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AUTOMOBILE MULTIFUNCTION STALK CONTROLS: LITERATURE, HARDWARE AND HUMAN FACTORS REVIEW

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16. Abstract

This report considers several topics related to the design of automobile multifunction stalk-mounted controls. (The most common example is the turn signal lever, which when pulled or pushed, switches the headlamps from high to low beam, or vice versa.)

In the first section a taxonomy for controls is presented. Four basic concepts--dedication, combination, directionality, and integration--are described, and examples of these concepts are included.

In the literature section roughly 20 major documents concerned with stalk control design are described in detail and critically reviewed. Topics covered included: design stereotypes (hardware reviews), human factors analyses, problem surveys, accident data, driver preferences, driver performance, and previous literature reviews. Abstracts of those documents appear in the appendix of this report. Those studies do not support a general recommendation favoring either panel-mounted or stalk-mounted controls. Panel-mounted controls are expected by American drivers whereas movements to stalk controls are quicker because they are closer. Research comparing alternative stalk designs is almost absent. Also lacking are studies of stalk direction-of-motion stereotypes. However, in all cases the literature provides considerable guidance as to how these studies should be conducted.

Current regulations for automobile controls (issued by the U.S. Dept. of Transportation and the International Standards Organization, among others) are described. It appears that more restrictive regulations will be drafted in the mid-1980's.

The types of multifunction stalk controls in 1977-1979 model year cars are tabulated. American cars of that period tended to use panel-mounted controls, while stalk controls were prevalent on foreign cars. The most common stalk configurations were one left stalk and a left plus a right stalk. Also observed were 3 other configurations: 2 left stalks, 2 left plus 1 right, and 1 left plus 2 right. Related types of controls ("Pod" and other novel designs) were found on the Citroen CX, Visa, and GSA.

Human Factors principles regarding the design of stalk controls are presented and basic guidelines are suggested. Based on these principles, Hick's Law, Fitts' Law, and predetermined time systems, a relationship for predicting the complexity of and time to use controls is outlined.

Finally, based on the information described above, limited design recommendations are offered favoring either a single left stalk or a one left plus one right stalk pair.

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THE VIEWS EXPRESSED IN THIS REPORT ARE SOLELY THOSE OF PAUL GREEN, THE AUTHOR, AND NOT NECESSARILY THOSE OF THE MOTOR VEHICLE MANUFACTURERS ASSOCIATION.

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FOREWORD

This study was funded by a gift from the Motor Vehicle Manufacturer's Association (MVMA) of the United States. Guidance of this research was provided by the MVMA Human Factors Engineering Subcommittee. Mr. Robert Ealba of MVMA served as the technical advisor.

The project statement (as revised October 18, 1979) called for the following:

<u>Phase I - Literature and Hardware Review (this report)</u>

1. "The literature relevant to stalk controls shall be reviewed."
2. "An abstract of each of the references shall be prepared."
3. "Requirements...shall be reviewed...including the proposed ISO DIS 4040, FMVSS 101 and the proposed revision of FMVSS 101."
4. "A state-of-the-art summary will provide the frequency of occurrence of specific configurations."

<u>Phase II - Human Factors Analyses (this report)</u>

1. "Previously used methods for studying human factors criteria for selecting and combining functions and modes of operation will be reviewed."
2. "A method for identifying and establishing additional functions and stalk locations will be developed."
3. "A set of configurations...for...functions with a high priority for being within fingertip reach" (will be developed).
4. "A control complexity index will be developed..."

<u>Phase III - (next report)</u>

1. "Conduct pilot testing to refine...(the) complexity index."

The assistance of Paul Olson (Human Factors, HSRI), Leo Ziegler (SAE), Chuck Finn (VW), Bill Burgess (Human Factors, HSRI), Robert Ealba (MVMA) and the MVMA Human Factors Engineering Subcommittee in preparing this report is gratefully acknowledged.

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INTRODUCTION

The Nature of the Problem

How well a person-machine system operates depends upon the training and selection of operators, its energy consumption and waste production, the performance and physical integrity of the machinery, and, finally, how well the machine has been designed to match the capabilities of its operators. In the context of automobiles, headlighting, taillighting, field of view requirements, steering systems, braking systems, and controls and displays must all be matched to the driving population.

Motivation for examining the research and design of controls comes from several sources. Members of the staff of Consumer Reports have complained about control design in several automobiles (Anonymous, 1979a, 1979b, 1979c, 1979d, 1979e). The International Standards Organization has aggressively pursued the development of standards for controls in the interest of international harmony. Manufacturers have moved towards producing "world cars." The U.S. Government has expressed interest in expanding its safety standard for automobile controls and displays. Several individuals have expressed the need to make vehicles easier to operate for the handicapped. Finally, the Society of Automotive Engineers Controls and Displays Subcommittee has discussed a possibility of Recommended Practice for Multifunction Controls. To accommodate these and other concerns, this summary was developed.

A Taxonomy for Controls

To understand the research on multifunction manual controls, one must be aware of the kinds of controls that exist. The advent of the digital computer and the advance of technology in general has brought about the design of several new types. Presented in the following section is a classification scheme for these controls (and some terminology).

1. Dedicated vs. Nondedicated. A dedicated control is one whose purpose or action does not depend upon the state or condition of

another control. The term dedication has been used before. (See Anacapa Sciences (1976) for example.) Until now, the term has not been formally defined.

The oldest example of such is a typewriter shift key. When the shift is not depressed, a particular key might type, for example, a lower case "p." When the shift is held down or locked, a capital "P" results. Thus, depressing the shift key changes what the p/P key does. The advantage of nondedicated controls is that they require less space then a dedicated set. In the case of the typewriter, eliminating the shift key would require replacing each key remaining with two, so that both lower and upper case could be typed.

Serving as the impetus for nondedicated controls is the shortage of panel space in jet planes (in aircraft jargon, "real estate"). (There is a similar space problem in some automobiles.) For example, shown in Figure 1 is a simplified arrangement of projection switches that has been proposed as a design alternative for single-seat fighters. When the aircraft is started up, all of the switch panel legends are in the logic level 1 (system) mode. If the pilot then depresses the "COMM" (communications) switch, all of these switch legends change to those appropriate for the communications mode (logic level 2). Further key presses will cause additional legend changes to succeeding logic levels. For example, pressing the "UHF" switch would allow the pilot to adust the UHF radio. If the pilot then wants to perform a navigation task, he or she would hit "clear" several times to get back the system level (logic level 1) and then depress the switch labeled "NAV" (short for "navigation computer). Other systems can be operated through an analogous sequence of switching. There have been several studies relating to the design of nondedicated controls for use in cockpits (Bateman, 1977; Bateman, Reising, Herron, and Calhoun, 1978; Calhoun, 1978; Crawford, Pearson, and Hoffman, 1978; Reising, 1977; Reising, Bateman, Calhoun, and Herron, 1976, 1977).

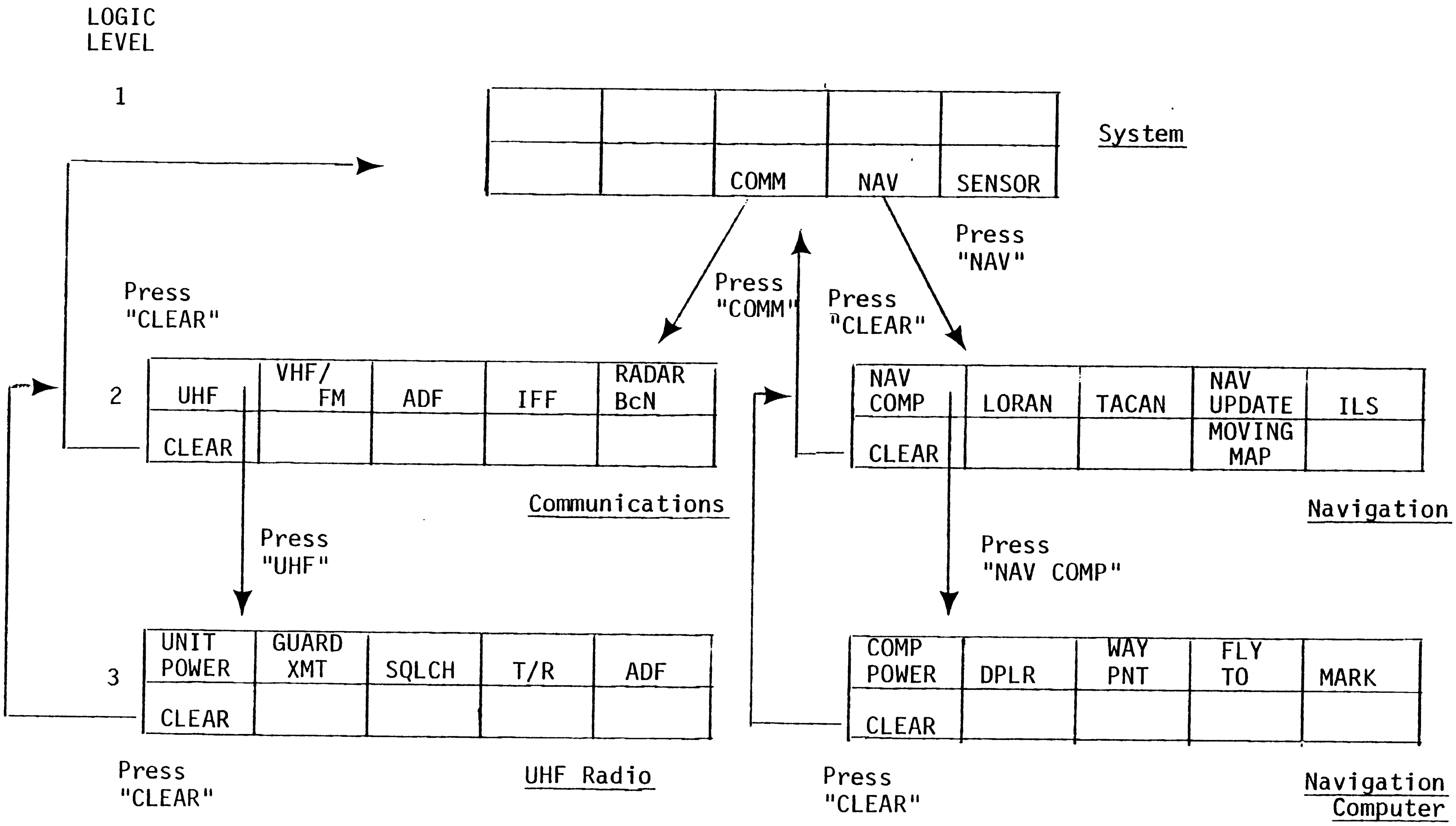


Figure 1. Aircraft Switch Logic.

Another common application of nondedicated controls is in calculators, for example the Hewlett-Packard model HP 41C shown in Figure 2.

It would be quite feasible to install a nondedicated switch panel in an automobile. Shown in Figure 3 is one possible arrangement. In generating this figure human factors considerations have been ignored. It is a feasible design, not necessarily a good one.

2. Combined vs. Noncombined. Combined controls are those which share a common point of attachment ("mounted on the same head") or are mounted on top of each other. Subclasses of this category are "motion-similar" devices (for which the same type of motion serves to operate each of the combined elements) and "motion-dissimilar" devices. Examples of motion-similar controls include stacked knobs (Bradley and Stump, 1955a) often used to adjust car radio volume/tone and tuning/balance, and identically operated joysticks mounted piggyback (sometimes found in aircraft). Examples of motion-dissimilar combined controls include joysticks for jet fighters where the cannon trigger switch is part of the same lever (see Figure 4), new types of helicopter controls (Waugh and Stephens, 1976), most car horns (push buttons on the steering wheel spokes or hub), and rocker and slide switches mounted on levers (automobile cruise controls are sometimes built into the turn signal lever.)

3. Multidirectional vs. Undirectional. Multidirectional controls are those for which the direction in which they move influences what they do. Examples include the panel-mounted headlights control in GM cars (pull/push = on/off, rotate = adjust panel light brightness and interior lights on/off) and certain kinds of stalk-mounted controls found in automobiles (up/down = right/left turn, forward/back = high/low beam). Neither the term "multidirectional" nor for that matter, the term "combined" imply that the functions being controlled are related.

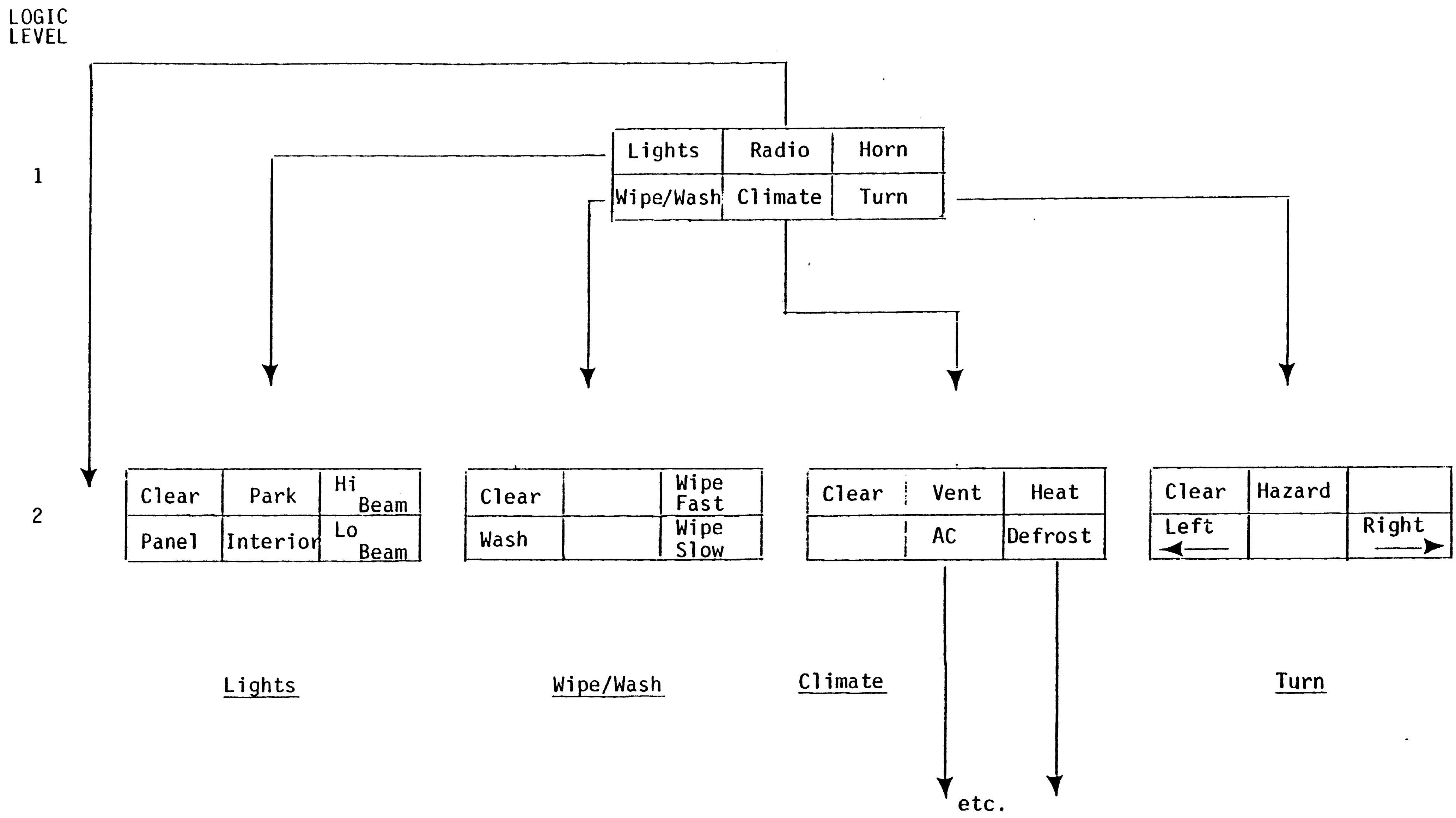


Figure 3. Automobile Switch Logic.

