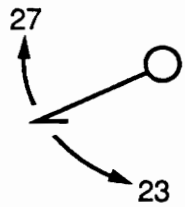
Grade = B

Study 3 — Manual Windows

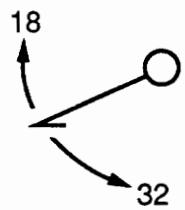
Condition A (See Figure 24 for an illustration of this configuration.)

Crank mounted on driver's door panel with handle facing rear of buck.

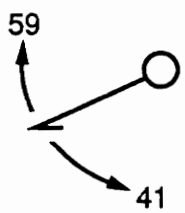
"Raise the driver's side window." (N = 50)



"Lower the driver's side window." (N = 50)



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver's side window," with "lower" values transformed to "raise" values by reversing direction of motion. (N = 100)



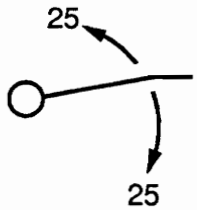
$\hat{p} = 59/100 = 0.59$

Grade = C

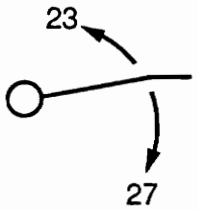
Condition B (See Figure 24 for an illustration of this configuration.)

Crank mounted on driver's door panel with handle facing front of buck.

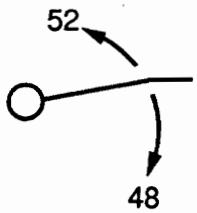
"Raise the driver's side window." (N = 50)



"Lower the driver's side window." (N = 50)



"$\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the driver's side window," with "lower" values transformed to "raise" values by reversing direction of motion. (N = 100)

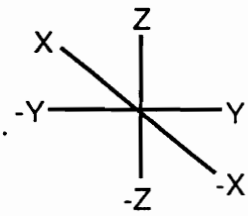


$\hat{p} = 52/100 = 0.52$

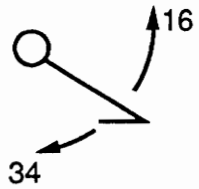
Grade = C

Condition C (See Figure 25 for an illustration of this configuration.)

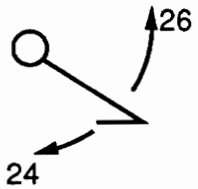
Crank mounted on passenger's door panel with handle facing rear of buck.
Note different orientation of axis system for this configuration.
Vantage point is that shown in Figure 25.



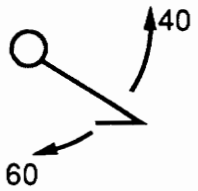
"Assuming you are the front seat passenger, please raise the passenger's side window." (N = 50)



"Assuming you are the front seat passenger, please lower the passenger's side window." (N = 50)



"Assuming you are the front seat passenger, please $\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger's side window," with "lower" values transformed to "raise" values by reversing direction of motion. (N = 100)

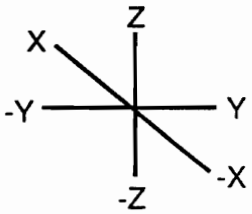


$\hat{p} = 60/100 = 0.60$

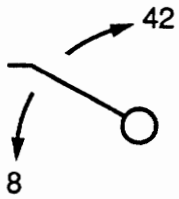
Grade = C

Condition D (See Figure 25 for an illustration of this configuration.)

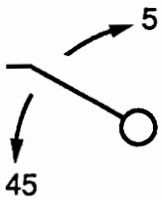
Crank mounted on passenger's door panel with handle facing front of buck.
Note different orientation of axis system for this configuration.
Vantage point is that shown in Figure 25.



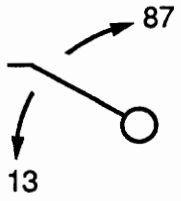
"Assuming you are the front seat passenger, please raise the passenger's side window." (N = 50)



"Assuming you are the front seat passenger, please lower the passenger's side window." (N = 50)



"Assuming you are the front seat passenger, please $\left\{\begin{matrix}\text{Raise}\\ \text{Lower}\end{matrix}\right\}$ the passenger's side window," with "lower" values transformed to "raise" values by reversing direction of motion. (N = 100)



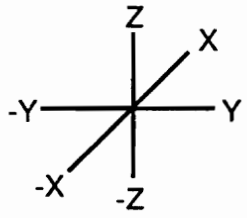
$\hat{p} = 87/100 = 0.87$

Grade = A

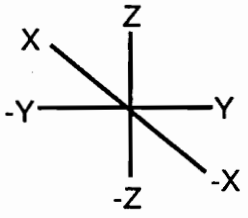
Study 4 — Stalk Controls

Note the following axes systems used to represent the results for the left and right stalks

Left Stalk



Right Stalk

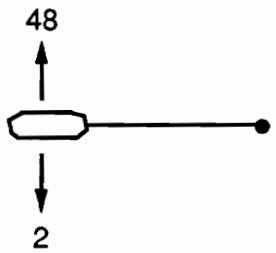


In both cases, vantage point is that of the driver.

Nonspecific Conditions

Condition A

"With the left stalk, raise or lower the stalk to turn something on." (N = 50)

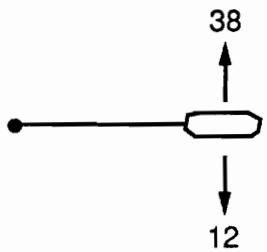


$\hat{p} = 48/50 = 0.96$

Grade = A

Condition B

"With the right stalk, raise or lower the stalk to turn something on." (N = 50)

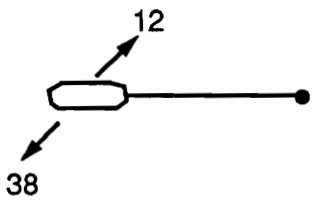


$\hat{p} = 38/50 = 0.76$

Grade = B

Condition C

"With the left stalk, push the stalk away from you, or pull it towards you to turn something on." (N = 50)

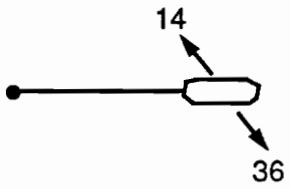


$\hat{p} = 38/50 = 0.76$

Grade = B

Condition D

"With the right stalk, push the stalk away from you, or pull it towards you to turn something on." (N = 50)

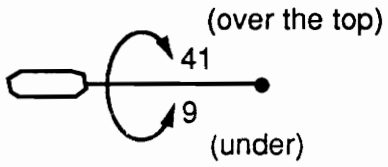


$\hat{p} = 36/50 = 0.72$

Grade = B

Condition E

"With the left stalk, rotate the barrel of the stalk to turn something on." (N = 50)

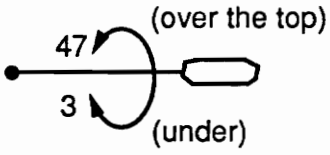


$\hat{p} = 41/50 = 0.82$

Grade = B

Condition F

"With the right stalk, rotate the barrel of the stalk to turn something on." (N = 50)



$\hat{p} = 47/50 = 0.94$

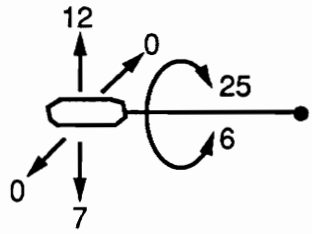
Grade = A

Specific Unconstrained Conditions

Condition G

"Given that the wipers are on the left stalk, how would you turn the wipers on?"

(N = 50)



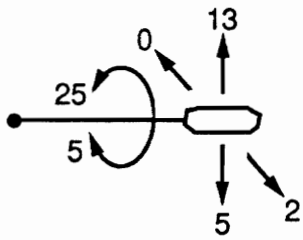
$\hat{p} = 25/50 = 0.50$

Grade = C

Condition H

"Given that the wipers are on the right stalk, how would you turn the wipers on?"

(N = 50)

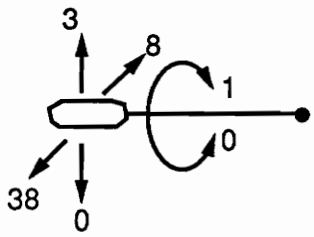


$\hat{p} = 25/50 = 0.50$

Grade = C

Condition I

"Given that headlight high beams are on the left stalk, how would you turn the high beams on?" (N = 50)



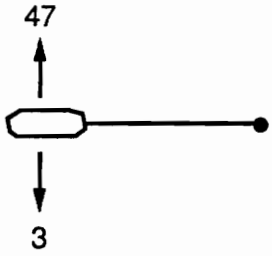
$\hat{p} = 38/50 = 0.76$

Grade = B

Specific Constrained Conditions

Condition J

"Given that the wipers are on the left stalk, and that they are turned on by raising or lowering the stalk, please turn the wipers on." (N =50)

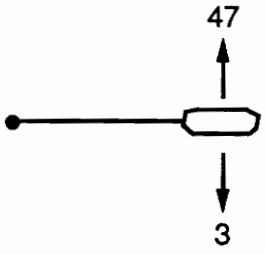


$\hat{p} = 47/50 = 0.94$

Grade = A

Condition K

"Given that the wipers are on the right stalk, and that they are turned on by raising or lowering the stalk, please turn the wipers on." (N =50)

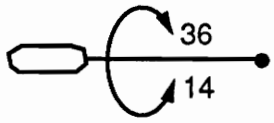


$\hat{p} = 47/50 = 0.94$

Grade = A

Condition L

"Given that the wipers are on the left stalk, and that they are turned on by rotating the barrel, please turn the wipers on." (N = 50)

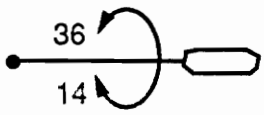


$\hat{p} = 36/50 = 0.72$

Grade = B

Condition M

"Given that the wipers are on the right stalk, and that they are turned on by rotating the barrel, please turn the wipers on." (N = 50)

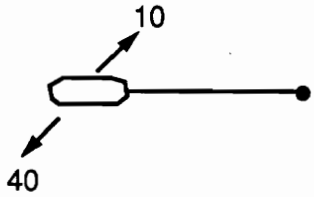


$\hat{p} = 36/50 = 0.72$

Grade = B

Condition N

"Given that the headlight high beams are on the left stalk, and that they are turned on by pushing the stalk away from you, or pulling it towards you, please turn on the high beams." (N = 50)

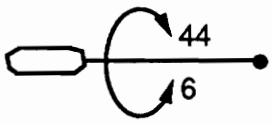


$\hat{p} = 40/50 = 0.80$

Grade = B

Condition O

"Given that the headlight ON/OFF switch is on the left stalk, and that the headlights are turned on by rotating the barrel, please turn on the headlights." (N = 50)



$\hat{p}$ = 44/50 = 0.88

Grade = A

Study 5 — Generic Controls

Thumbwheel: For each thumbwheel condition, subjects were instructed to increase something with the thumbwheel. Five of the conditions had the thumbwheel located on the instrument panel left of the steering wheel. The other five conditions were situated on the right instrument panel. Vantage point is always that of the driver.

Left Instrument Panel

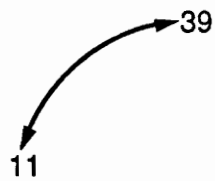
Condition A — Top orientation

(N = 50)

$\hat{p}$ = 43/50 = 0.86

Grade = A

Condition C — Top orientation



(N = 50)

$\hat{p}$ = 39/50 = 0.78

Grade = B

Condition E — Front orientation

(N = 50)

$\hat{p}$ = 39/50 = 0.78

Grade = B

Condition G — Front orientation

(N = 50)

$\hat{p}$ = 48/50 = 0.96

Grade = A

Condition I — Left orientation, outside of Instrument Panel

(N = 50)

$\hat{p}$ = 46/50 = 0.92

Grade = A

Right Instrument Panel

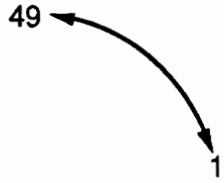
Condition B — Top orientation

(N = 50)

$\hat{p}$ = 45/50 = 0.98

Grade = A

Condition D — Top orientation



(N = 50)

$\hat{p}$ = 49/50 = 0.98

Grade = A

Condition F — Front orientation

(N = 50)

$\hat{p}$ = 46/50 = 0.92

Grade = A

Condition H — Front orientation

(N = 50)

$\hat{p}$ = 47/50 = 0.94

Grade = A

Condition J — Right orientation, outside of Instrument Panel

(N = 50)

$\hat{p}$ = 40/50 = 0.80

Grade = B

Toggle Switch: For each toggle switch condition, subjects were instructed to turn something on with the toggle. Seven of the conditions had the toggle located on the instrument panel left of the steering wheel, seven conditions were also located right of the steering wheel. Two conditions were located on the center console. Vantage point is always that of the driver.

Left Instrument Panel

Condition A — Top orientation

14 ⟷ 36 (N = 50)

$\hat{p} = 36/50 = 0.72$

Grade = B

Condition C — Top orientation

40

10 (N = 50)

$\hat{p} = 40/50 = 0.80$

Grade = B

Condition E — Front orientation

11 ⟷ 39 (N = 50)

$\hat{p} = 39/50 = 0.78$

Grade = B

Condition G — Top orientation

48

↕ (N = 50)

2

$\hat{p} = 48/50 = 0.96$

Grade = A

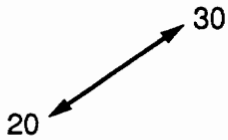
Condition I — Right orientation, Inside of Instrument Panel

(N = 50)

$\hat{p} = 49/50 = 0.98$

Grade = A

Condition K — Left orientation, Outside of Instrument Panel



(N = 50)

$\hat{p} = 30/50 = 0.60$

Grade = C

Condition L — Left orientation, Outside of Instrument Panel

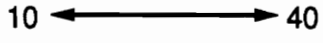
(N = 50)

$\hat{p} = 48/50 = 0.96$

Grade = A

Right Instrument Panel

Condition B — Top orientation



(N = 50)

$\hat{p} = 40/50 = 0.80$

Grade = B

Condition D — Top orientation

(N = 50)

$\hat{p} = 40/50 = 0.80$

Grade = B

Condition F — Front orientation

16 ⟷ 34 (N = 50)

$\hat{p} = 34/50 = 0.68$

Grade = B

Condition H — Front orientation' b

49

↕ (N = 50)

1

$\hat{p} = 49/50 = 0.98$

Grade = A

Condition J — Right orientation, Outside of Instrument Panel

46

↕ (N = 50)

4

$\hat{p} = 46/50 = 0.92$

Grade = A

Condition N — Right orientation, Outside of Instrument Panel

33 ↖↘ 17 (N = 50)

$\hat{p} = 33/50 = 0.66$

Grade = C

Condition M — Left orientation, Inside of Instrument Panel

47

↕ (N = 50)

3

$\hat{p} = 47/50 = 0.94$

Grade = A

Center Console

Condition O — Top orientation

(N = 50)

$\hat{p}$ = 44/50 = 0.88

Grade = A

Condition P — Top orientation

(N = 50)

$\hat{p}$ = 36/50 = 0.72

Grade = B

Slide Control: For each slide control condition subjects were instructed to increase something with the slide. Twelve conditions were located on the instrument panel, six on the left and six on the right. One condition was located on the center console. Vantage point is always that of the driver.

Left Instrument Panel

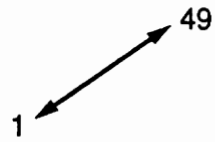
Condition A — Top orientation

(N = 50)

$\hat{p}$ = 41/50 = 0.82

Grade = B

Condition C — Top orientation



(N = 50)

$\hat{p}$ = 49/50 = 0.98

Grade = A

Condition E — Front orientation

12 ⟷ 38 (N = 50) $\hat{p} = 38/50 = 0.76$

Grade = B

Condition G — Front orientation

49 ↕ 1 (N = 50) $\hat{p} = 49/50 = 0.98$

Grade = A

Condition I — Left orientation, Outside of Instrument Panel

48 ↕ 2 (N = 50) $\hat{p} = 48/50 = 0.96$

Grade = A

Condition K — Right orientation, Inside of Instrument Panel

46 ↕ 4 (N = 50) $\hat{p} = 46/50 = 0.92$

Grade = A

Right Instrument Panel

Condition B — Top orientation

10 ⟷ 40 (N = 50) $\hat{p} = 40/50 = 0.80$

Grade = B

Condition D — Top orientation

47 ↔ 3 (N = 50) $\hat{p} = 47/50 = 0.94$

Grade = A

Condition F — Front orientation

2 ↔ 48 (N = 50) $\hat{p} = 48/50 = 0.96$

Grade = A

Condition H — Front orientation

46 ↕ 4 (N = 50) $\hat{p} = 46/50 = 0.92$

Grade = A

Condition J — Left orientation, Inside of Instrument Panel

47 ↕ 3 (N = 50) $\hat{p} = 47/50 = 0.94$

Grade = A

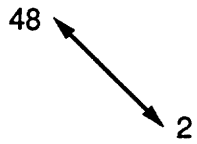
Condition L — Right orientation, Outside of Instrument Panel

48 ↕ 2 (N = 50) $\hat{p} = 48/50 = 0.96$

Grade = A

Center Console

Condition M — Top orientation



(N = 50)

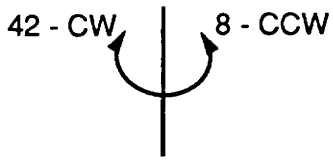
$\hat{p}$ = 48/50 = 0.96

Grade = A

Rotary Control: For each rotary control condition subjects were instructed to increase something with the rotary knob. Six conditions were examined, three on the left instrument panel and three on the right. Vantage point is always that of the driver.