THE CALCULATOR

By itself, the HP-41C can accomplish an astonishing array of calculations. The 39 keys on the face of the calculator control an amazing number of functions: in all, 130. Yet, there is only *one* shift key! The message, here, is very clear: keep it simple and friendly and easy to use.

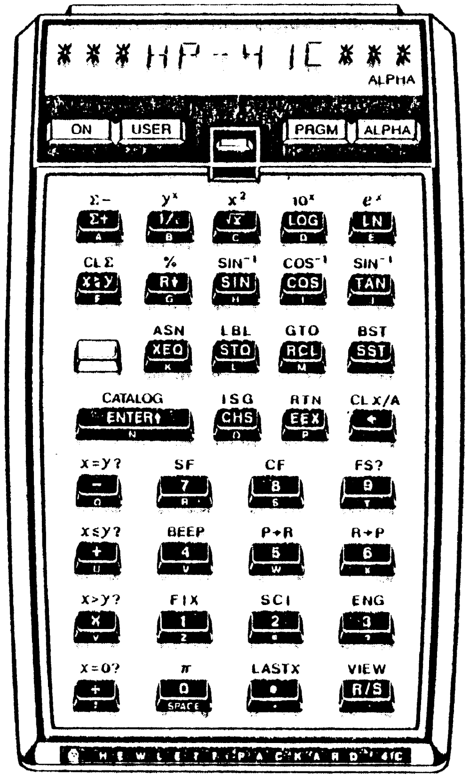


Figure 2

Hewlett-Packard HP-41C Calculator

(Note the nondedicated keys.)

Figure 4

Measurement Systems Model 1505-2 Control Grip

(This combined control consists of a primary joystick and mounted on it, a miniature joystick, two push buttons, and a trigger.)

4. Integrated vs. Separated. Integrated (or integral) controls are those for which a single physical action has two or more consequences. Integration is one way to solve the problem of the number of functions requiring continuous control exceeding the number of operator limbs (as in the case of a helicopter). An automotive candidate for integration is for the horn (auditory horn) and headlight flashing function (optical horn or optical warning) to be operated by the same button. (An optical warning function is fitted on many European vehicles. When activated it permits the driver to flick the headlights between the off and high beam positions even when the main headlight switch is off. It is used by European drivers in the same way that the American drivers use their horn.)

Combination, Directionality, and Integration are parallel qualities for pairs of functions. That is, two functions can be combined on the same control head, actuated by moving a control in different directions, or integrated and jointly operated by the same control and control motion. On the other hand, dedication and all of the other properties are orthogonal.

None of these concepts is particularly new. Three of them (dedication, combination, and integration) relate not only to controls but also to displays. (For a discussion of integration and displays see Hardzinski and Pachella (1977), Pachella, Somers, and Hardzinski, (to appear), Somers (1978), and Somers and Pachella (1977)).

What then is a Multifunction Control?

The term "multifunction control" has been used in several ways. In automotive applications it usually refers to a manually operated switching device that is either multidirectional or combined. In aircraft, the term commonly refers to nondedicated controls. Defined by exclusion, a multifunction control is a switch that is not unifunctional. A unifunctional control is everything else. It serves a single fixed purpose, is independently mounted, and has but one method of operation.

In the past, the automotive industry has been primarily concerned with a subset of all types of multifunction controls, namely those associated with levers or stalks. One focus of such interest has been International Standards Organization Technical Committee 22, Subcommittee 12 (ISO/TC22/SC13); Ergonomics of Road Vehicles. (Their efforts are described in detail in the section on design standards.) Definition 4.13 of the latest proposed revision of the ISO standard for control location (Standard 4040) states:

> "Stalk Control: A rigid, elongated control device with a visible length at least five times as great as the least cross-sectional dimension. This device may be fixed or moveable and located on the steering column or instrument panel. The operational area is located within the reach of the driver."
> (International Standards Organization, 1978)

Some have not been satisfied with that proposed definition of a stalk control. As an alternative for discussion some have suggested the following:

> "Stalk Control: A control device operated by means of a moveable elongated arm that transmits all the movements required to operate the device."
> (International Standards Organization, 1978)

The second suggestion omits the length to cross-section ratio restriction and adds a movement requirement.

These changes have been offered to differentiate between multidirectional lever controls and fixed arms that extend from the steering column on which switches are mounted. Some have suggested the latter should be called "rod" controls. ("Rod" controls are currently found in the Citroen VISA.)

A distinction also needs to be made between multifunction controls and "pod" controls. "Pod" controls are those mounted on instrument panels that are within fingertip reach of the steering wheel. Such controls are found in the Citroen CX.

What then are multifunction stalk controls? For the purposes of this report they will be defined as lever-type controls which can either be operated in more than one direction or have secondary controls mounted on them, or both. In the newly developed terminology, they are multidirectional or combined lever controls.

This section is intended to develop the thought that there are many kinds of controls and that multifunction stalk-mounted controls found in cars are but a small subset. Because adopting a definition of a multifunction control has implications for future standards and design, it is important to distinguish between multifunction and stalk controls.

Second, in examining the literature, one should consider the source industry. There are marked differences between how the aircraft and automobile manufacturers will apply the term multifunction control.

Finally, and most importantly, because the constraints relevant to each property of controls differ (dedication, directionality, combination, and integration), so too will the appropriate human factors criteria.

LITERATURE REVIEW

Approach

Shown in Table 1 are the major studies included in this literature ordered chronologically, along with the approaches taken by each study. Eight approaches are listed.

1) Literature review--collections of research evidence
2) Accident data--attempts to connect accident information to control design
3) Control location expectancy surveys--investigations of where drivers think they will find controls
4) Driver performance--response time, errors, and other measures of driver utilization of controls
5) Problem surveys--inquiries as to what difficulties drivers experience in locating, reaching for, and activating controls
6) Human factors (HF) analysis--evaluations of particular designs with regard to Human Factors principles and research
7) Preference studies--asking drivers which control arrangements they favor
8) Design stereotypes or hardware reviews--surveys of the location and arrangement of controls in cars

Each section is discussed separately in detail. The abstracts of all the reports and ISO research documents listed in this section are contained in Appendix A. Because of the length of this report (especially the literature review), a tabular summary has been included as Appendix B. Several topics, while they are part of the literature, are dealt with in other sections, including some aspects of International Standards Organization (ISO) activities (see the standards section), previous hardware reviews (see the design stereotypes section), and previous attempts at modeling (see the section on the Response Time Index).

Previous Literature Reviews

Several literature reviews have dealt with controls design, though most as part of larger reviews. Perel (1974) reviews five National Highway Traffic Safety Administration (NHTSA) sponsored

Table 1. Documents Applicable to Automobile Multifunction Controls Design.

DOCUMENT	Approaches Used								
	Literature Review	Accident Data	Expectancy	Driver Performance	Problem Survey	HF Analysis	Preference Studies	Design Stereotypes (hardware review)	Related Issues
Fowler, Williams, Fowler & Young, 1968									X
Woodson, Conover, Miller & Selby, 1969 (also reported as Conover, Selby & Miller, 1969)						X		X	
Malone, Krumm, Shenk, & Kao, 1972 (also reported as Kao, Malone & Krumm, 1972)				X		X		X	
Nevit, 1972a, b									X
Nissley & Elliot, 1972									X
Mortimer & Post, 1973						X	X		
Anacapa Sciences, 1974			X	X	X			X	
ISO, 1974								X	
Krumm, 1974				X				X	
Kuechemeister, 1974				X			X		
McGrath, 1974			X					X	
Middendorf, Dineen & Habsburg, 1974				X					
Perel, 1974	X								
Faust-Adams & Nagel, 1975				X					
ISO, 1975						X			
Kuechemeister, 1975				X			X		
Knaff, 1975	X								
Woodson & Selby, 1975						X			
Anacapa Sciences, 1976			X	X	X			X	
ISO, 1976a, b						X			
Perel, 1976		X				X			
Burger, Smith, Queen & Slack, 1977			X		X	X			
Black, Woodson & Selby, 1977			X			X			
Mourant, Moussa-Homouda & Howard, 1977				X	X			X	
Elsholz & Bortfeld, 1978			X						
Nicholson, 1979	X								

studies on the subject of controls and displays. Three of them are concerned with determining the location of specific controls. The other two reports deal with force and reach considerations. Perel's paper captures the gist of the three studies mentioned above, and his review may be of interest to readers seeking a different perspective than provided by this review.

An even briefer review is that of Knaff (1975). It considers an even larger collection of issues (human brake pedal force capabilities, seat belt usage, and control design). Only two of the reports mentioned are concerned with the design of controls. For the purpose of understanding research on the design of automobiles, the Knaff (1975) paper is of low priority.

The most current review of the research literature concerned with human factors and multifunction control design is that of Nicholson (1979). His paper summarized NHTSA sponsored research on a wide variety of subjects, some of which are related to controls design. (Other issues discussed include restraint systems, driver visibility, ride quality, accident data systems, etc.) The paper has a total of 72 references, six of which are concerned with controls. This paper captures the highlights of the work on controls. Because of the SAE paper format, it lacks detail. It also tends not to be very critical. Those who know little about automotive human factors should read it first as an introduction to the field.

Accident Data

As one of the purposes of standardizing auto controls is to reduce the number of accidents, it would be valuable to know the number associated with each design. Similar epidemiological approaches have been successful in addressing other public health problems.

Taking this statistical perspective, Perel (1976) performed a computer search in which key words (e.g., wiper, dimmer) were matched with police report narratives contained in a file maintained by the University of North Carolina Highway Safety Research Center (HSRC). Examined were 95,879 accidents for 1974 and 19,017 accidents for the first few months of 1975. Search terms fell into four general classes: foot controls, hand controls, visibility, and lighting. Shown in Table 2 are the results for hand controls.

Table 2. Hand Control Problems found by Perel (1974).

Control	Problem	Number
(1975 file)		
Heater	Distracted from driving task while adjusting or turning on heater.	3
Radio	Distracted from driving task while adjusting radio.	6
Tape	Distracted while changing tape or adjusting controls of tape player.	7
Horn	Another car's horn distracted driver.	3
	Did not blow horn while passing.	6
	The horn was sounded as warning and was heard but collision took place anyway.	6
	The horn was sounded as a warning but it was apparently not heard.	28
(1974 file)		
Air Conditioner	Distracted from driving task while turning on or adjusting air conditioner.	3
Lighter	Distracted by dropped lighter.	2
	Distracted while operating lighter.	2
Ashtray	Distracted while using ashtray	2
Defroster	Distracted while operating defroster.	4
Windshield Wiper	Distracted while operating wipers.	6

The number of citations of controls in the files searched by Perel is quite small. (Perel suspects instances of such were "underreported.") Because of the few number of reports, distinguishing control designs is not possible with these data. Also because there were few cars in North Carolina in 1974/1975 with multidirectional or combined lever controls, there probably were not any accidents associated with such. The additional four years of data since Perel's search should boost these frequencies to levels where statistical analysis will be meaningful.

Also pertinent for review are numerous other data files in which the data are more structured. The author examined several HSRI accident data bases for similar relationships. Preliminary investigation showed the indexing terms to be inappropriate for addressing questions of control design.

Driver Performance

Where accident data for various control designs are unavailable or incomplete, as is true in this case, driver performance studies can serve as a basis for comparison. In several studies response time and error data have been collected for various control designs. Malone, Krumm, Shenk, and Kao (1972) (especially Appendix D) compared four switching arrangements for a three-beam headlighting system.

In a vehicle buck, six drivers time-shared between a visual pursuit tracking task (three light stimulus array) and operating the dimmer in response to verbal commands. The dependent variables were response time, errors, and an unspecified measure of tracking performance. The first two are shown in Table 3.

The author believes that this task was too simple and the results may be misleading. With one secondary control to operate, the subject could have rehearsed the needed motions (normally retrieved from long-term memory) in short-term memory. (Increasing the number of controls would eliminate this problem.) The differences between controls in practice should be larger and the mean times longer.