Left Instrument Panel

Condition A — Top orientation

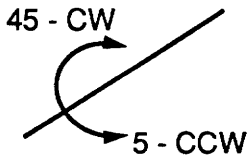


(N = 50)

$\hat{p}$ = 42/50 = 0.84

Grade = B

Condition C — Front orientation

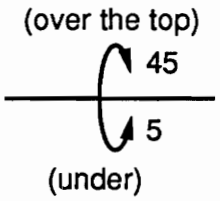


(N = 50)

$\hat{p}$ = 45/50 = 0.90

Grade = A

Condition E — Left orientation, Outside of Instrument Panel



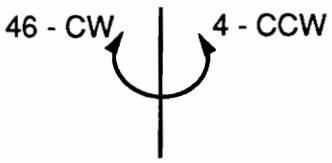
(N = 50)

$\hat{p} = 45/50 = 0.90$

Grade = A

Right Instrument Panel

Condition B — Top orientation

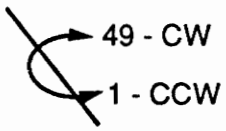


(N = 50)

$\hat{p} = 46/50 = 0.92$

Grade = A

Condition D — Front orientation

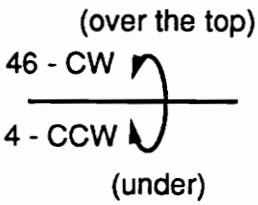


(N = 50)

$\hat{p} = 49/50 = 0.98$

Grade = A

Condition F — Right orientation, Outside of Instrument Panel



(N = 50)

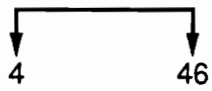
$\hat{p} = 46/50 = 0.92$

Grade = A

Rocker Switch: For each rocker switch condition, subjects were instructed to turn something on with the rocker. Six of the conditions had the rocker located on the left instrument panel, six conditions had it located on the right instrument panel. Four conditions were located on the center console. Vantage point is always that of the driver.

Left Instrument Panel

Condition A — Top orientation

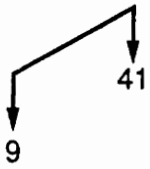


(N = 50)

$\hat{p}$ = 46/50 = 0.92

Grade = A

Condition C — Top orientation



(N = 50)

$\hat{p}$ = 41/50 = 0.82

Grade = B

Condition E — Front orientation

(N = 50)

$\hat{p}$ = 35/50 = 0.70

Grade = C

Condition G — Front orientation

(N = 50)

$\hat{p}$ = 46/50 = 0.92

Grade = A

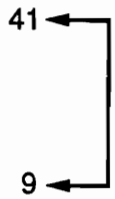
Condition I — Left orientation, Outside of Instrument Panel

(N = 50)

$\hat{p}$ = 46/50 = 0.92

Grade = A

Condition K — Right orientation, Inside of Instrument Panel



(N = 50)

$\hat{p}$ = 41/50 = 0.82

Grade = B

Right Instrument Panel

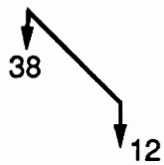
Condition B — Top orientation

(N = 50)

$\hat{p}$ = 38/50 = 0.76

Grade = B

Condition D — Top orientation



(N = 50)

$\hat{p}$ = 38/50 = 0.76

Grade = B

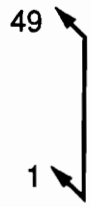
Condition F — Front orientation

(N = 50)

$\hat{p}$ = 38/50 = 0.76

Grade = B

Condition H — Front orientation



(N = 50)

$\hat{p}$ = 49/50 = 0.98

Grade = A

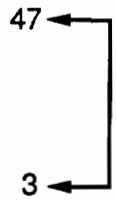
Condition J — Left orientation, Inside of Instrument Panel

(N = 50)

$\hat{p}$ = 49/50 = 0.98

Grade = A

Condition L — Right orientation, Outside of Instrument Panel



(N = 50)

$\hat{p}$ = 47/50 = 0.94

Grade = A

Center Console

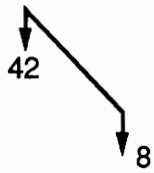
Condition M — Top orientation

(N = 50)

$\hat{p}$ = 48/50 = 0.96

Grade = A

Condition N — Top orientation



(N = 50)

$\hat{p} = 42/50 = 0.84$

Grade = B

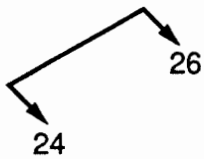
Condition O — Top orientation, -45° tilt

(N = 50)

$\hat{p} = 37/50 = 0.74$

Grade = B

Condition P — Top orientation, -45° tilt



(N = 50)

$\hat{p} = 26/50 = 0.52$

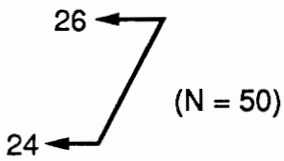
Grade = C

Study 6 — Power Door Locks

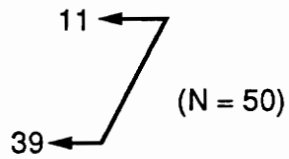
Condition A

Rocker switch on carrier plate mounted flush on driver's door panel (X-Z plane). Switch has fore/aft movement.

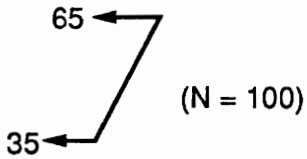
"Lock the Doors"



"Unlock the Doors"



"$\left\{\begin{matrix}\text{Lock}\\ \text{Unlock}\end{matrix}\right\}$ the doors," with "unlock" values transformed to "lock" values by reflection to opposite half of switch.



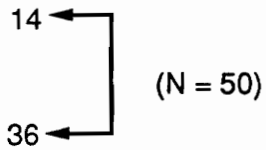
$\hat{p} = 65/100 = 0.65$

Grade = C

Condition B

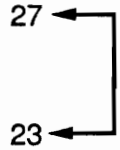
Rocker switch on carrier plate mounted flush on driver's door panel (X-Z plane). Switch has up/down movement.

"Lock the Doors"



(N = 50)

"Unlock the Doors"



(N = 50)

"$\left\{\begin{matrix}\text{Lock}\\ \text{Unlock}\end{matrix}\right\}$ the doors," with "unlock" values transformed to "lock" values by reflection to opposite half of switch.

(N = 100)

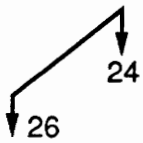
$\hat{p} = 63/100 = 0.63$

Grade = C

Condition C

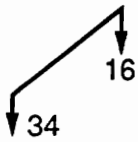
Rocker switch in control cube extending from driver's door panel in a horizontal (X-Y) plane. Switch has fore/aft movement.

"Lock the Doors"



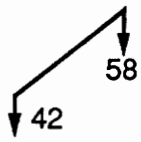
(N = 50)

"Unlock the Doors"



(N = 50)

"$\left\{\begin{matrix}\text{Lock}\\ \text{Unlock}\end{matrix}\right\}$ the doors," with "unlock" values transformed to "lock" values by reflection to opposite half of switch.



(N = 100)

$\hat{p} = 58/100 = 0.58$

Grade = C

Condition D

Rocker switch in control cube extending from driver's door panel in a horizontal (X-Y) plane. Switch has right/left movement.

Condition C

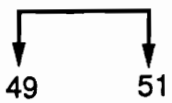
"Lock the Doors"

(N = 50)

"Unlock the Doors"

(N = 50)

"$\left\{\begin{matrix}\text{Lock}\\ \text{Unlock}\end{matrix}\right\}$ the doors," with "unlock" values transformed to "lock" values by reflection to opposite half of switch.



(N = 100)

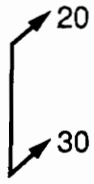
$\hat{p} = 51/100 = 0.51$

Grade = C

Condition E

Rocker switch in control cube extending from driver's door panel in a vertical (Y-Z) plane. Switch has up/down movement.

"Lock the Doors"

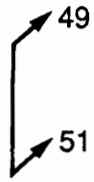


(N = 50)

"Unlock the Doors"

(N = 50)

"$\left\{\begin{matrix}\text{Lock}\\ \text{Unlock}\end{matrix}\right\}$ the doors," with "unlock" values transformed to "lock" values by reflection to opposite half of switch.



(N = 100)

$\hat{p} = 51/100 = 0.51$

Grade = C

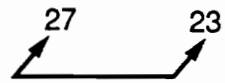
Condition F

Rocker switch in control cube extending from driver's door panel in a vertical (Y-Z) plane. Switch has right/left movement.

"Lock the Doors"

(N = 50)

"Unlock the Doors"



(N = 50)

"$\left\{\begin{matrix}\text{Lock}\\ \text{Unlock}\end{matrix}\right\}$ the doors," with "unlock" values transformed to "lock" values by reflection to opposite half of switch.

(N = 100)

$\hat{p} = 64/100 = 0.64$

Grade = C

STATISTICAL TESTS FOR AGE, TYPE OF CAR DRIVEN, GENDER, AND HANDEDNESS

The results in the previous section summarized the frequencies of occurrence for preferred direction in each of the 170 control conditions. The data can also be used to determine if differences exist in subject responses due to age, type of vehicle driven, gender, and handedness. This determination is conducted by testing the hypothesis that two groups differ with respect to some characteristic. In this case the two groups are either younger or older participants, domestic car drivers or foreign car drivers, males or females, or right-handers or left-handers. The characteristic from which differences are measured is the preferred control activation direction chosen by subjects.

Since the level of measurement of the data is in number of occurrences, non-parametric measures should be used in the analysis (Siegel and Castellan, 1988). The Chi-square test is the most appropriate nonparametric test for such data. There were four groups of interest and 170 conditions, resulting in $4 \times 170 = 680$ Chi-square statistics to be calculated. Of the 680, only 11 were significant at p values less than 0.05. The 11 significant conditions and associated p values are presented in this section.

Significant Age Differences for Directional Stereotypes

Generic Control Study — Rocker Switch

Condition C — Control cube mounted on left instrument panel with top orientation. Switch has fore-aft movement. Subject is asked to turn something on.

	Older	Younger	
Aft	8	1	9
Fore	17	24	41
	25	25	50

$p < 0.05$

Generic Control Study — Toggle Switch

Condition P — Toggle switch on carrier plate mounted horizontally on center console. Switch has left-right movement. Subject is asked to turn something on.

	Older	Younger	
Left	12	2	14
Right	13	23	36
	25	25	50

$p < 0.01$

Power Door Lock Study

Condition E — Rocker switch in control cube, cube facing rear of buck. Switch has up-down movement. Subject is asked to $\left\{ \frac{\text{lock}}{\text{unlock}} \right\}$ doors. "Unlock" values have been transformed to "lock" values by reflection to opposite half of switch.

	Older	Younger	
Up	32	17	49
Down	18	33	51
	50	50	100

$p < 0.01$

Significant Vehicle Type Differences for Directional Stereotypes

Power Window Study

Condition J — Push-pull control extending from driver's door panel in a horizontal plane. Subject is asked to $\left\{\frac{\text{raise}}{\text{lower}}\right\}$ window. "Lower" values transformed to "raise" values by reflection to opposite half of switch.

	Domestic	Foreign	
Pull	31	6	37
Push	5	8	13
	36	14	50

$p < 0.01$

Stalk Control Study

Condition B — "Using the **right** stalk, raise or lower the stalk to turn something on."

	Domestic	Foreign	
Lower	5	7	12
Raise	31	7	38
	36	14	50

$p < 0.05$

Condition G — "Given that the windshield wipers are on the **left** stalk, turn the wipers on."

	Domestic	Foreign	
Counter-clockwise	19	6	25
Clockwise	6	0	6
Lower	1	6	7
Raise	10	2	12
	36	14	50

$p < 0.001$

Condition I — "Given that the high beams are on the **left** stalk, turn on the high beams."

	Domestic	Foreign	
Counter-clockwise	1	0	1
Pull	32	6	38
Push	1	7	8
Raise	2	1	3
	36	14	50

$p < 0.001$

Condition M — "Given that the windshield wipers are on the **right** stalk, and that they are turned on by rotating the barrel, turn the wipers on."

	Domestic	Foreign	
Counter-clockwise	14	0	14
Clockwise	22	14	36
	36	14	50

$p < 0.02$

Power Door Lock Study

Condition D — Rocker switch in control cube, cube facing top. Switch has right-left movement. Subject is asked to $\left\{\frac{\text{lock}}{\text{unlock}}\right\}$ doors. "Unlock" values have been transformed to "lock" values by reflection to opposite half of switch.

	Domestic	Foreign	
Left	41	8	49
Right	31	20	51
	72	28	100

$p < 0.05$

Significant Gender Differences for Directional Stereotypes

Power Door Lock Study

Condition A — Rocker switch on carrier plate mounted flush with driver's door panel. Switch has up-down movement. Subject is asked to $\left\{\frac{\text{lock}}{\text{unlock}}\right\}$ doors. "Unlock" values have been transformed to "lock" values by reflection to opposite half of switch.

	Females	Males	
Up	26	11	37
Down	24	39	63
	50	50	100

$p < 0.01$

Significant Handedness Differences for Directional Stereotypes

Generic Control Study — Rocker Switch

Condition E — Control cube mounted on left instrument panel with front orientation. Switch has right-left movement. Subject is asked to turn something on.

	Left-Hand	Right-Hand	
Left	3	12	15
Right	0	35	35
	3	47	50

$p < 0.05$

DISCUSSION

Responses for 170 conditions were graded for strength of directional stereotype. There were 93 conditions, or 54.7% of the sample, that had response grades of A. There were 43 conditions (25.3%) with B grades, and 34 conditions (20%) with C grades.

Power Mirrors

Response proportions for every command in Conditions A, B, C, and J produced A grades, indicating strong directional stereotypes. This is most likely due to the similar control and display reference planes. For each of these conditions, the control, whether a pad switch or joystick, extended in a vertical manner from the driver's door panel. For Conditions A and J the control extended in a vertical plane perpendicular to the door panel. For Conditions B and C the pad switch was angled, relative to the y axis, away from the driver 30° and 60°, respectively. In these four conditions possible directions for control activation were classified as up, down, right, or left. A high degree of compatibility existed, because the display, in this case the mirror, was configured on approximately the same plane as the controls. For example, if the command called for downward mirror movement, subjects were likely to activate the portion of the control closest to the bottom. This resulted in strong directional stereotypes.

Three conditions existed in which the control plane was horizontal. The pad switch in Condition D and the joystick in Condition I both extended from the door panel in a horizontal plane, while the pad switch in Condition F was mounted horizontally on the center console. Hence, the possible directions for control activation were fore, aft, right, or left. Although the control planes (horizontal) and display plane (vertical) were not

compatible, 12 of the 14 grades were A. The other two grades were B, and these occurred in the responses for up and down mirror movements in Condition D. In general, subjects had strong association of forward control activation with upward mirror movement and aft activation with downward mirror movement. As one might expect, the lateral mirror movements of right and left exhibited strong directional stereotypes because the controls could actually be activated right or left.

Conditions E and H used a pad switch and joystick, respectively, mounted flush with the driver's door panel. Possible control activation directions were up, down, fore, and aft. Results from these conditions indicated stronger directional stereotypes for the joystick than for the pad switch. The joystick had three grades of A and one grade of B. The B grade occurred for left mirror movement (away from the subject). The pad switch on the other hand, had only one A grade, two B grades, and one C grade. The most confusion occurred for lateral mirror movements. Perhaps the subjects performed more consistently with the joystick, because many cars that do not have power mirror controls have manual joysticks. The familiarity may have resulted in more consistent responses.