While a multivariate ANOVA would have been preferred, each of the three dependent variables was analyzed separately. Tracking performance was not affected by the simultaneously used control. There were,

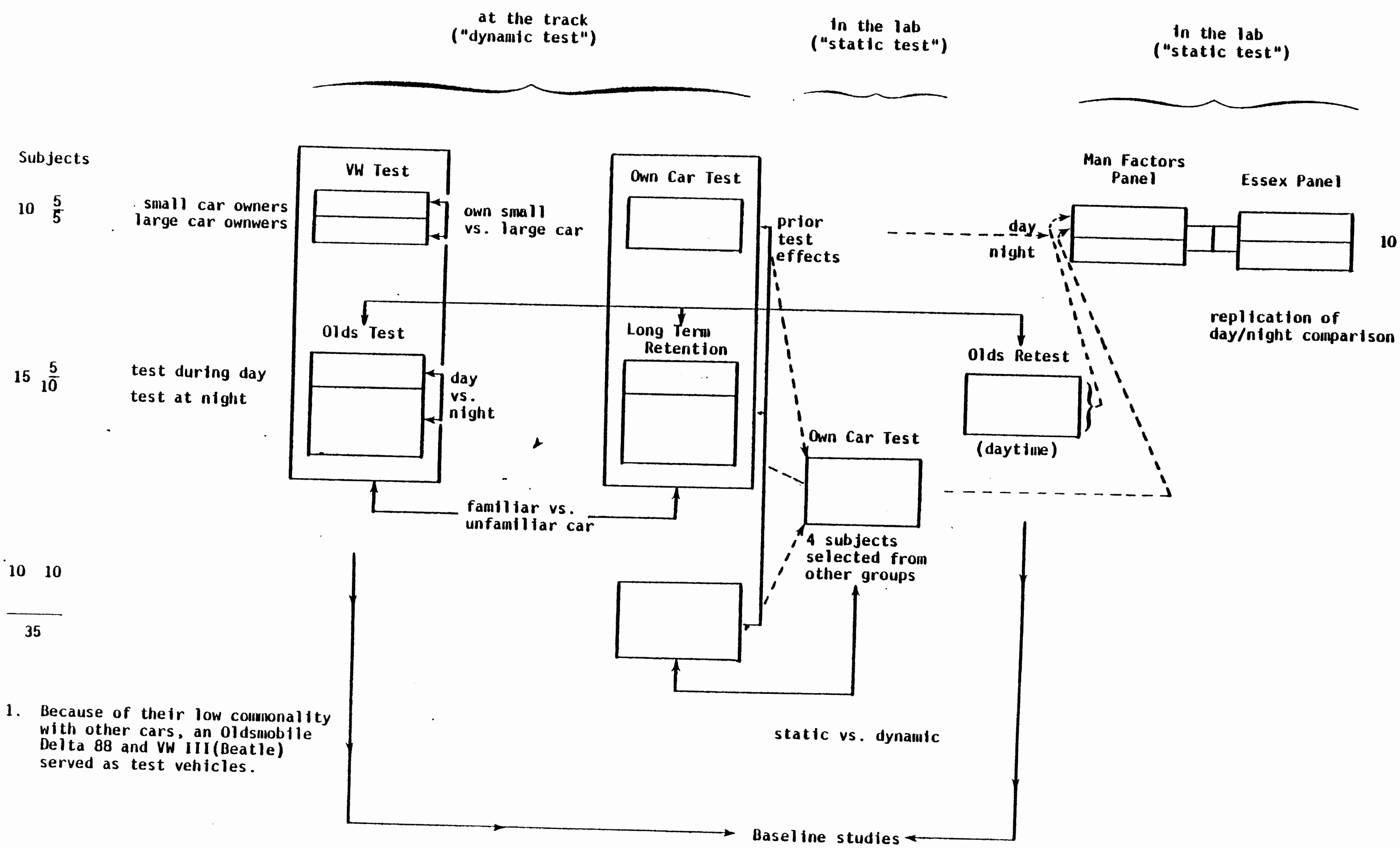
Table 3. Response Times and Errors for Dimmer Controls in Malone, Krumm, Shenk, and Kao (1972)

	Steering Wheel Spoke Button (push to high)	Left Stalk Turn Signal (pull to high)	Right Stalk "delta switch" (push forward and down = low, pull back and up = medium, pull back = high)	Right Panel Rocker Switch (push up = high)
RT (ms)	760	790	880	900
	p >.05 (760–790)	p >.05 (790–880)	p >.05 (880–900)	
% errors	3.2	3.7	2.8	3.7

however, significant differences in response time. (See Table 3.) Most rapidly responded to was the spoke button. The stalk-mounted location was only slightly slower. In general, these results emphasize the need to minimize the movement distance to the control.

In Appendix C of Malone, Krumm, Shenk, and Kao (1972), a series of experimental studies examining the learning of instrument panel configurations is reported. While stalk-mounted controls other than the turn signal lever were not investigated, those studies address many important methodological issues. Only those studies in which cars were the test vehicles will be described. Before dismissing the truck and bus studies, it should be noted they indicate advantages to commonality of control and display location between passenger cars and other vehicle types.

In the initial set of car baseline studies, 35 persons were tested. The assignment of subjects to conditions has been reconstructed and is presented in Figure 5. In most of the conditions (dynamic tests) each subject time-shared between driving around a serpentine test track and touching 20 controls and displays five times. A digital timer was manually operated by the experimenter to measure response time.



1. Because of their low commonality with other cars, an Oldsmobile Delta 88 and VW III(Beatle) served as test vehicles.

Figure 5. Studies of Malone, Krumm, Shenk and Kao (1972), Appendix C.

In the static condition four subjects (selected from those tested previously) were tested in their own vehicles several weeks after the dynamic tests. The procedure was similar to that of the previously described dimmer switch study.

Comparing the various conditions (see Figure 5) the following were noted:

1. There were significant differences in initial response time between familiar (I.4 seconds) and unfamiliar (4.3 seconds) cars. Half second differences remained after five responses for each function.

2. There was some tendency for more errors on unfamiliar panels.

3. There were substantial improvements with practice, with performance leveling off after about five trials.

4. No significant differences were found due to the test time (day vs. night).

5. No significant differences were found between the static and dynamic tests (but static test RTs were briefer).

6. No significant differences were reported due to the size of the car one owns (large versus small).

7. No statistically significant transfer of training occur prior test in an unfamiliar car to a later test in a familiar car (one's own).

8. No differences in response time were found between performance in one's own car and a retest of a previously unfamiliar car six weeks after the initial test. (Performance stabilizes to the familiar car level after five cycles.)

Two months subsequent to the initial experiments, ten subjects were tested on an instrument panel designed by Man Factors Incorporated. Another two months later a panel designed by Essex Corporation was tested. Both had been optimized with respect to Human Factors principles. Under "static" conditions subjects responded five times to each of the 20 controls and displays. For the initial sequence, response times for the optimized panels were half those obtained for unfamiliar cars (VW and Olds) and double those for the familiar (own) cars. By the second pass through the 80-item sequence, the differences between the familiar and optimized panels were extremely small. Response times for optimized panels remained almost a full second faster than unfamiliar panels. The error data did not indicate a difference between performance on the optimized panels and one's own car. Both were superior to than of an unfamiliar car. To repeat, these studies showed that instrument panels that have been optimized with regard to human factors considerations were responded to more rapidly and accurately than those unfamiliar to the driver, and that differences between optimized and higly familiar panels almost disappeared after one response to each control and display.

Middendorf, Dineen, and Habsburg (1974) reported several studies in which different headlight switching systems were compared. In the first study, 32 General Motors employees were tested on three dimmer switch designs, one floor-mounted and two column-mounted (pull/pull and pull (high) /push (low)). Subjects were cued to operate the controls via slides, and response times were collected electronically. Times are reported for both with and without practice. After practice, response times were 1.22 seconds for the foot switch and 1.06 (pull/pull), and 1.14 (pull/push) seconds for the column switches.

Using the same protocol, 32 General Motors employees and 32 Texas drivers operated three types of three beam-switching systems. Shown in Table 4 are the mean response times after practice. The differences are small, favoring neither panel- nor column-mounted controls.

Table 4. Response Times for Three-Beam Switches in Middendorf, Dineen and Habsburg (1974).

Design	Response Time (seconds)		Method of Operation
	GM Study	Texas Study	
Column Stalk "A"	1.21	1.20	Pull toward for low, intermediate, high
Delta Stalk	1.21	1.20	Toward panel = low, toward ceiling = intermediate, toward driver = high
Panel Stalk	1.24	1.14	Push up for low, intermediate, high

Kuechenmeister (1974) had 30 General Motors employees operate an "older design" Mercedes Benz multifunction control unit mounted in a 1972 Chevrolet station wagon. The single left stalk operated as follows:

turn signal - standard
wiper/washer - rocker switch mounted on push/push switch on face of lever; wiper on/off = push/push; rocker switch left position - wash, center position = low speed wipe, right position = high speed wipe
headlights
push lever away = high beam, center position = low beam, pull towards = spring return headlamp flash

Stopwatch times from the start of each operation instruction until the driver's hands returned to the wheel were collected, as were errors. (In most studies, timing stops when the control is operated.) Three levels of formal practice were used: "some" (operating controls under speed stress until one errorless sequence was completed), "little" (operating each control once while being timed) and "inspection" (the driver leisurely operated functions named by the experimenter). Two fixed sequences were used, one for practice and one for test trials.

On the average, after about three trial blocks, subjects operated the multifunction control without error. Further decreases in response time with practice were negligible.

There were substantial (but not statistically significant) differences in response times between switch types. Averaged across subjects and blocks of trails (practice & test), means of 1.73 sec. (on/off panel knob for headlights), 3.10 sec (fore/aft motion of lever for beam switching), 1.30 sec (lever up/down for turn signal), 2.40 sec (rocker switch) and 2.17 sec (push button) were obtained. Thus, in this study, response time to the panel-mounted control was less than that for all stalk controls except for the turn signal. Subjects had difficulty with the stalk-mounted beam switch, as they were accustomed to floor mounting. Difficulties with the rocker switch were the result of grouping different functions (washer on/off and wiper speed) on the same switch. By about the fourth trial block (first test block of the "some" practice condition), the response time differences between panel-mounted and stalk-mounted controls disappeared. Subjects, though, still had difficulty with the beam switch. As response times then averaged 1.25 seconds, these stopwatch values are of dubious reliability.

The error data supported the response time differences. Error rates for the panel-mounted controls and the turn signal remained low across practice.

The Kuechenmeister study is weak in several respects. The error data are confusingly reported. Only one control configuration was examined and it was strongly suspected, a priori, that the design was not a good one. To draw conclusions about alternative configurations, more than one must be tested.

To assess the effect of airbags on vehicle design, Krumm (1974) repeated the Malone et al. (1972) "static" procedure. Choice response times were collected for operating the horn (amber stimulus light), the footbrake (red light) and the headlight dimmer (white light). Six horn location vehicle combinations were examined for 336 American adults.

For each subject, four responses for the horn and five for the dimmer were obtained. Prior to testing, each subject honked the horn once.

The median choice response times across trials are shown in Table 5 along with simple response times (e.g., "Honk the horn when I say so"). According to these data, subjects experienced considerable initial difficulty with rim-blow and stalk-mounted horns and those problems persisted for the stalk-mounted horns. While expectancies for controls and performance in locating them does change with exposure, the author is confident that those results could be replicated today with American drivers.

In regard to the other controls examined, response times favor floor-mounting over stalk-mounting. The author is less confident this result is now replicable.

Table 5. Time to Sound the Horn Reported by Krumm (1974).

Control Type	Vehicle	Time in Seconds	
		Simple RT	Choice RT
360° ring	(Taurus)	.41	1.64
2-spoke lever	(Oldsmobile Cutlass)	.44	1.29
center	(Fiat 124)	.62	1.65
3-spoke push button	(BMW 202)	1.96	1.86
stalk	(Austin Marina)	9.60	2.07
rim	(Oldsmobile 98)	29.00	1.61

Faust-Adams and Nagel (1975) had 24 Australian nondrivers reach for six controls in two cars, a right-hand drive 1972 Holden HQ with panel-mounted controls and a left-hand drive 1971 Mazda Capella RX2 with stalk-mounted controls. Shown in Table 6 are the mean response times to touch each control after its name was visually presented.

Table 6. Response Times Reported by Faust-Adams and Nagel (1975).

	Control					
	Beam Switch	Lights On/Off	Wiper	Horn	Ignition	Handbrake
Holden	1.76	1.63	1.74	1.46	1.68	1.94
	floor	on dash far right	right side dash, near	steering wheel spokes	right side of column	between seat and door
	p < .01	p < .01	p < .01		p < .01	
Mazda	1.36	1.67	1.44	1.34	1.61	1.68
	near right stalk	far right stalk	near right stalk	center of steering wheel	apex of column + dash	between seats

For finger tip reach stalk-mounted controls (beam-switching and wiper), response times averaged 300 milliseconds less than those that were panel- or floor-mounted. There was no difference between the response times for the lights switch (panel vs. a far right stalk). This argues against locating two stalks on the same side of the steering wheel. In general, when two stalks are mounted on the same side of the column, one must be displaced from the steering wheel plane. Stalk mounting is intended to reduce movement distance and therefore movement time.

In International Standards Organization (1975), 32 subjects were split into two groups. One group operated the controls in a standard 1975 Oldsmobile (column-mounted turn signal and dimmer, panel mounted wiper/washer); the other, controls in a modified 1975 Oldsmobile (wiper/washer also stalk-mounted - the Chevette design). The timing procedure was similar to that of Kuechenmeister (1974). Each subject responded to each of 14 commands four times.

The analysis of the results showed that there were statistically significant differences due to control design and practice. (See Figure 6.) Panel controls were responded to more rapidly, though the differences decreased with practice. This was true overall and for each of the individual functions.

In a later retest of subjects on the Chevette stalk design, an additional improvement in performance was noted. The overall differences in error rates between designs were small. (A statistical analysis of the errors is not presented.) While ISO (1975) concludes that by the fourth trial "the differences between the two designs are 1/3 of a second or less and therefore probably not practical differences," the author disagrees. At 55 mph this translates into an increased stopping distance approaching two car lengths.

Anacapa Sciences (1976) presented numerous studies assessing driver performance and expectancy in locating controls. Because those studies are so central to controls standardization, an outline of their research is shown in Figure 7. The Anacapa findings were presented in three documents: an early progress report (Anacapa Sciences, 1974), an analysis of foreign cars and drivers (McGrath, 1974), and a final report summarizing the early work and describing the later work in detail (Anacapa Sciences, 1976). In their first performance study 28 U.S. drivers stopping at a roadside rest area served as subjects. Each chose one of three general sketches most resembling the instrument panel in their car. Drivers then marked on the sketch where seven controls were in their own car. Three-to-four inch recall errors were typical.