Condition G used a pad switch mounted on the center console angled *away* from the driver, 45° below the horizontal. Perhaps the best way to classify potential control movements is fore/down, aft/up, right, and left. The directional stereotype grades for lateral mirror movements were both graded as A, as subjects consistently activated the portion of the pad switch on the right or left. Responses for both up and down mirror movements were graded as C. The control was angled below the horizontal resulting in inconsistent responses for up and down commands.

Power Windows

In discussing the results for power windows two factors must be considered. Since participants were instructed to raise or lower specific windows in the vehicle both the direction of control activation *and* the control selected for activation are important.

In terms of *direction*, all conditions exhibited strong stereotypes (A grades) except Conditions D, H, J, and K. Conditions D and H incorporated a 2 × 2 toggle switch array and a 2 × 2 rocker switch array, respectively. Both conditions extended from the driver's door panel, and were angled *away* from the driver 30° below the horizontal plane. Potential responses for each switch could therefore be classified as fore activation (portion of switch farthest from subject) and aft activation (portion closest to subject). When "lower" commands were transformed by reflection to the "raise" commands, the results showed that subject responses were quite inconsistent on choice of direction (three B's, five C's). These conditions, similar to Condition G for power mirrors, had an angle below the horizontal, which had an adverse affect on subject to subject consistency. Conditions J and K both utilized a 2 × 2 push-pull switch array extending from the driver's door panel. Condition J was mounted in a horizontal plane, while Condition K was angled 45° towards the driver. Response classification was either push or pull for both conditions. The results for raising the windows for these conditions showed five B grades and three C grades. The inconsistencies that resulted for these conditions may be due to the fact that the push-pull switch is a relatively new control design. Although a strong geometric correspondence between the push-pull switch and the windows appears to be present, most subjects probably had not been exposed to this type of control previously. It must be pointed out that although directional problems were

associated with Conditions D, H, J, and K subjects were consistent in their choice of control for activation.

In analyzing control *selection* by far the most, and really only, variability occurred for Condition I and Condition E. Condition I used a 1 × 4 lateral toggle array mounted flush with the driver's door panel. The highest degree of selection consistency occurred for the raise driver side front window condition, in which 39 of the 50 participants chose the same control. The lowest degree of consistency occurred for the raise driver side rear window, in which only 19 of the participants selected the same control. Condition E used a 2 × 2 toggle array mounted flush with the driver side door panel. Selection results showed 25 of 50 participants to be consistent in their selection of each of the rear window conditions, and 29 of 50 participants consistent for each of the front window conditions. In the case of Conditions I and E, where selection was an obvious problem, direction of activation was clearly not because *every* participant preferred the same direction.

Manual Windows

The strength of the directional stereotypes for three of the four manual window conditions was weak. Both handle positions, facing front and facing rear, on the driver's side and handle facing rear on the passenger's side had grades of C. The only A grade directional stereotype occurred for the passenger side crank facing forward. Inconsistencies are probably due to the fact that the directions of rotation for the handle during "window raise" and "window lower" are not the same in all automobiles. In addition,

some subjects may have been out of the practice in using manual window cranks, because their primary vehicles were equipped with power windows.

Stalk Controls

For the 15 stalk conditions, five had directional stereotype grades of A, eight had grades of B, and two had grades of C.

Nonspecific Conditions. When instructed to move the stalk in one of two directions to turn something on, participants generally adhered to control movement stereotypes already established. Subjects perceived that raising the stalk, pulling the stalk, and rotating the barrel of the stalk over the top would each accomplish the task of turning something on. This held true for both the right and left stalks. The only A grades occurred in Condition A, where the left stalk was raised for "on," and Condition F, where the barrel of the right stalk was rotated over the top for "on." The rest of the conditions had B grades.

Specific Unconstrained Conditions. When subjects had the freedom to choose the method of control activation for a function, the strengths of the directional stereotypes appeared to weaken. When asked to activate the wipers, subjects preferred rotating the barrel over the top for both the left and right stalks; nevertheless, C grades resulted. To turn on the high beams using the left stalk, most subjects pulled on the stalk, yet the grade was still only a B. It is highly likely the participants were influenced by their own automobiles, which as the survey in Appendix A shows, varied a great deal from car to car.

Specific Constrained Conditions. The strength of stalk directional stereotypes was strongest when subjects were given a specific function and instructed on the

method of operation. Perhaps this is because over the years many subjects have been exposed to the variety of activation methods, and they simply respond in a manner they have witnessed or experienced before. In addition, the fact that response choices were reduced to a binary choice for specific constrained conditions probably strengthened subject expectancies. When instructed that the wipers were activated by raising or lowering the stalk, subjects had strong preferences (A grades) for raising, for both the left and right stalks. An additional A grade occurred when 44 of 50 participants rotated the left barrel over the top to turn on the headlights. The three other conditions in this phase of the stalk study resulted in B grades.

Generic Controls

There were 61 conditions used in the generic control phase of the research. For all configurations, control movement was either up/down, right/left, fore/aft, or clockwise/counter-clockwise. In each case subjects were instructed to either increase a function or to turn something on. In general, subjects conformed to the recommended control movements outlined in Figures 1 and 2. Of the 61 conditions, 36 were graded as A, 20 as B, and 5 as C. Only those five conditions with weak directional stereotypes will be discussed to prevent a lengthy and unnecessary discussion. The reader is referred to the RESULTS section if more detailed information is desired on a specific generic control configuration.

Three of the five C grades occurred for conditions using the toggle switch. Condition K had the toggle mounted on the left instrument panel facing left (towards the outside), with switch movement of fore/aft. Responses showed 30 of 50 subjects activating the switch forward to turn something on, while 20 activated towards the back

(aft). Condition N is the mirror image of Condition K, and it too had a weak stereotype. In Condition N the toggle is mounted on the right instrument panel facing right (towards the outside), with switch movement of fore/aft. This situation resulted in 33 forward activations and 17 aft movements. Perhaps these two conditions have weak stereotypes because the control is difficult, if not impossible, to see since it faces the outside of the vehicle. Hence subject behavior is affected. Also, the design of the toggle makes it easy to simply place a finger behind it, and pull the toggle towards oneself. In Condition F, the toggle is mounted on the right instrument panel facing front, or towards the driver, with right/left movement. Of the 50 subjects, 34 activated the switch to the right, and 14 to the left. In an automotive environment perhaps some research participants may have associated movement towards the center of the control system (steering column) with an on or increase function. For Condition F this would be a movement to the left, contradicting recommended right control movement, and resulting in a weak stereotype.

The two remaining C grades occurred for conditions utilizing the rocker switch. One was for Condition E in which the rocker was mounted on the left instrument panel facing front, with right/left movement. Movements to the right were carried out by 35 subjects, and left movements by 15. For Condition F above, with the toggle switch, it was hypothesized that some subjects may have associated movement towards the center of the control system with an "on" or "increase" function. However, in the case of rocker switch Condition E, 15 participants obviously associated movement towards the outside, or away from the control system, with turning something on. The other weak stereotype for rocker switches occurred in Condition P. For this condition the rocker

switch was mounted on a flat carrier plate and affixed to the center console angled *away* from the driver 45° below the horizontal. Movements toward the rear (aft/up) were executed by 26 subjects and movements towards the front (fore/down) by 24. Previous results for power mirror and power window controls showed inconsistencies when the control was angled away from the driver. Therefore, it is not surprising to see a weak directional stereotype for the rocker switch configuration in Condition P.

Power Door Locks

The weakest stereotype, by far, occurred for the power door lock configurations. The strength of the directional stereotype for all six conditions was classified as C. A possible explanation is in how people associate "lock" and "unlock" with "on" and "off."

If one thinks of the traditional "post" locks which are locked by manually pushing them down and the more generic concept in which a switch would normally be pushed up, forward, or right to turn something on, a conflict arises. Words such as "locking" and "braking" create discrepancies because they are positive words for negative concepts, that is, denial of entry and deceleration. Thus, some people probably classified the lock function as "on" while others felt it was more like "off."

Another explanation is that many people use the power door lock to lock the doors of the car once they have exited the vehicle, and are getting ready to shut the door. This point is raised because during the experimental session the commands were issued while the subject was seated in the buck. Perhaps this procedure distorted some subjects' perspective, resulting in weaker stereotypes.

Chi-Square Analysis

Of the 680 Chi-square tests conducted, 11 were significant. The minimum criterion used to judge significance was a value of $p < 0.05$. The distribution of p values for the 11 significant conditions were as follows: four at $p < 0.05$, one at $p < 0.02$, four at $p < 0.01$, and two at $p < 0.001$. In some instances it was relatively easy to determine a specific cause or attribute that may have affected participant behavior. In certain other cases, however, because so many statistical tests were conducted, it can be hypothesized that certain conditions were significant purely by chance.

Age Differences. Two generic control conditions and one power door lock condition showed significant age differences. One of the generic configurations, Condition C for the rocker switch, had the rocker switch mounted on the left instrument panel facing up, with fore-aft movement. The most obvious disagreement in preferred control direction occurred for the number of participants choosing aft actuation of the switch. Eight of the subjects in the older category preferred aft movement, while only one in the younger category preferred aft. Aft movement is opposite of the recommendations dictated by human factors principles.

The other significant generic configuration due to age occurred for the toggle switch in Condition P. In this condition the toggle was mounted on a flat carrier plate and affixed to the center console with left-right switch movement. Again, more older subjects than younger subjects preferred control movement opposite of recommended motion. Nearly half (12) of the older group activated the toggle to the left while only two in the younger group chose this direction. Over the years it is likely that subjects in the older age category have been exposed to a greater variety of control configurations both

in and out of automobiles. Perhaps this exposure led to different expectations for the older subjects, thus resulting in weaker stereotypes for the rocker in Condition C and the toggle in Condition P.

Condition E in the power door lock study was also significant due to the effects of age. For Condition E, the rocker switch was in a control cube facing the driver with up-down switch movement. To lock the doors 32 of the older participants preferred *up* activation, while 33 of the younger group preferred *down* activation. This distribution illustrates just how weak the directional stereotype was. For this condition, it was obvious that the subjects in the younger and older categories had a distinct difference in their association of the "lock" function with a corresponding activation direction.

Vehicle Differences. Results showed that the type of vehicle a subject drove had a significant effect on behavior for six conditions. The only power window configuration found significant was the command to raise the passenger side rear window in Condition J. This configuration utilized the push-pull control mounted in a horizontal plane extending from the driver door panel. While 31 of 36 domestic car drivers pulled the switch for activation, only 6 of 14 foreign car drivers preferred pull movement. The effect of chance is the likely explanation since none of the results for the other three windows in Condition J were found to be significant.

The position for the power door lock in Condition D was also significant due to vehicle type. For this configuration the rocker switch in the control cube was facing up with right-left switch alignment. Left side activation was preferred by 41 of 72 domestic car drivers and by 8 of 28 foreign car drivers. This significance could be attributed to

different designs between domestic and foreign car manufacturers, and also to the mental reasoning associated with the lock function that was discussed earlier.

The remaining four conditions significant due to type of vehicle driven occurred for commands in which stalk controls were operated. In Condition B subjects were instructed to raise or lower the right stalk to turn something on. For domestic car drivers 31 of 36 raised the stalk, however, only 7 of 14 foreign car drivers preferred raise movement. In domestic vehicles some wipers are activated by raising the stalk, while in many foreign vehicles wipers are activated by lowering the stalk. This affiliation with the operational mode of the wipers may have influenced how the drivers perceived "on" for this condition.

In Condition G subjects were asked how they would activate the wipers using the left stalk. Domestic car drivers preferred stalk rotation over the top and raised stalk movements. Foreign car drivers were also partial to rotation over the top, but preferred lowering the stalk rather than raising it. Again, the fact that stalks are employed differently in domestic and foreign cars probably resulted in a transfer of previous learning. This appears to be a reliable result because the level of significance was $p < 0.001$.

In Condition I participants were asked how they would activate the high beams using the left stalk. Those who operated domestic vehicles overwhelmingly pulled the stalk. Foreign car drivers were about evenly split on pulling or pushing the stalk. Since the design that incorporates pushing the left stalk for high beam activation is used almost exclusively by foreign car manufacturers, the transfer effects of previous learning

are again the obvious explanation for subject behavior. Like Condition G, Condition I was significant at $p < 0.001$.

The last significant stalk function occurred for Condition M, in which subjects were asked to turn on the wipers by rotating the right stalk. Most of the drivers, both domestic and foreign car, rotated the barrel over the top for activation. However, 14 of 36 domestic car drivers rotated the barrel under the bottom. Significance again is probably due to the fact that stalk designs vary from car to car.

Gender Differences. Condition A in the power door lock study was the only significant condition due to gender differences. The rocker switch was mounted on a carrier plate and configured flush with the driver door panel. Switch movement was up-down. For locking the door 39 of 50 males actuated the switch downward, while only 24 of 50 females preferred this motion. Condition A is another example of the confusion power door locks present to many drivers.

Handedness Differences. The only condition for which handedness significantly affected behavior occurred for the generic rocker switch in Condition E. For this configuration the rocker was mounted facing front on the left instrument panel. The switch had right-left movement. Out of the 50 subjects exposed to Condition E only three were left-handed. However, all three preferred actuating the left portion of the switch, their dominant side. Most right-handed subjects (35 of 47) chose the right portion for actuation. Although this condition was significant it is difficult to critique the design because of the handedness distribution. More left-handers would be needed in the analysis to be more certain there is an effect due to handedness.

CONCLUSIONS

The results of the research indicate that directional stereotypes in an automotive environment are very similar to the recommended control movements outlined in existing literature. Certain control designs and configurations, however, did cause inconsistencies in subject behavior.

Power Mirrors

Most of the conditions tested for power mirror controls displayed strong directional stereotypes. When a control extended from the driver's door in a vertical plane there was always strong compatibility between control and display. This compatibility existed for both joystick and pad switch controls. The designs incorporated in Conditions A, B, C, and J are therefore all recommended for power mirror controls.

When a control was mounted in a vertical plane *flush* with the driver's door, stereotypes were moderately strong for the pad switch control and strong for the joystick. The joystick (Condition H) is recommended over the pad switch (Condition E) if the control is configured flush on the door. Nevertheless, the pad switch configuration responses for Condition E were by no means inconsistent to the point that the design is considered inappropriate.

As far as controls mounted in a horizontal plane, no serious problems appeared during the study. In fact, even though the control plane (horizontal) and display plane (vertical) were not compatible, the pad switch and joystick configuration on the door panel, and the pad switch configuration on the center console had fairly strong directional stereotypes. Thus, controls mounted in a horizontal plane (Conditions D, F, and I) appear to be effective as power mirror controls.

Lastly, the one and only control that was weak directionally speaking was the pad switch mounted on the center console 45° below the horizontal (Condition G). Confusion between up and down mirror movements indicates that this design should not be used.

Power Windows

Three salient points were uncovered during the power window study. First, inconsistencies arose when participants used the push-pull control (Conditions J and K). This result was surprising because a strong geometric relationship was present between control movement and window movement for these two conditions. As stated earlier, subject behavior was probably inconsistent because the push-pull switch is a new design. Although directional stereotypes were weak for the push-pull switch it is recommended that further testing of this design be carried out. As subjects become more familiar with the push-pull control perhaps stereotypes will become stronger.

A second important finding is related to the angle of presentation for those window controls extending from the driver door panel. For the two conditions (D and H) in which a 2 × 2 switch array extended from the driver door and was angled *away* (or down) from the subject, weak directional stereotypes were present. On the other hand, except for the push-pull switch, all conditions configured in the horizontal plane (A and F) or angled *towards* the driver (B, C, and G) had strong directional stereotypes. The results therefore dictate that window controls extending from the door panel should be placed in the horizontal plane or angled towards the driver, not away.

The third prominent result occurred for those conditions (E and I) in which the power window control was mounted flush with the driver door panel. In both cases, a

great deal of variability existed in control selection. In other words, subjects were unsure about which control corresponded to which window. Although direction of activation was not a problem with conditions E and I the designs are not recommended for power window controls due to the high degree of confusion associated with control selection.

Manual Windows

The directional stereotypes for manual window controls were generally weak. A possible solution for strengthening the stereotype is directional standardization. If the direction of rotation for "raise" and "lower" was the same in all automobiles perhaps the stereotype would become stronger over time.

Stalk Controls

It is difficult to outline a list of recommendations for stalk controls because stalk use varies between vehicles. In fact, results from the experiment indicate that preferred direction discrepancies existed between domestic car drivers and foreign car drivers. A general observation is that most domestic car drivers prefer stalk movements of raising over lowering and pulling over pushing to turn on a function. About half of the foreign car drivers prefer stalk movements of lowering over raising and pushing over pulling to turn something on. The majority of both domestic and foreign car drivers do agree, however, that rotation of a stalk over the top is the correct direction for "on" activation. In allocating stalk functions and control movement, designers should consider the type of vehicle before any decision is made. Drivers will likely have preconceptions on stalk use based on the type of the vehicle, that is, traditionally foreign or traditionally domestic.