To address several methodological issues, 24 U.S. drivers were shown slides of instrument panels from 30 different cars and each subject's own car. Widely varying on those slides were locations of the lights, wiper, radio, and climate controls. Included were column-mounted locations for the headlight and wiper controls. In all, response times for eight controls were collected. Times were measured

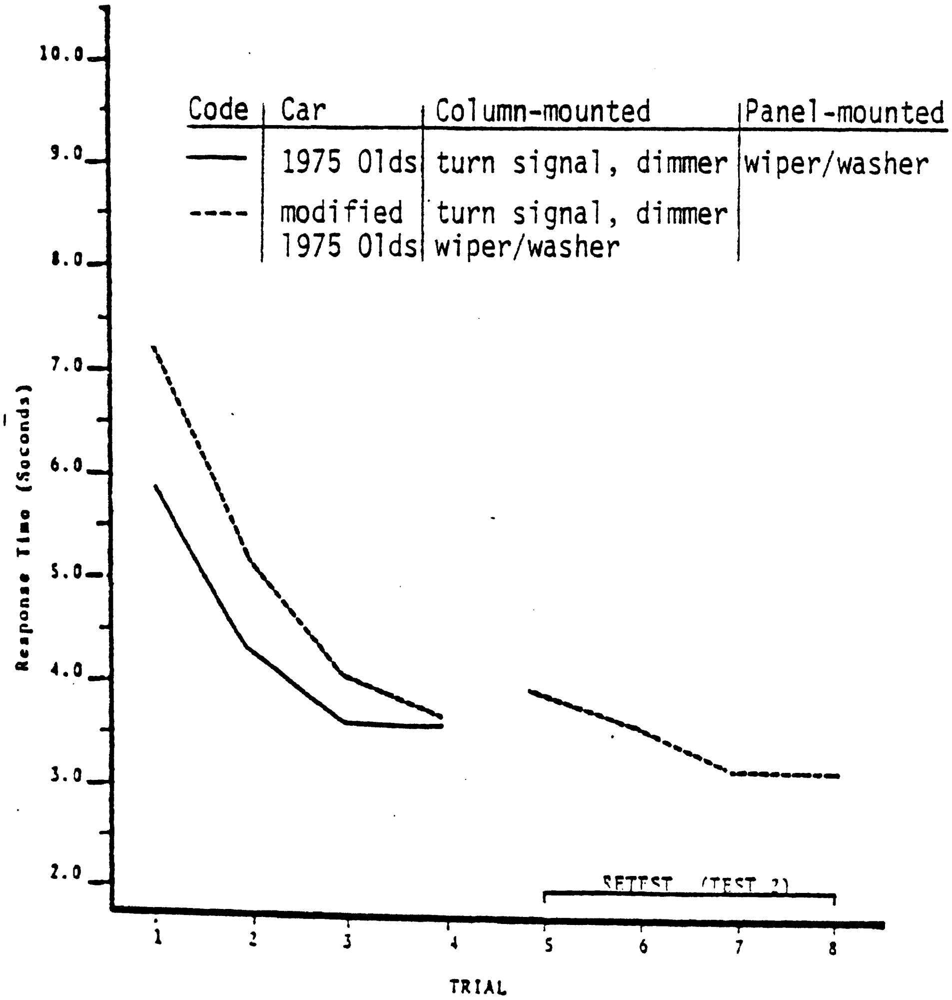


Figure 6

Mean Response Time for Two Multifunction Stalk Controls Reported by International Standards Organization (1975).

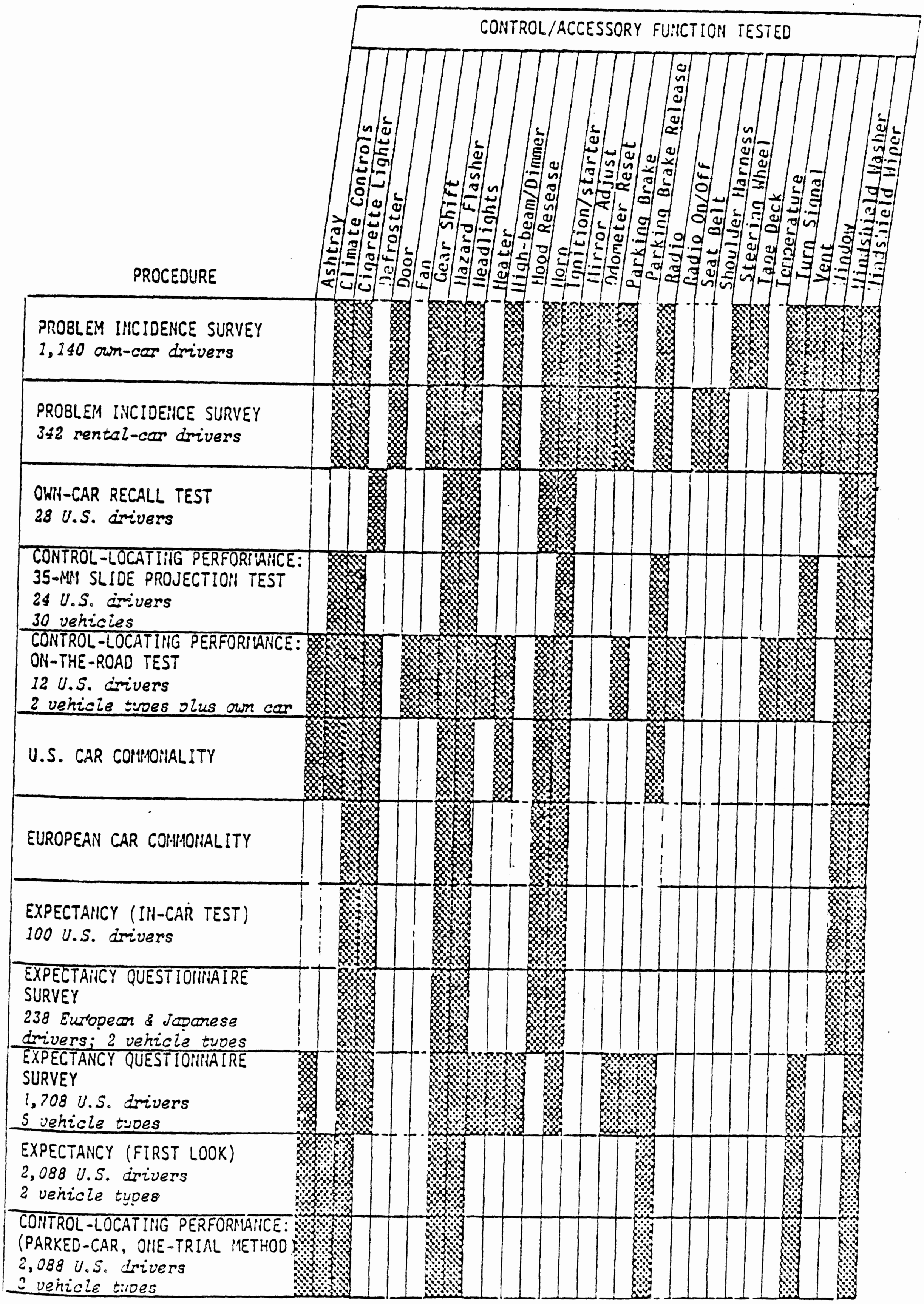


Figure 7. Summary of Studies of Anacapa Program (shaded cells indicate data collected). Source: Anacapa Sciences (1976), p. 4.

from when the projector shutter opened until the subject touched the control on the screen. The timer was stopped manually by the experimenter.

As shown in Figure 8, response times for panel-mounted controls were shorter and less likely to be in error. Other findings included:

1) There were differences between controls in terms of the time and errors made in locating them.

2) Older drivers were slower in responding than younger ones.

3) There were large differences between vehicles.

4) Response time and error rate were highly correlated (r = .89).

5) Response time and errors were correlated with expectancy patterns from previous studies (r = .54).

6) Error rates tripled when labels were covered.

To validate the laboratory procedure, 12 U.S. drivers located ten controls while driving. Subjects were assigned to groups based on similarity of the control configuration in their own car with four general configurations. The test cars were a 1974 Pontiac Catalina, a 1974 Ford Torino and each subject's own car. The test course consisted of two miles of a winding two-lane rural road. Except for the horn (to be activated), subjects were asked only to touch controls called out by the experimenter. Each control was responded to five times in each vehicle. Times were collected manually. Performance in each subject's own car was best, followed by the Pontiac (high expectancy test car) and the Torino (low expectancy test car). Response times and error rates for the road tests of the Pontiac and Torino "were in reasonably good agreement" with the lab data, though they were greater in the photo test. In most cases, performance reached an asymptote after one or two sequences of trials. Times for panel-mounted controls were less than those for stalk controls. In addition, in both cases, there were no statistically significant interactions between the location of those controls in one's own car (left

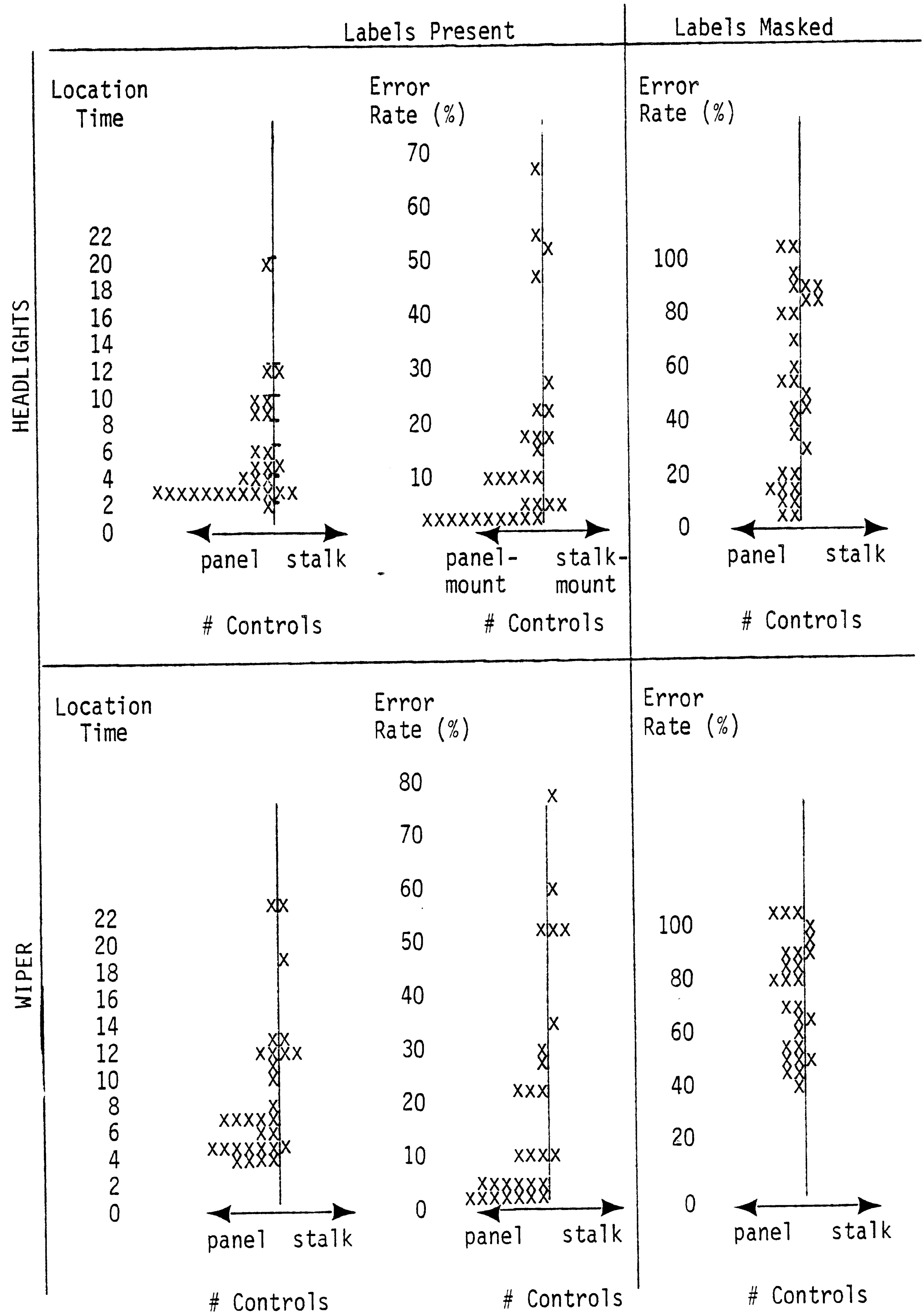


Figure 8. Histograms of Time and Errors to Locate Headlamp and Wiper Controls. Reported in Anacapa Sciences (1976).

panel, right panel or pod/stalk) and location in the test vehicle. Consequently, further Anacapa work focused on expectancy based on each driver's total experience rather than the control location in their current cars.

In the final performance study reported in Anacapa Sciences (1976), response times were collected for eight controls and accessories in a full-size American station wagon (1973 Ford LTD) and a foreign-made subcompact (1969 Toyota sedan). The instrument panels in these vehicles were replaced with mock-ups. Thirty different control arrangements were presented in the station wagon and 15 in the subcompact. Only panel-mounted configurations of the headlights and wiper/washer switch were tested. Each of the 2088 U.S. drivers responded exactly twice, once in each car for a different control. In each test the subject fixated at a distant target while gripping the steering wheel. After naming a control, the experimenter removed a curtain covering the panel and started a clock. The experimenter stopped the clock when the subject touched the correct control. Subjects committing errors were asked to continue to search (and timing continued) until the correct control was found within a 60 second limit. Many important findings emerged:

1) The mean time to correct an error was two seconds. For the vent control those delays approached seven seconds. It is suspected these data underestimate the time to correct an error while driving.