Generic Controls

For the most part the preferred movement for generic controls resulted in stereotypes which closely matched those found in the human factors literature: "on" or "increase" corresponded to movements to the right, up, forward, or clockwise. For those cases in which there was a conflict between clockwise and forward, subjects chose forward, that is, over the top.

Conditions K and N for the toggle switch both faced the outside and resulted in weak stereotypes. These controls were placed in such a way that they were difficult to see. This is something designers may want to keep in mind. If a control does have to face the outside or away from the subject, it is important that the control can still be seen so the driver knows the movement capabilities.

Power Door Locks

Every condition tested in the power door lock study resulted in a weak stereotype. It is recommended that power door lock controls be studied in greater detail. Only rocker switches were used in the present study. Other types of controls should be used in future studies.

Recommendations

In a proposed control layout designers are advised to select those configurations found in the research to have moderate to strong stereotypes. These designs have been shown through empirical measures to produce the least amount of confusion. However, if a new design evolves with no previous data, then attributes of this design should be compared to attributes of designs already evaluated. Will attributes such as the plane in which the control is mounted, type of control, or control location affect how

drivers use the new design? It must also be kept in mind during development that designs are situation specific. For example, guidelines that are appropriate for power mirrors may be different for power windows.

Further Research

As mentioned above, power door lock controls must be investigated further. In addition, several subjects volunteered complaints about cruise controls and power seat controls.

Use of an interview approach would be an appropriate starting point for all three of the above proposed studies. The physical factors and mental images affecting users of cruise, power seat, and door lock controls could then be determined. New designs could then be proposed which minimize difficulties and circumvent conflicts in stereotypes to the maximum extent possible. The newer designs could then be compared with the conventional designs in an experiment evaluating directional stereotypes.

Great care, however, must be taken. The push-pull switches used in the power window study demonstrate that what appears to be good human factors design does not always work out well in practice, at least initially. It is possible that even though the push-pull switch array was demonstrated to the subjects, for the most part their previous lack of exposure to the control did not allow them to surmise the strong geometric relationship between the switch and the windows. If repeated trials are used maybe stereotypes will become stronger as subjects gain familiarity with new designs.

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APPENDIX A: SAMPLE COMMAND SCRIPT USED IN EXPERIMENT

Group #1
Block I

Generic Control: Slide/RIGHT/FRONT/right-left

1. Move the slide control on the right dash to increase something.

Response: Left _____ Right _____

Power Window: Condition A

2. Using the toggle switches on the door panel, move the switch to RAISE/ LOWER the passenger's side rear window.

Response: Fore _____ Aft _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Generic Control: Toggle/LEFT/FRONT/up-down

3. Move the toggle switch on the left dash to turn something on.

Response: Up _____ Down _____

Power Mirror: Condition A RIGHT

4. Using the pad switch on the door panel, press the portion of the switch corresonding to this movement [right].

Response: Up _____ Down _____ Left _____ Right _____

Generic Control: Thumbwheel/LEFT/TOP/right-left

5. Move the thumbwheel on the left dash to increase something.

Response: Left _____ Right _____

Power Window: Condition K

6. Using the push/pull controls on the door panel, move the control to RAISE/ LOWER the passenger's side front window.

Response: Push _____ Pull _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Power Mirror: Condition G RIGHT

7. Using the pad switch on the center console, press the portion of the switch corresonding to this movement [right].

Response: Fore _____ Aft _____ Left _____ Right _____

Generic Control: Rocker/CONSOLE/TOP/right-left

8. Move the rocker switch on the center console to turn something on.

Response: Left _____ Right _____

Generic Control: Rotary/RIGHT/FRONT

9. Move the rotary control on the right dash to increase something.

Response: CW (away from body) _____ CCW (towards body) _____

Power Mirror: Condition I UP

10. Using the joystick on the door panel, move the joystick in a direction corresponding to this movement [up].

Response: Fore _____ Aft _____ Left _____ Right _____

Stalk Control

11. For the right stalk, push or pull on the stalk to turn something on.

Response: Push Pull

Power Window: Condition I

12. Using the toggle switches on the door panel, move the switch to RAISE/LOWER the passenger's side front window.

Response: Control selected:

Up ____ Down ____ 1. ____ 2. ____ 3. ____ 4. ____

Manual Window: Condition A

13. Assuming you are the driver, move the window crank to RAISE your window.

Response: CW (away at the top) _____ CCW (toward at the top) _____

Power Mirror: Condition G LEFT

14. Using the pad switch on the center console, press the portion of the switch corresponding to this movement [left].

Response: Fore _____ Aft _____ Left _____ Right _____

Generic Control: Toggle/RIGHT/LEFT/up-down *Inside

15. Move the toggle switch on the right dash to turn something on.

Response: Up _____ Down _____

Power Window: Condition A

16. Using the toggle switches on the door panel, move the switch to RAISE/LOWER the driver's side rear window.

Response: Fore _____ Aft _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Block II

Generic Control: Rocker/LEFT/LEFT/up-down *Outside

17. Move the rocker switch on the left dash to turn something on.

Response: Up _____ Down _____

Power Mirror: Condition I DOWN

18. Using the joystick on the door panel, move the joystick in a direction corresponding to this movement [down].

Response: Fore _____ Aft _____ Left _____ Right _____

Stalk Control

19. For the left stalk, rotate the barrel of the stalk to turn something on.

Response: CCW (over the top) _____ CW (under the bottom) _____

Power Window: Condition A

20. Using the toggle switches on the door panel, move the switch to RAISE/ LOWER the driver's side front window.

Response: Fore _____ Aft _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Generic Control: Slide/LEFT/TOP/fore-aft *Inside

21. Move the slide control on the left dash to increase something.

Response: Fore _____ Aft _____

Power Mirror: Condition A DOWN

22. Using the pad switch on the door panel, press the portion of the switch corresponding to this movement [down].

Response: Up _____ Down _____ Left _____ Right _____

Generic Control: Thumbwheel/RIGHT/RIGHT/up-down *Outside

23. Move the thumbwheel on the right dash to increase something.

Response: Up _____ Down _____

Power Door Lock: Condition A LOCK

24. Lock the doors.

Response: Up _____ Down _____

Power Window: Condition K

25. Using the push/pull controls on the door panel, move the control to RAISE/ LOWER the passenger's side rear window.

Response: Push _____ Pull _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Generic Control: Rocker/CONSOLE -45°/TOP/fore-aft

26. Move the rocker switch on the center console to turn something on.

Response: Fore _____ Aft _____

Generic Control: Toggle/RIGHT/TOP/right-left *Inside

27. Move the toggle switch on the right dash to turn something on.

Response: Left _____ Right _____

Power Window: Condition I

28. Using the toggle switches on the door panel, move the switch to RAISE/ LOWER the driver's side rear window.

Response: Up ____ Down ____

Control selected: 1. ____ 2. ____ 3. ____ 4. ____

Power Mirror: Condition G UP

29. Using the pad switch on the center console, press the portion of the switch corresponding to this movement [up].

Response: Fore _____ Aft _____ Left _____ Right _____

Manual Window: Condition A Lower

30. Assuming you are the driver, move the window crank to LOWER your window.

Response: CW (away at the top) _____ CCW (toward at the top) _____

Power Mirror: Condition I LEFT

31. Using the joystick on the door panel, move the joystick in a direction corresponding to this movement [left].

Response: Fore _____ Aft _____ Left _____ Right _____

Stalk Control

32. For the left stalk, raise or lower the stalk to turn something on.

Response: Raise _____ Lower _____

Power Window: Condition K

33. Using the push/pull controls on the door panel, move the control to RAISE/ LOWER the driver's side front window.

Response: Push _____ Pull _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Block III