2) Considerable confusion data was gathered which should be of value in comparing alternative control arrangements. The key findings for control-location performance are presented in the form of "discrepancy plots," (figures that present the time to locate a control as a function of the difference between the actual and expected location for each subject). Shown in Figures 9 and 10 are the data for the headlights and wiper/washer controls. To the author these and other data suggest the application of the "five inch rule" to instrument panel design. (i.e., as long as a control is within five inches of where drivers expect it, performance will not suffer.) Anacapa

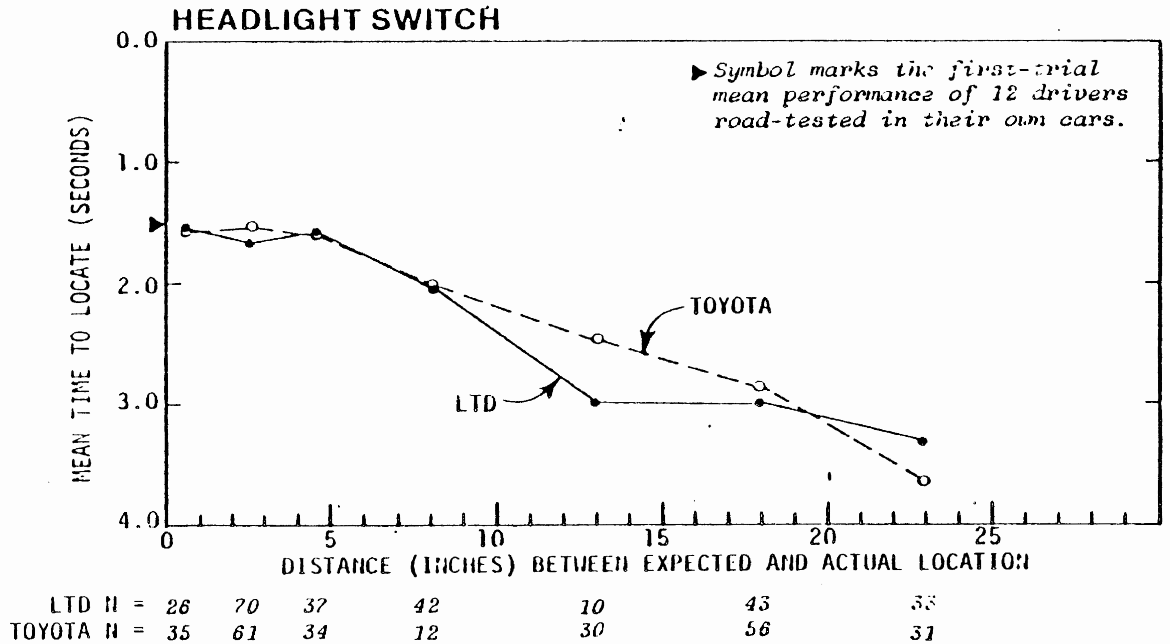


Figure 9. Mean Time to Locate the Headlight Switch as a Function of the Distance between the Expected and Actual Locations. Source: Anacapa Sciences (1976), p. 72.

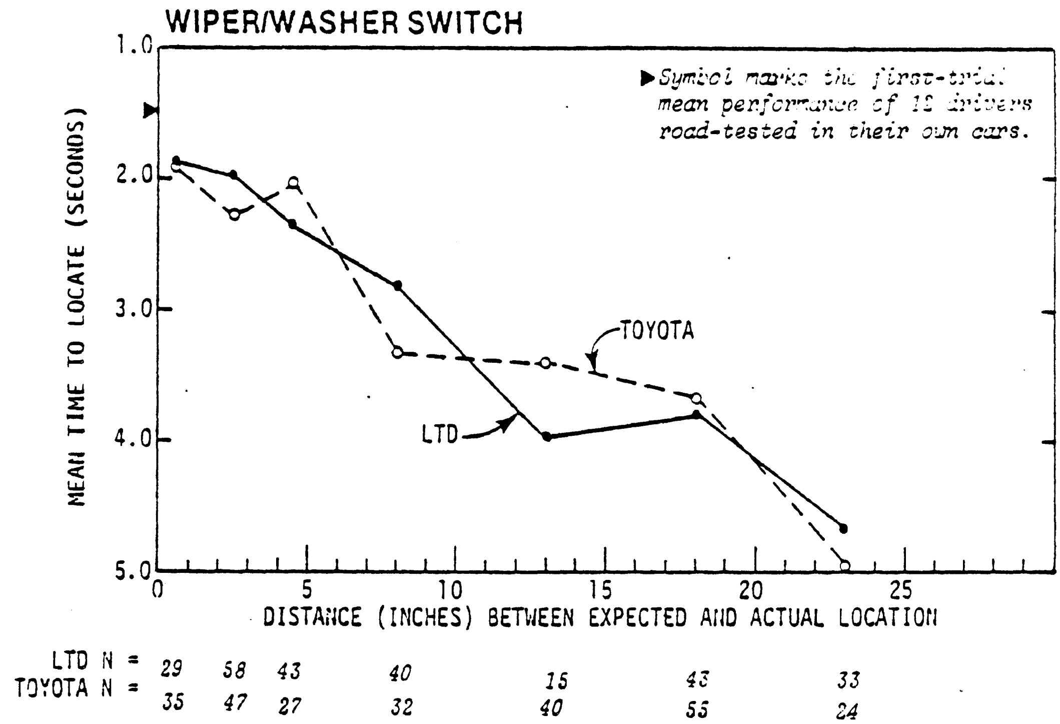


Figure 10. Mean Time to Locate the Wiper/Washer Switch as a Function of the Distance between the Expected and Actual Locations.

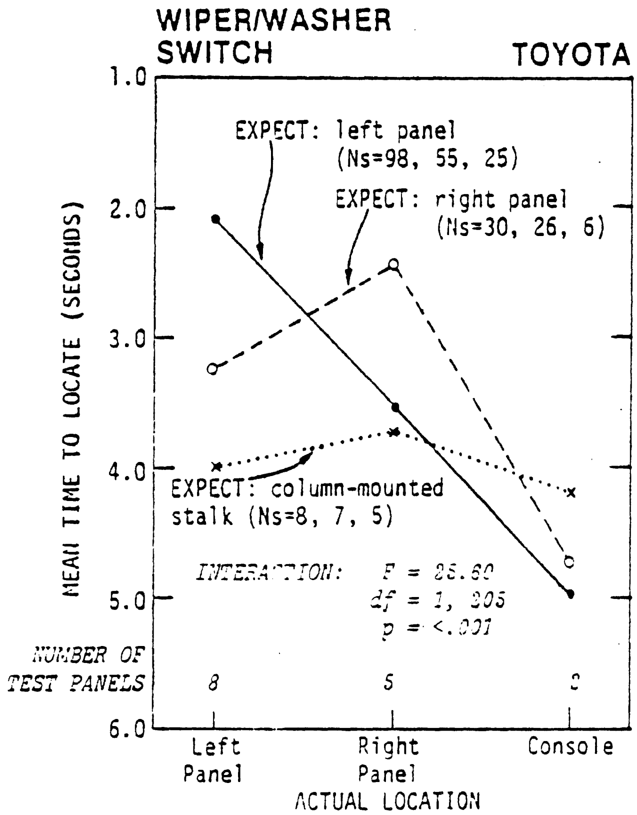


Figure 11. Interaction Between Expected and Actual Locations of the Wiper/Washer Switch in the Toyota.
Source: Anacapa Sciences (1979), p. 79.

Sciences prefers a seven-inch rule. (This difference of opinion is due to different interpretations of where the "knee" in the discrepancy plots are located.) These analyses show that most of the performance differences are due to uncertainty regarding in which panel section (left, right, console) a particular control will be found. Anacapa therefore argues that controls should be restricted only to a panel section. This specificaiton would be insufficient only in very large cars where an abundance of panel space would facilitate violation of their seven-inch rule. It should be noted that Anacapa Sciences (1976) (p. 82) expresses great caution in extending these results to column-mounted controls. As shown in Figure 11 drivers who expect stalk control respond in a categorically different manner from those who expect panel-mounted controls. It appears that the five-inch rule holds only for panel-mounted controls.

Mourant, Moussa-Hamouda, and Howard (1977) compared five single left-stalk configurations in a laboratory study. The stalks differed as to how the wiper and washer operated (see Figure 12). The stalk was added to a working buck of a 1967 Chevrolet instrument panel.

Five groups of 16 subjects were tested. Each group was paired with a different type of control. Subjects operated the multifunction (stalk-mounted) and instrument panel controls and simultaneously performed a pursuit tracking task in response to visual stimuli. Dependent variables included decision time (from message presentation until a hand left the steering wheel), movement time (from leaving the wheel to touching the control), operation time (from touching the control until completion of its operation), number of errors, and frequency and duration of direct looks at each control. Tracking error was not examined in detail.

Decision times were not analyzed. The other two time measures (movement and operation time) were summed and examined with an analysis of variance. A more appropriate technique would have been to perform a multivariate analysis of variance (Reising, 1977).

In comparing performance times for the wiper control, Mourant et al. found the "rotate forward" (.85 sec) and "rotate away" (.87 sec)

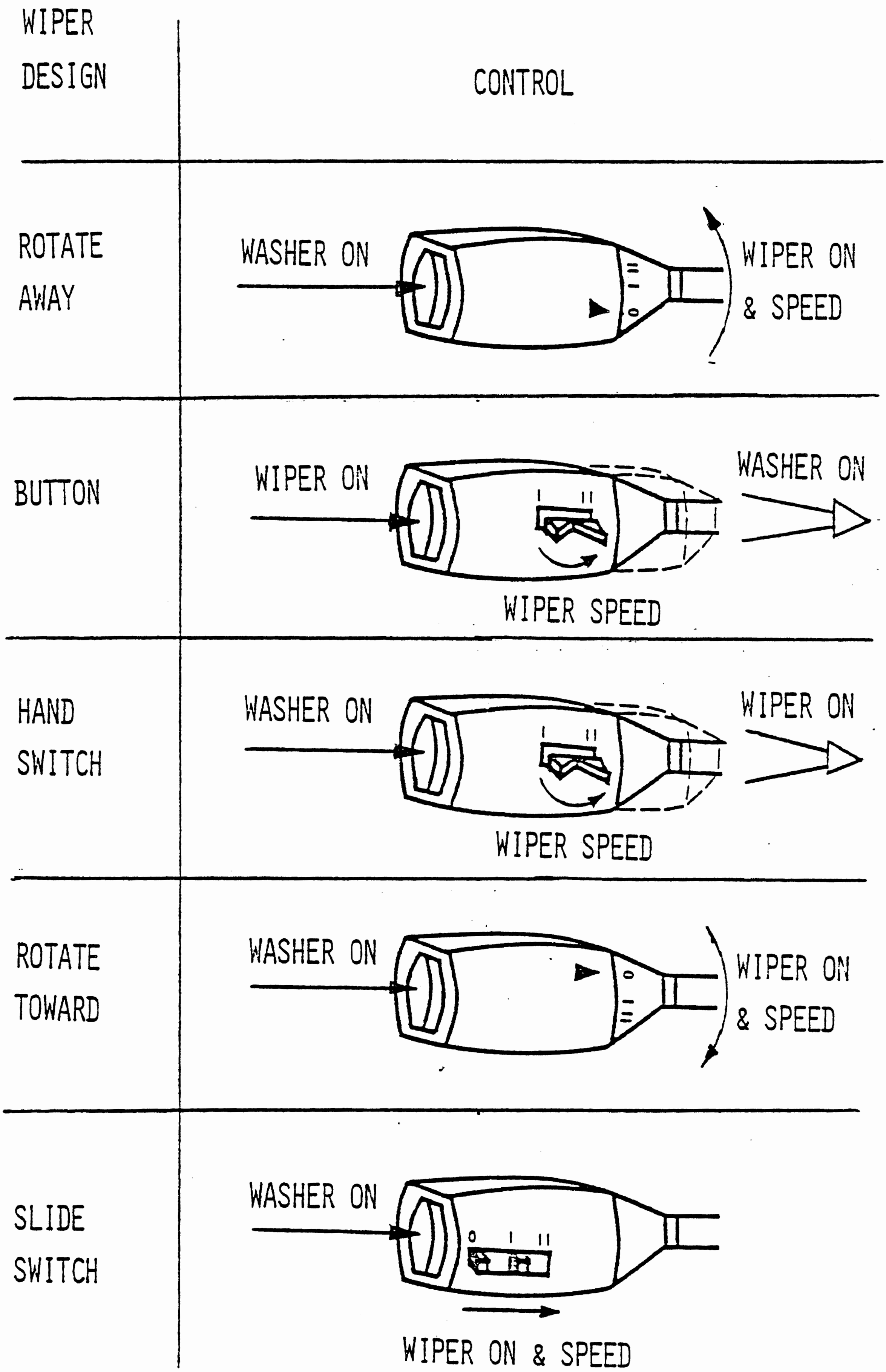


Figure 12. Controls Compared by Mourant et al. (1977).

designs to be significantly better ($p < .01$) than the slide switch design (1.19 sec). Performance times for button and hand switch designs were in the middle of the range and were not significantly different from the other designs. Performance differences between control designs were due to differences in operation time and not movement time. Except for where performance suffers due to their coaxial mounting (e.g., where the wiper is a hand switch), there are no performance time differences between washer switch designs. (See Figure 12.)

As Mourant et al. found no significant differences between the five test groups in moving to or operating panel controls, these differences reflect stalk design and not between-subject group differences. Also, since panel-mounted controls were rarely operated in this study, movement times for them were larger than those for stalk-mounted controls (900 vs. 400 ms).

Examined in a separate analysis of variance were the effects of sex (females faster, $p < .05$), hand dominance (lefties faster, $p < .05$) and practice (not significant). There were no significant interactions of these differences with control configurations. This analysis should have been combined with the main analysis and the ANOVA error term adjusted accordingly.

Comparisons of the direct-look frequency for each stalk configuration agree with the performance time analysis. The fewest looks (about 5/100 responses) were required to turn on wiper with rotate forward or away configurations, and the most (18/100 responses) were required for the button configuration. Even larger and significant differences ($p < .01$) were found where wiper speed was being controlled. There, 37 looks/100 responses were required for the "button" design. (Speed was controlled by a rocker switch.) For the washer, the design in which the washer button was coaxial with the wiper handswitch required significantly more direct looks ($p < .01$). Overall, fingertip controls required 1/6 the number of direct looks of other controls.

While the fingertip reach controls were used more often and consequently their locations were better known to the subjects, this difference arises primarily from the need for visual guidance in reaching for conventional panel-mounted controls.

Finally, in a chi-square test of the error data, a significant difference between designs was found ($p < .01$). The error rate for the button design (12%) was almost double that of other designs.

There were substantial (but not statistically significant) differences between groups in tracking task performance. Time-off-target (error) for the rotate-away group was roughly double that of the rotate-forward group, which was in turn larger than any of the other groups. Mourant does not partition the tracking errors into those associated with stalk controls versus panel-mounted controls. These differences could therefore be either between-group, between-control design, or spurious.

Overall, what should one conclude from Mourant's work? The performance time, direct look, and error data all indicate that the rotate designs are preferable. Subjects had particular difficulty with designs in which a handswitch and a button were mounted coaxially. Contrary to these conclusions are the tracking error data. The outcome may reflect subjects trading-off performance time for tracking error in this dual-task experiment, rather then true design differences.

Summary

The driver performance studies of control operation do not indicate whether panel or stalk controls are superior in terms of time to use them or errors committed. An exception is the horn control, where steering wheel hub mounting is preferred to stalk mounting. There are no performance studies in which the number of stalks has been varied, though there have been a few comparisons of the design of specific stalks. The data indicate that superior performance is obtained where controls were close to the driver so as to minimize movement distance and time. About 50% of the time required to use an automobile control is spent moving towards it. Drivers performed well when controls were mounted where they are expected. As will be shown later, Americans expect panel-mounted controls, and they have served as subjects in all but one of the performance studies. To the author these two findings suggest that very brief response times should be obtained for fingertip-reach panel-mounted controls, at least for American drivers.

In previous studies response time for controls in a laboratory were well correlated with on-the-road performance. Furthermore, the various performance measures (response time, errors, steering (tracking) error, and direct looks) were also well correlated. This suggests to the author that laboratory studies in which multiple performance measures are collected is the most appropriate way for evaluating driver performance in operating controls.

Expectancy

In designing and positioning controls for cars, where drivers expect them to appear and how they expect them to operate should be considered. As was noted in the previous section, Anacapa Sciences (1976) found that deviation from expectancy radically altered performance. In many instances the expected and theoretically optimal designs are not the same. The designer must then decide how to trade off short-term performance (favoring the expected design) with long-term performance (favoring the optimal one). (For a thorough discussion of this issue, see Anacapa Sciences (1976).)

Four studies of control expectancy are summarized in the Anacapa Sciences (1976) report. In the first study (originally reported in Anacapa Sciences (1974)) expectancies for the locations of seven controls were obtained from 100 U.S. drivers. Drivers responded both by pointing to the location on a simplified sketch of an instrument panel and by placing adhesive-backed dummy knobs on a blank panel mounted in a 1973 Chevrolet Impala. (Stalk controls were not examined.)

Differences between the two methods were minor. For the controls of interest the following expectancies were obtained:

headlight - far left side of panel
wiper/washer - either left or right of panel but mostly on left
flasher - mostly on column with right side preference

In the second study (reported in detail in McGrath (1974)) survey data from 238 European (UK, France, Italy, Sweden) and Japanese drivers was examined. (The data was supplied by ISO.) Drivers were asked to mark on two sketches (one of an American-made and the other of a foreign-made auto) where they expected to find eight controls. Except for the "European car" sketch shown to drivers in the UK and the "Japanese car" sketch shown to drivers in Japan, all sketches depicted left-hand-drive cars.

In general, expectancies for control location in left-hand-drive cars were somewhat consistent, though there were marked differences between left-hand and right-hand-drive cars. Shown in Table 7 are the expectancies for the controls being considered for stalk-mounting. For the headlight switch, French and Italian drivers expected it on a left-side stalk, whereas other drivers expected an outboard panel location. Expectancies for the wiper and washer are similar. American drivers expected these controls to be on the left side of the panel.

Depending upon the nation, expectancies exist for mounting these controls on either side of the steering wheel or the instrument panel. For the hazard switch there is a strong expectancy among Americans for it to be mounted on the right side of the column, whereas all others expected it on the right side of the panel. French and British drivers expected the horn to be stalk-mounted. Others expected it to be mounted on the steering wheel hub.

In a third expectancy study reported by Anacapa Sciences, 7,000 questionnaires were mailed to drivers in California, of which 1,708 were returned. There were several different forms of the questionnaires (nonorthogonal combinations of vehicle type (car or truck), size

Table 7. Expectancies for Control Location (%) Reported by McGrath, (1974). European-Made Sedan--(Left-Hand Drive)

		HEADLIGHTS LEFT	HEADLIGHTS RIGHT	WIPER LEFT	WIPER RIGHT	WASHER LEFT	WASHER RIGHT	HAZARD FLASHER LEFT	HAZARD FLASHER RIGHT
FRANCE (n=39)	Panel or console	11	11	39	20	28	18	31	61
	Steering column	68	11	10	31	13	28	8	
	Floor					13			
ITALY (n-50)	Panel or console	10	24	8	39	29	35	44	48
	Steering column	56	10	7	46	4	13	4	4
	Floor					19			
SWEDEN (n=50)	Panel or console	68	19	32	44	30	36	32	64
	Steering column	11	2	8	16	6	18	4	
	Floor					10			
FRANCE, ITALY, & SWEDEN COMBINED (n-139)	Panel or console	30	19	25	36	29	31	36	58
	Steering column	44	7	9	31	7	19	5	1
	Floor					14			
	Panel or console	87	12	60	28	NOT TESTED		35	24
	Steering column	1		3	9			8	33
	Floor								

HORN (See headings below)

FRANCE (n=39)	n	Steering wheel	28	0	0
		Stalk - left/right	44	28	
		Panel	0		
ITALY (n-50)	n=50	Steering wheel	66	16	2
		Stalk - left/right	6	8	
		Panel	2		
SWEDEN (n=50)	n=50	Steering wheel	68	8	8
		Stalk - left/right	8	8	
		Panel	0		

EUROPEAN-MADE SEDAN--(RIGHT-HAND DRIVE)

		HEADLIGHTS LEFT	HEADLIGHTS RIGHT	WIPER LEFT	WIPER RIGHT	WASHER LEFT	WASHER RIGHT	HAZARD FLASHER LEFT	HAZARD FLASHER RIGHT
UNITED KINGDOM (n=49)	Panel or console	37	40	53	35	41	25	31	45
	Steering column		23	8	4	14		7	17
	Floor					20			
JAPAN (n=50)	Panel or console	4	78	28	58	33	55	22	38
	Steering column	3	15	7	7	5	7	18	22
	Floor								
U.K. & JAPAN COMBINED (n=99)	Panel or console	20	59	40	47	37	40	26	42
	Steering column	1	20	8	5	10	3	9	23
	Floor					10			

HORN

UNITED KINGDOM (n=49)	n=50	Steering wheel	32	0	0
		Stalk - left/right	8	58	
		Panel	2		
JAPAN (n=50)	n=50	Steering wheel	52	24	0
		Stalk - left/right	4	18	
		Panel	2		

Center hub, spoke crossbar, inner ring

Table 7. Expectancies for Control Location (%) Reported by McGrath, (1974). (cont.) American-Made Sedan.

		HEADLIGHTS		WIPER		WASHER		HAZARD FLASHER	
		LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
FRANCE (n=30)	Panel or console	21	10	27	30	24	13	30	60
	Steering column	59	10	7	33	13	37	7	3
	Floor					13			
ITALY (n=50)	Panel or console	10	20	14	43	29	47	40	50
	Steering column	56	14	6	37		8	8	2
	Floor					16			
SWEDEN (n=43)	Panel or console	48	37	37	37	26	39	41	59
	Steering column	10	5	9	17	7	14		
	Floor					14			
UNITED KINGDOM (n-44)	Panel or console	18	55	33	47	27	40	34	50
	Steering column	11	16	13	5	11	4	9	7
	Floor			2		18			
JAPAN (n=50)	Panel or console	28	54	30	52	36	40	32	36
	Steering column	10	8	9	7	10	12	12	20
	Floor			2		2			
FRANCE, ITALY, SWEDEN, U.K., & JAPAN COMBINED (n=217)	Panel or console	24	37	28	42	29	37	36	50
	Steering column	28	11	9	19	8	13	7	7
	Floor			2		13			
UNITED STATES (n=261)	Panel or console	81	18	71	28	68	32	19	18
	Steering column	1			1			14	49
	Floor								

HORN (see headings below)

		Steering wheel: Center hub	Steering wheel: spoke crossbar	Steering wheel: inner ring	Stalk - left	Stalk - right	Panel
FRANCE	n=29	45	7	0	34	14	0
ITALY	n=49	66	16	6	4	6	2
SWEDEN	n=43	72	19	7	2	0	0
UNITED KINGDOM	n=46	33	11	2	17	37	0
JAPAN	n=50	38	60	0	0	2	0

Center hub, spoke crossbar, inner ring

(full-size vs. compact), transmission type (manual or automatic), seat/panel style (bucket seats and console vs. bench seats) and the order in which the 14 controls and accessories appeared). Chi-square tests revealed no significant differences between any of the subsamples (with regard to age, sex, driving experience, or between the California driving population and the sample responding).

Summarized in Table 8 are the expected locations for controls now being considered for stalk mounting. The following generalizations were evident.

headlights - low on left side of panel
wiper/washer - left side of panel
hazard - right side of column
dimmer - floor mounted and on left

Apparent in these data is what Anacapa calls "expectancy lag." Very few American automobiles have the wiper/washer switch on the right side of the instrument panel. Nevertheless, because that was prevalent in the 1960's, drivers still expect to find it there. Similarly, foreign vehicles have had stalk-mounted wiper/washer controls for many years, but drivers still expect panel-mounting.

In the final expectancy study described in Anacapa Sciences (1976) 2,088 U.S. drivers were tested. After participating in the final performance study described earlier, each subject marked on a sketch the expected location of two different controls (from a set of eight of interest). In addition, drivers rated the strength of their expectancies on a nine-point scale.

The expected locations (presented in the appendix of the 1974 McGrath report as dot-density distributions) for controls being considered for stalk-mounting were:

headlights - panel left
wiper/washer - panel left
hazard - right side of column

The design of the experiment made stalk expectancies unlikely.

Table 8. Expectancies for Control Location Reported in Anacapa Sciences (1976). (Third Study)

(%)

Control		Panel Left	Panel Right	Column Left	Column Right
Headlights (on/off)	U.S. full-size sedan (n = 633)	88	12	0	
	U.S. compact (n = 315)	89	11	0	
	Foreign car (n = 352)	84	16	0	
Wiper/Washer	U.S. full-size sedan (n = 629)	72	27	1	
	U.S. compact (n = 307)	72	27	2	
	Foreign (n = 339)	61	34	5	
Hazard	U.S. full-size sedan (n = 609)	16	17	18	49
	U.S. compact (n = 295)	21	17	15	47
	Foreign (n = 321)	22	23	12	43
		Floor		Stalk	
Dimmer	U.S. full-size sedan (n = 643)	--		--	
	U.S. compact car (n = 315)	85		15	
	Foreign (n = 355)	74		26	

This series of expectancy studies and, or that matter, all the Anacapa Sciences performance studies were extremely well done. The experimental designs are clear, the data were carefully collected, and the analyses directly addressed the issues of interest. While the amount of information presented in this series is so voluminous as to deter many readers, they should persevere.

Black, Woodson, and Selby (1977) collected driver expectancies for 10 functions. Roughly 900 U.S. drivers were shown two sandwich boards, one at a time. One contained 20 panel-mounted controls and the other 10 stalk controls. Drivers selected a control for each function and specified its method of operation. Accompanying this information was a picture of the car in which the controls were to be found. There was a tendency to associate gaudy controls (chrome, simulated wood faces) with American cars and austere controls (dull black, large rounded corners) with foreign vehicles.

Summarized in Table 9 are the results obtained for controls now being considered for stalk-mounting.

For the headlights (on/off) and wiper/washer controls, subjects had strong expectancies (3:1 or better) in favor of panel over stalk mounting. Where column-mounting was considered, subjects generally didn't know where to find the control. If forced to choose, the left was preferred over the right side. There was no consensus among drivers as to how a stalk control for the headlights (on/off) should operate. Also lacking was a consensus for the wiper and washer controls.

For the cruise and high-low beam controls, only stalk locations were considered. (Subjects actually expected the beam control to be located on the floor near the driver's left foot.) In both cases left stalks were favored. As with the washer, pushing an end button was favored. For the high-low beam, pulling the lever towards the driver was favored. In a certain sense, the results for the cruise control are misleading. While one could design a speed control with a

Table 9. Control Expectancies of Black, Woodson, and Selby (1972).

Control	Expected Location (%) panel/stalk	If Column Located left/right/other[1] (%)	What look like? (%)	How Operate (%)
Headlights (on/off)	89/11	35/0/55	rotary switch 30 lever 30 rocker 20	rotate away 24 depress rocker 20 lever up 12 lever toward 10
High-Low Beam	0/100 (stalk test only)	51/ - /39[2]	lever 65 rocker 14	lever toward 34 lever away 13 depress rocker 13 lever up 11
Wiper	80/20	37/ - /47	lever 31 rotary switch30 rocker 17	rotate away 22 lever up 17 depress rocker 17 lever toward 14
Windshield Washer	74/26	33/7/51	end button 34 lever 32	push button in 34 lever toward 14 rocker 12
Hazard	17/83	-/73/-	Pull/push or push/pull switch 82	pull out 49 push in 31
Cruise	0/100 (stalk test only)	46/ - /37	end button 34 rocker switch 19 rotary switch 12	push button in 34 depress rocker 19 rotate away 12

Notes

1. Other = combined response from "none of these," and "don't know."

2. Many of the subtotals do not add up to 100%. It is not clear why.

single button (push to set current speed, turn off by touching brake or accelerator), most systems are more complex. Cruise control systems usually have at least an on/off switch and a setting switch. (See the hardware review for details.) For the hazard switch, subjects expected it to be mounted on the right side of the column and to pull on.

While Black's approach suggests which type of control is appropriate for each function, the author believes any final assignment of functions must be done in a complete panel context. For example, these data indicate that left stalk and button is expected for both the cruise and washer controls. If the vehicle had only a single left stalk, it would be unwise for both to be integrated.