Generic Control: Thumbwheel/RIGHT/TOP/fore-aft

34. Move the thumbwheel on the right dash to increase something.

Response: Fore _____ Aft _____

Power Window: Condition I

35. Using the toggle switches on the door panel, move the switch to RAISE/ LOWER the passenger's side rear window.

Response: Up ____ Down ____

Control selected: 1. ____ 2. ____ 3. ____ 4. ____

Power Mirror: Condition A LEFT

36. Using the pad switch on the door panel, press the portion of the switch corresponding to this movement [left].

Response: Up _____ Down _____ Left _____ Right _____

Generic Control: Toggle/CONSOLE/TOP/fore-aft

37. Move the toggle switch on the center console to turn something on.

Response: Fore _____ Aft _____

Generic Control: Slide/LEFT/LEFT/up-down *Outside

38. Using the pad switch on the door panel, press the portion of the switch corresponding to this movement [up].

Response: Up _____ Down _____ Left _____ Right _____

Power Mirror: Condition A UP

39. Move the slide control on the left dash to increase something.

Response: Up _____ Down _____

Power Window: Condition K

40. Using the push/pull controls on the door panel, move the control to RAISE/ LOWER the driver's side rear window.

Response: Push _____ Pull _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Generic Control: Rocker/RIGHT/FRONT/up-down

41. Move the rocker switch on the right dash to turn something on.

Response: Up _____ Down _____

Power Mirror: Condition G DOWN

42. Using the pad switch on the center console, press the portion of the switch corresponding to this movement [down].

Response: Fore _____ Aft _____ Left _____ Right _____

Power Door Lock: Condition A Unlock

43. Unlock the doors.

Response: Up _____ Down _____

Power Window: Condition A

44. Using the toggle switches on the door panel, move the switch to RAISE/ LOWER the passenger's side front window.

Response: Fore _____ Aft _____

Control selected: 1. _____ 2. _____ 3. _____ 4. _____

Stalk Control

45. Given that the headlights on/off switch is on the left stalk, and that the headlights are turned on by rotating the barrel, turn the headlights on.

Response: CCW (over the top) _____ CW (under the bottom) _____

Power Mirror: Condition I RIGHT

46. Using the joystick on the door panel, move the joystick in a direction corresponding to this movement [right].

Response: Fore _____ Aft _____ Left _____ Right _____

Stalk Control

47. Given that the wipers are on the right stalk, and that they are turned on by raising or lowering the stalk, turn the wipers on.

Response: Raise _____ Lower _____

Power Window: Condition I

48. Using the toggle switches on the door panel, move the switch to RAISE/ LOWER the driver's side front window.

Response:	Control selected:
Up ____ Down ____	1. ____ 2. ____ 3. ____ 4. ____

APPENDIX B:

BACKGROUND INFORMATION, QUESTIONNAIRE, AND INFORMED CONSENT

DRIVER EXPECTANCY STUDY

INTRODUCTION

The purpose of this study is to evaluate drivers' expectancies for the operational characteristics of automobile controls. These include controls for power mirrors, power windows, manual windows, headlights, windshield wipers, power door locks, and some other instrument panel operations. The data obtained will be used as a basis to make design recommendations for automotive controls.

The study is being conducted by the Vehicle Analysis and Simulation Laboratory, Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061-0118 (telephone number: 703-231-9084). The research team consists of John McFarlane and Jana Moore, who are graduate students in Industrial and Systems Engineering, under the direction of Dr. Walter W. Wierwille, principal investigator and P. T. Norton Professor of Industrial and Systems Engineering (telephone number: 703-231-7952).

In this study you will be asked to perform a number of control operations while you are sitting in an automotive buck. The buck is a stationary apparatus that contains contemporary automotive seating, steering wheel, foot pedals, and hardware that can

accommodate different types of controls commonly found in modern automobiles. There will be an experimenter beside the buck to advise you of tasks to perform. Another experimenter will be observing and recording your actions.

After reading this introductory material, you will be given an informed consent form. If you understand what this experiment entails and agree to participate in it, you must sign this form. We will also ask to see your driver's license and will have you fill out a brief questionnaire on your driving history. Assuming that you meet all of our standardization criteria, we will schedule you for an experimental session, a brief outline of which follows.

EXPERIMENTAL PROCEDURE

You will first be seated in a comfortable position inside the buck. You will then be asked to direct your attention to the instrument panel, door panel, console, and stalk controls to become familiar with the location and types of controls you will be using during the experiment. At this time you will be asked to perform different control tasks using the associated hardware found in the buck. For each of these tasks, specific instructions will be provided.

Throughout the study, an experimenter will be changing the controls around to present different configurations. This is not intended to confuse you. Just respond naturally, as if you were sitting in an automobile. We are interested in the *direction* that you move the controls, and that is what we will be observing. For multiple controls, such as power windows, we will also be observing which individual control you select. You should move the desired or designated control in the direction that feels correct to you,

assuming you were in an actual automobile. Please do not be concerned about how the control feels when you move it. Control "feel" is not an issue in this study (control feel would be optimized in further studies after the driver's preference for direction has been determined).

ADDITIONAL INFORMATION

At any time during the study, if you no longer wish to continue, you have the right to terminate your participation; you will be compensated for the length of your participation up to that point.

If you have any questions about the experiment or your rights as a participant after reading the attached informed consent form, please do not hesitate to ask. We will answer your questions honestly and as openly as possible. We ask that you do not discuss the details of this experiment with any person, particularly those who may participate, as prior knowledge of seemingly incidental facts might compromise the data. It is expected that all data will have been gathered by May 1, 1990; you may feel free to discuss the study with any persons after that time. All data will be analyzed with anonymity, i.e., immediately upon completion of your experimental session, your data will be identified only by a randomly assigned serial number.

DRIVER EXPECTANCY STUDY

We ask that you answer questions 1 through 6 as thoroughly and as accurately as you can. If you feel that you cannot answer a question for any reason, simply leave it blank.

1. How many years have you been driving? _____

2. Estimate the number of miles you drive each year (check the appropriate box).

☐ 0 - 2,000 miles	☐ 10,000 - 14,000 miles
☐ 2,000 - 6,000 miles	☐ 14,000 - 20,000 miles
☐ 6,000 - 10,000 miles	☐ 20,000 or more miles

3. Are you required to wear glasses when you drive?

   Yes No

4. Are you right-handed or left-handed? (circle one) **LEFT** **RIGHT**

5. What is the make, model, and year of the car you drive most often?

   Make _____
   Model _____
   Year _____

6. If there is a second automobile that you may drive occasionally or even frequently, what is the make, model, and year?

   Make _____
   Model _____
   Year _____

Coding_____

Participant's Informed Consent

1. You are being asked to volunteer to be a participant in a research project whose purpose and description are contained in the document entitled *"Driver Expectancy Study,"* which you have already read.

2. A potential risk involved in this experiment includes the possibility of minor injury if you attempt to enter or exit the buck hastily. To eliminate this risk, you agree to enter or exit the buck slowly and with the experimenter's guidance.

3. A potential discomfort involved in this experiment includes fatigue due to the length of the experimental session, which will last no longer than one and a half hours total.

4. The data gathered in this experiment will be treated with anonymity. Immediately after your participation, your name will be separated from your data.

5. While there are no direct benefits to you from this research (other than compensation), you may find the experiment interesting. Your participation, along with that of other volunteers, should make possible the improved design of automotive controls.

6. You should not volunteer for participation in this research if you are under 18 years of age, or if you do not have a valid driver's license.

7. Please note that the principal investigator of this research project and his graduate assistants will answer any questions that you may have about this project, and you should not sign this consent form unless you are certain that you understand all of the previous descriptions and conditions.

   You may also contact Dr. E. R. Stout, Chairman of the University's Institutional Review Board (telephone number: 703-231-5281), if you have questions or concerns about this experiment.

8. You may withdraw from participation at any time during the experiment without penalty. You will be compensated at the rate of $5.00 per hour for the actual length of your participation.

9. Signature of the volunteer participant.

   I have read and understand the details of this experiment, and I have no further questions. I hereby give my consent to participate. I understand that I may discontinue participation at any time.

   _____

   Signature Date

10. Signature of a member of the research team:

   _____

   Signature Date

VITA

John McFarlane was born on June 16, 1963 in Mt. Kisco, New York. After graduating from Somers High School in 1981 he attended the State University of New York at Buffalo where he received a B.S. in Industrial Engineering in 1985. John then worked for Woodward and Lothrop in Washington, D.C. for two years prior to attending Virginia Tech. During his stay at Virginia Tech, John worked as a research assistant under Dr. Walter Wierwille and as a teaching assistant under Dr. Dennis L. Price and Dr. Wolter J. Fabrycky. He now plans on traveling in Europe for approximately one month, soon after he hopes to gain employment somewhere in the northeast or on the west coast.

John McFarlane.