While the Black et al. study was well-planned and executed, and the overall format of the report makes it easy to read, it has several major weaknesses. First, in many places the percentages do not add up to 100%. It is not clear whether this is due to missing responses on some questionnaires returned, calculation errors, or both. For each question, both the actual number responding and the percentages should have been reported. Also lacking are the details regarding control selection. Black et al. report summary percentages for each class of controls (e.g., knob 10%, lever 5%) but not the percentages for each design (e.g., knob #1 = 3%, knob #2 = 6%, etc.).

For stalk controls, not only is style information lacking (Did the subject select a plain style or one with other functions on it?) but so is configuration information (Did the subject select a one- or two-stalk design, and if two, which stalk was selected?). This information would be very useful both to the designers and those interested in developing standards for multifunction stalk controls.

Elsholz and Bortfeld (1978) and Elsholz and Frings (1979) (personal communication) asked five groups of 30 foreign drivers to operate controls in an Audi 100 LS, BMW 728, Citroen CX 2000, Peugeot 604 SL, or Renault 30 TS. The results of that study are summarized in a large table in Elsholz and Bortfeld (1978). Because so few have understood it, that table has been reproduced here (Table 10) in a slightly modified form with an explanation. The control designs have been spelled out, as have the directions of operation. Only controls being considered for stalk-mounting are reported. Table 10 has seven columns. The first three indicate the function, control design, and location of the control. The fourth column states how the control operates. "Up" and "down" refer to the plane parallel to the face of the steering wheel. "In" and "out" refer to the instrument panel.

The fifth column states how the control operates to set the controlled item on or increase it. The sixth column indicates the percentage of those responding who associated the wrong control with a control name. For example, for windshield wiper, 10% of those tested on the first vehicle (right-side stalk control) mistakenly selected something else. (After responding, those subjects in error were informed of the assigned control.) Column seven indicates the percentage of subjects who turned on the control in the wrong direction. (Again, for the windshield wiper on the first vehicle, 7% of those tested did not move the right stalk up.) The last column indicates the percentage of those who performed the wrong operation for controlling intensity. Here, for example, 13% of those tested in the first vehicle incorrectly operated the control to change the wiper from low to high speed.

For each function there are as many as five rows, one for each of the five vehicles tested. As some vehicles were not fitted with all controls, there are less then five rows for some functions. There are a number of instances in which the author's interpretations of these data differ from the conclusions of Elsholz and Bortfeld (1978). They consider a 25% error rate to be acceptable, whereas the author considers that criterion too permissive. (See Table 10).

Table 10. Control use Errors Reported by Elsholz and Bortfeld (1978).

Function	Control	Location	To Operate	% Unable to Locate	% Wrong Direction to Operate	% Wrong Direction to Control Intensity
Windshield Wiper	Stalk	Column: Right	Up	10	7	13
↓	↓	Column: Right	Out	30	80	80
		Panel: Left	↓	70	13	27
		Column: Left	In	63	77	77
		Column: Right	Up	7	10	63
Windshield Washer	Stalk	Column: Right	Right	10	20	23
↓	↓	↓	↓	27	27	27
				3	13	13
		Column: Left	Up	53	83	83
		Panel: Left	Right	70	43	47
Horn	Stalk	Column: Right	Right	83	47	47
↓	Touch	Column: Control	Left	0	0	0
	↓	↓	↓	13	0	0
				0	0	0
		Panel: Left	In	77	3	3
Turn Signal	Stalk	Column: Left	Up/Down	20	0	0
↓	↓	↓	↓	17	0	0
				3	0	0
		Column: Right		37	0	0
	Rocker	Panel: Left		27	0	3
Parking Light	Stalk	Stalk: Left	Up	57	10	17
↓	↓	↓	Right	53	77	77
		Panel: Right	Out	73	3	10
		Panel: Left	Up	47	7	23
	Rocker	↓	↓	60	0	10
Headlights On/Off	Stalk	Column: Left	Up/Down	43	3	23
↓	↓	↓	Down	17	80	90
		Panel: Right	Out	43	3	7
		Panel: Left	Up	43	7	17
	Rocker	↓	↓	60	0	13
High Beam	Stalk	Column: Left	Left	39	46	68
↓	↓	↓	↓	10	14	31
				17	83	93
				30	20	70
	Touch	Panel: Right	Down	67	0	0
Front Fog Light	Stalk	Panel: Right	Up	70	17	47
↓	Rocker	Panel: Left	Out	43	0	7
Rear Fog Light	Stalk	Panel: Right	Up	70	27	57
↓	Rocker	Panel: Left	↓	63	0	50
Hazard Flasher	Stalk	Column: Left	Up	77	20	37
↓	Rocker	Panel: Right	↓	77	0	40
	↓	↓		77	0	30
				57	0	3
				83	0	0
Parking Light	Stalk	Column: Left	Up/Down	27	0	0
	Rocker	Column: Center	↓	90	0	0

The author's conclusions are shown below:

1. For the windshield wiper there were problems with right-side stalk controls that twisted or moved towards or away from the driver but not those that moved up or down.

2. Neither a stalk control mounted on the left of the column (push away = on) nor one mounted on the left of the instrument panel (up = on) were stereotypical modes of operation for the windshield washer.

3. Drivers had difficulty with stalk-mounted horn controls but not with "touch controls" mounted on the steering wheel.

4. When the turn signal was not operated by a left side lever, drivers had difficulty locating it.

5. None of the control type/direction combinations for the parking lights were fully understood by subjects.

6. None of the tested controls for turning on the headlamps (left stalk - push up/down; instrument panel stalk control, right side - pull toward the driver, or left side - push up; rocker switch on the left side of the instrument panel) were easily located by subjects.

7. Similar difficulty was experienced with controls for the high beam (left stalk control - moves left or right; touch control on right side of instrument panel - push up).

8. For the fog lights (front and rear) neither a stalk control (right side of instrument panel - push up) nor a rocker switch (left side of instrument panel - push forward) were easily located by subjects. Separate controls for fog lights are not fitted on most cars, especially American vehicles.

9. Of the five location/method-of-operation combinations tested for the hazard flasher, drivers experienced considerable difficulty with all of them (left-side stalk control - push left; rocker switch on right side of the instrument panel - push down; touch control in same place - push left; left-side panel-mounted push button - push right).

10. A stalk control (left side - push up or down) was not easily located by drivers for the parking lights, and a rocker switch (on steering wheel - push right side forward) was extremely difficulty to locate.

The Elsholz and Bortfeld study offers many insights into how multifunction controls should be designed. While the sample sizes are small and the description of their procedure is deficient, this report deserves more attention than it has received in the past. As the bulk of the paper is concerned with symbols, it is easy to overlook.

Summary

With one exception studies of control expectancy have dealt with American drivers. American drivers expected the wiper/washer and headlight controls to appear on the left side of the instrument panel whereas foreign drivers expected stalk locations. Much of the data were biased by the use of paper and pencil methods for collecting expectancies. This approach leads the respondent to believe that one's expectations should be confined to a flat surface, like the paper (i.e., the panel) and not away from it (on a stalk). Further insights into American expectations could be gained by analyzing the Black et al. (1977) data further, especially for stalk controls.

Problem Surveys

Near-Accidents

Two kinds of data that have been combined in this section: reports of near-accidents, and somewhat more general problem-incidence surveys. The first type is primarily concerned with safety issues. The second, at times, address comfort and convenience questions.

Using near-accident and critical incident data to address safety questions is a long-established practice in the aircraft (Fitts and Jones, 1947; Falkenberg, 1973; Shannon and Waag, 1973; Ricketson, Johnson, Brenham, and Dean, 1973) and in the motor vehicle industries (McFarland and Mosley, 1954; Zuercher, Sass, and Weiss, 1971).

Of particular interest to this review is the Burger, Smith, Queen, and Slack (1977) report. Questionnaires were sent to 9,966 drivers. The 3,478 returns cited 1,691 accidents or near-accidents, some of which indicated driver/vehicle incompatibilities. Problem areas investigated included vision, steering, braking, shifting, seating, and controls. Shown in Table 11 is a summary of factors reported to contribute to accidents. The number of problems associated with finding and using controls is somewhat less than those for other factors, though it is greater than those allegedly due to alcohol and drugs (a reporting problem?). It is in the middle of the range of factors associated with vehicles. Details of problems with controls are shown in Table 12. The responses indicate that using secondary controls has been associated with potentially dangerous situations. Noteworthy are the large number of problems experienced in finding and operating the horn, the defogger, and the dimmer switch.

Given special examination in the Burger et al. (1977) study was the relationship between the number of functions/stalks and reports of finding, reaching, and operating problems. As shown in Figure 13, reported difficulties rapidly increased as the number of functions/stalks goes from 2 to 3. For the most part, the jump shown is due to difficulties with the horn in the '71, '72, and '76 Capri. They represented 13 of the 14 three function/stalk vehicles. One weakness with this study is the failure to report, with the stalk problem data, equivalent information on panel controls. The key questions are (1) how many problems are reported for functions on stalks across functions on panels, and (2) does adding a function to a stalk interact with functions already on that stalk and make them more difficult to operate?

Because of the findings of the Krumm (1974) study concerning horn location (discussed later), problems of finding and operating the horn were given special attention. (See Table 13.) These problems were analyzed for drivers who regularly operate vehicles with stalk-mounted

Table 11. Factors Contributing to Near Accidents Reported by Burger et al. (1977).

	Played No Part	Contributed Somewhat	Contributed Greatly
Vehicle			
Poor vision from car	2196	692	261
Steering or braking difficulties	2738	271	83
Gear shift difficulties	2989	83	8
Finding and using controls	2792	246	126
Visibility of other vehicles, pedestrians, signs, etc.	1777	974	266
Driver			
Fatigue	2045	883	190
Alcohol/Drugs	2788	176	81
Disregarding driving rules	2584	410	72
Inattention	1900	1014	212
Lack of driving skills	2899	125	26
Environment			
Darkness	1876	998	197
Rain/snow/ice	1366	1260	472
Fog	1521	1247	309
Sun glare	1617	1211	252
Roadway			
Poor signs (location/ readability)	1630	1144	294
Poor road conditions	1753	999	285
Poor street markings	1638	1084	283

Table 12. Problems of Finding, Reaching and Operating Controls Reported by Burger et al. (1977).

		No Problem	Annoying	Potential Danger	Close Call	Caused Accident
Headlights	Find	3219	184	20	3	0
	Reach	3378	52	10	0	0
	Operate	3332	66	21	2	0
Climate Control	Find	2722	531	34	0	2
	Reach	2995	301	31	0	1
	Operate	2794	458	51	3	1
Headlight Dimmer	Find	2926	407	78	2	2
	Reach	3073	269	57	0	0
	Operate	3019	284	83	5	0
Window Washer or Wiper	Find	3033	321	53	5	0
	Reach	3223	159	24	1	0
	Operate	3056	267	58	6	0
Defogger/De-Icer	Find	2801	490	59	6	1
	Reach	3016	293	45	2	1
	Operate	2814	418	93	8	1
Emergency Flasher	Find	2905	378	48	3	0
	Reach	3146	183	19	2	0
	Operate	3059	216	43	3	0
Horn	Find	3052	277	74	16	1
	Reach	3253	125	33	5	1
	Operate	3101	208	76	11	2
Radio, Ashtray, Lighter, Vent, Mirror, Interior Lights, Dash Lights, and Turn Signal	Find	2879	478	78	2	0
	Reach	2939	387	92	8	0
	Operate	2973	390	53	2	0

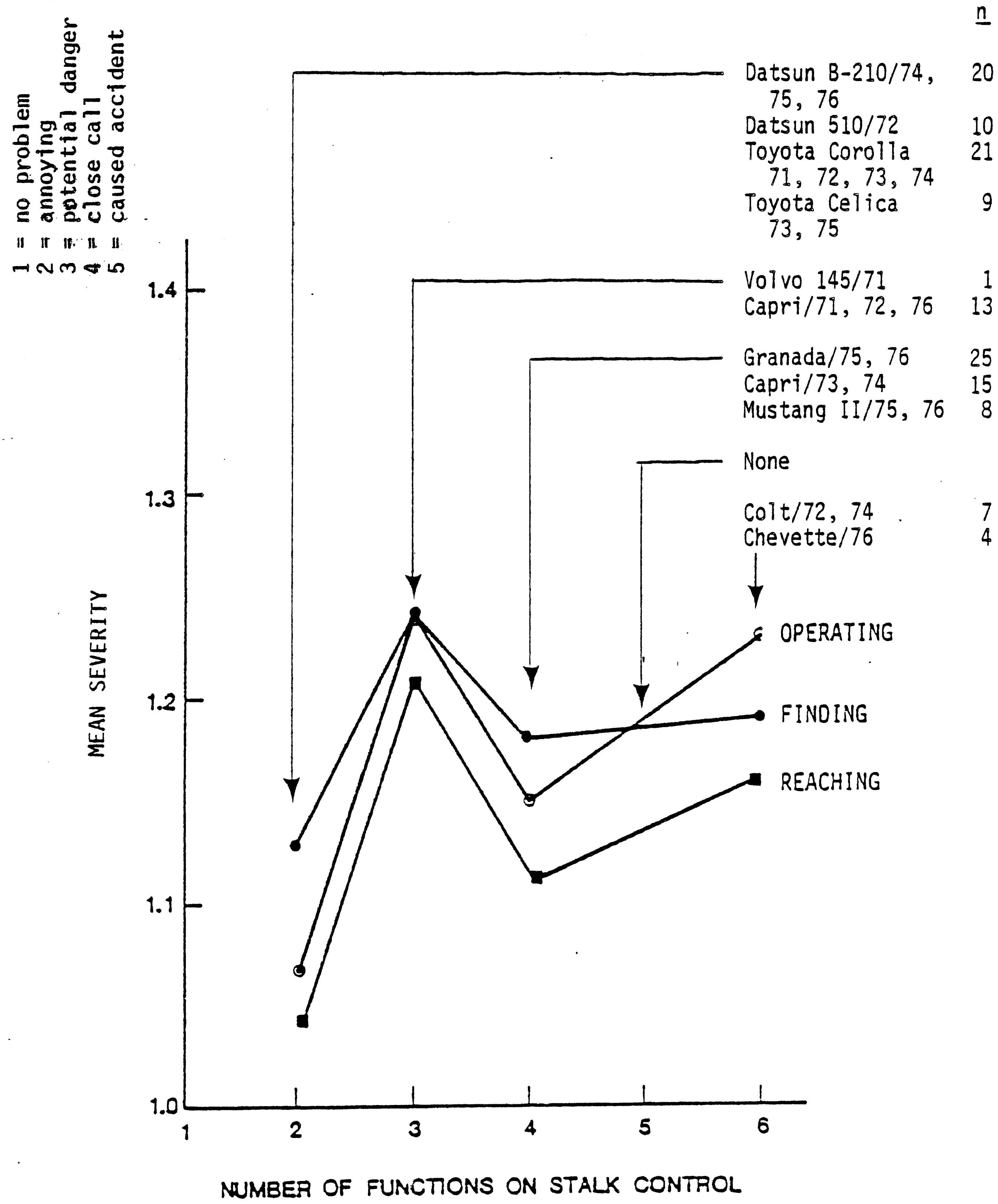


Figure 13. Control Problems vs. Number of Functions/Stalk. Reported in Burger, Smith, Queen, and Slack (1979).

Table 13. Finding and Operating Problems for the Horn, Reported by Burger et al. (1977).

Vehicle (year)		Severity Category					Type Horn
	$\overline{X}$	No Problem 1	Annoying 2	Potential Danger 3	Close Call 4	Caused Accident 5	
FINDING HORN							
Cutlass (72,73)	1.24	20	4	1	-	-	2-spoke lever
BMW 2002 (All)	1.10	9	1	-	-	-	3-spoke pushbutton
Fiat 124 (All)	1.25	6	2	-	-	-	center
Capri (All)	1.07	28	2	-	-	-	stalk
OPERATING HORN							
Cutlass (72,73)	1.16	21	4	-	-	-	2-spoke lever
BMW 2002 (All)	1.10	9	1	-	-	-	3-spoke pushbutton
Fiat 124 (All)	1.00	8	-	-	-	-	center
Capri (All)	1.27	25	3	1	1	-	stalk

horns. While those data indicate that drivers experienced more difficulty in operating stalk-mounted horns than other designs, this conclusion is based on very few responses.

General Problem Surveys

The earliest of the general problem incidence surveys is that of Krumm (1974). Summarized were interviews of 392 mostly young drivers of foreign automobiles in regard to control location and operation difficulties. As neither a copy of the survey, a list of the questions, nor univariate summaries of responses were reproduced in their report, it is most difficult to discuss this report in detail.

As was noted previously, alternative locations for the horn were compared in this study. Shown in Table 14 are problem incidence rates for the various horn locations. Higher problem rates were well correlated with longer response times in the performance study described earlier. The stalk-mounted and rim-mounted configurations caused problems for drivers.

Table 14. Problem Incidence vs. Horn Location, Reported by Krumm (1974).

	Sample Size	# Problems	%
2-spoke lever	116	5	4.
360^0 ring	32	2	6.
center	26	3	12.
3-spoke pushbutton	14	3	21.
stalk	18	5	28.
rim	9	3	33.

Also contained in that document are insights into the assignment of functions to stalks. Two plots are reproduced in a modified form. Figure 14A shows that for a single left stalk, adding functions to a stalk increases the average difficulty of finding and operating controls on that stalk. The more controls present on a single stalk, the greater the difficulty for the driver. But, it should be noted that the difficulty of operating the controls when they are panel-mounted is not reported. The question here is, "which leads to the fewest problems--all controls on the panel, all controls on the stalk, or a mix?"

Shown in Figure 14A are the results for the 2 left, 1 right stalk configuration. Criticisms of this figure have appeared in a research proposal (Highway Safety Research Institute, 1975). Due to the resemblance to Figure 14A, Figure 14B is easy to misinterpret. In Figure 14B the two points above "3 Functions" represents the mean (and not the sum) of the % reports of difficulty for finding the dimmer, the optical horn, and the headlights when all three are on left stalk 2. (Some have thought that each point in Figure 14B represents reports for the last function added to the stalk. For example, for the top indicated "left stalk 2," the point to the upper left was thought to be associated with finding the dimmer ("the first function"), the middle point associated with finding the optical horn ("the second function"), and the point on the right with finding the headlights (the third function).)

Complete data for the 2L - 1R configuration are present only where there is one function/stalk. Missing are data for finding and operating left stalk 1 when two and three functions are present on left stalk 2, and finding/operating data for the right stalk when three functions are present on left stalk 2.

The data for the 2 left - 1 right configuration appear to contradict those of the 1 left configuration. Here, instead of leading to increased difficulty, adding functions to left stalk 2 led to fewer problems. The conclusions from the 2 left - 1 right configuration must be treated as very tentative, as problem percentages for the multiple function conditions are not reported for the turn signal

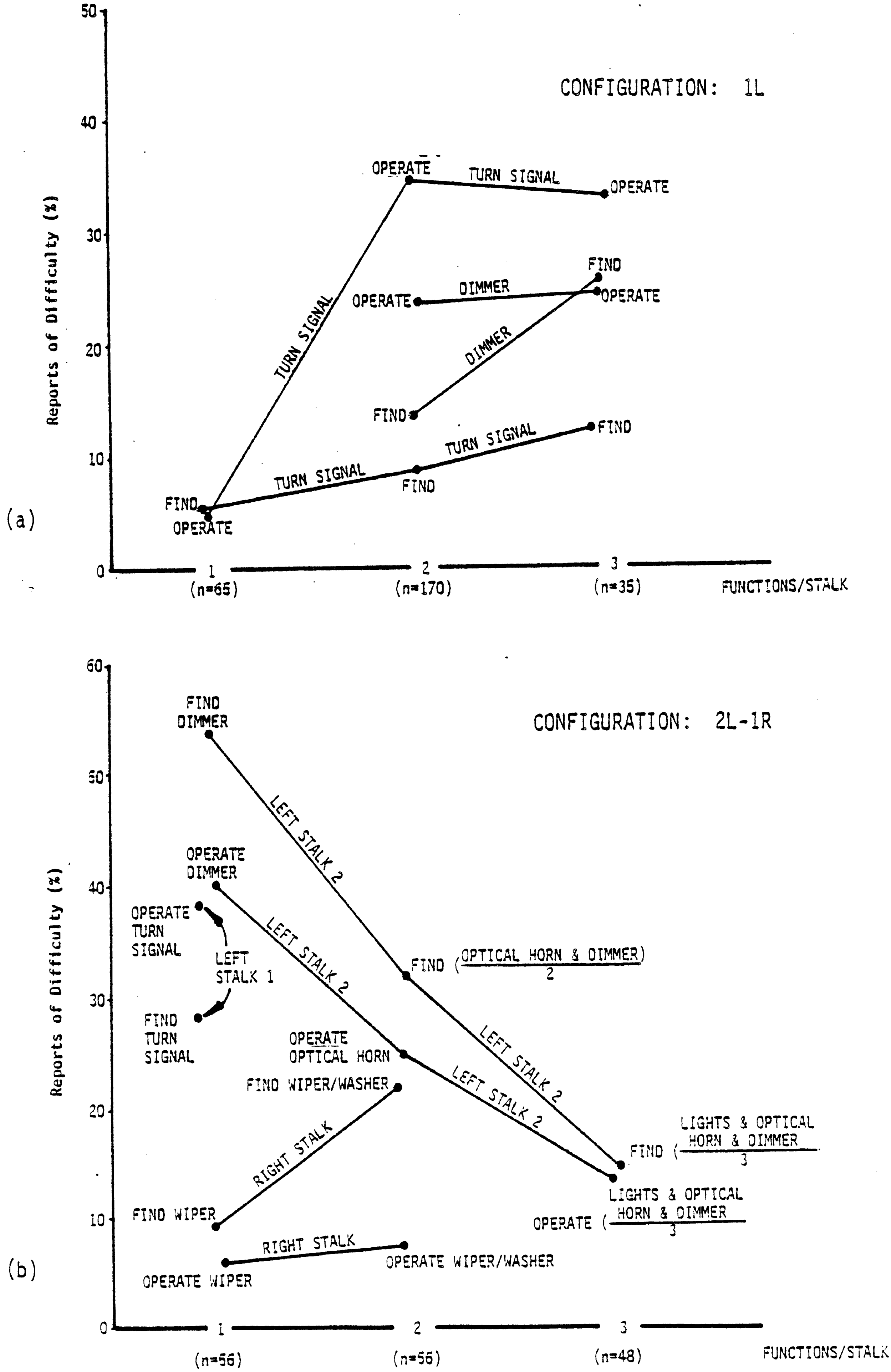


Figure 14. Stalk Operation Difficulties Reported in Krumm (1974).

(left stalk 1). It seems likely that adding functions to left stalk 2 should lead to increased difficulty with the adjacent left stalk 1.

The Krumm results do permit a conclusion to be drawn with respect to the function distribution question. For the three-function-single-left stalk roughly 23% of the drivers reported problems finding/operating for each function. For the 2 left - 1 right configuration, where only one function was on each stalk, the problem was about 30%. Given the variability in the data, these two values are not significantly different.

One point that is quite clear in the Krumm (1974) data is that the type of transmission must be considered when stalks are selected. Far more problems are experienced with stalk configurations when the vehicle (presumably left hand drive) has a manual transmission. (See Table 15.)

Finally, it should be noted that a portion of the Krumm (1974) data was reanalyzed by Mourant et al. (1977). Eleven critical incidents for finding stalk controls (8 for the dimmer, 2 for the horn, 1 for the wiper on/off) were reported. For stalk control operation four incidents (two for wiper on/off, one each for washer and headlights on/off) were reported. It is not known if these rates differ from those for non-stalk mounted controls.

Table 15. Control Problems and Transmission Type (single left, single right stalk), Reported by Krumm (1974).

	Location Difficulty		Activation Errors	
	Left Stalk	Right Stalk	Left Stalk	Right Stalk
Automatic	0.0%	9.1%	6.2%	3.0%
Manual	13.5%	25.9%	18.4%	19.9%

Reported in Anacapa Sciences (1974) (see also Anacapa Sciences (1976) are two surveys of driver-reported problems with controls. In the first, 1,140 motorists were interviewed about their own cars. At roughly the same time, about 1,900 questionnaires were distributed to drivers renting cars at an airport. Of those, 342 (18%) were returned. Shown in Table 16 are the results for controls now being considered for stalk-mounting. (Most controls in those vehicles were panel-mounted.) Noteworthy in Table 16 are the following:

1) Renters reported much greater use of accessory controls (e.g., wiper, lights, etc.), in some cases double or triple the rates, than those driving their own cars.

2) Drivers had about equal difficulty with locating and operating controls.

3) Posing special difficulty to drivers were locating and operating the horn, operating the wiper and washer, and locating the dimmer (foot switch).

Shown in McGrath (1974) for the own-car study, and reproduced in Table 17 are the difficulties encountered in locating and operating controls as a function of the control design. Problem report rates for multifunction wiper and washer controls are about the same as those for panel controls. For the horn and headlamp, there are too few cases of multifunction controls on which to base any conclusions.

Probably the most extensive examination of stalk-mounted controls to date is that by Mourant, Moussa-Hamouda, and Howard (1977). They catalogued existing configurations, collected problems associated with their use, and performed a laboratory evaluation of five configurations. The laboratory study was discussed previously. The hardware review appears later. In the problem survey, 405 drivers were interviewed while seated in their own cars (31 different makes). The sample was representative of the driving population by sex but included a disproportionately large number of younger individuals. There were

Table 16. Availability and Problems with Controls Reported by Anacapa Sciences (1976).

	Own Car Survey n = 1140						Rental Car Survey	% Problems [2]			
	% Availa-bility	% Use (current trip)	% since owned problems[1] Locate	Operate	Current trip problems % Locate	Operate	% Use (current trip) n = 342	(all renters) n = 342 Locate	Operate	First time Renters n = 342 Locate	Operate
Wiper	100	15	10.1	7.3	1.8	16.0	51	6.9	8.6	6.4	7.4
Washer	85	11	8.6	9.9	5.1	11.1	35	8.3	19.2	8.7	14.5
Horn	100	19	9.8	12.6	1.9	10.3	47	18.2	10.1	15.6	11.1
Turn Signal	100	87	2.1	7.4	0.5	3.1	89	1.3	2.6	1.8	2.4
Headlight	100	15	6.9	3.5	0.6	3.4	70	3.4	2.5	2.4	2.4
Dimmer	100	10	15.2	7.0	8.0	8.8	44	6.0	3.3	9.5	2.4
Hazard Flasher	73	7	11.0	5.5	2.0	5.9	25	3.6	3.6	4.3	--
Gear Shift	100	100	1.5	8.5	0.5	1.9	99	2.4	3.8	2.7	2.7

1. Rates based on control availability

2. Rates based on control use

Table 17. Locating and Operating Difficulties for Various Control Designs Reported by Anacapa Sciences (1974).
(n = 1140 driver owners)

CONTROL DESIGN	WIPER			WASHER			HORN			TURN SIGNAL			HEADLAMP			DIMMER			SHIFT LEVER		
	n	% DIFFICULTY LOCATING	% DIFFICULTY OPERATING	n	% DIFFICULTY LOCATING	% DIFFICULTY OPERATING	n	% DIFFICULTY LOCATING	% DIFFICULTY OPERATING	n	% DIFFICULTY LOCATING	% DIFFICULTY OPERATING	n	% DIFFICULTY LOCATING	% DIFFICULTY OPERATING	n	% DIFFICULTY LOCATING	% DIFFICULTY OPERATING	n	% DIFFICULTY LOCATING	% DIFFICULTY OPERATING
PUSH/PULL KNOB	204	10.8	7.4	178	6.7	10.7							956	6.8	2.7	1					
ROTARY KNOB	349	9.5	6.9	62	8.1	9.6							48	10.4	8.3						
LEVER	6	0.0	0.0	4	0.0	0.0	2	0.0	0.0	932	1.3	6.9	6	16.7	16.7	21	19.0	23.8	225	2.7	12.4
POD	5	60.0	20.0	7	42.9	14.3	18	27.8	0.0	144	6.9	10.4	9	22.2	11.1	185	14.6	13.5			
TAB	86	10.5	8.1	50	14.0	16.0							7	0.0	0.0						
PUSHBUTTON	30	13.3	13.3	172	6.4	9.9	148	23.6	17.6										23	4.3	21.7
RING							179	6.7	15.1												
1/2 RING							119	14.3	10.1												
PAD							392	5.9	11.2												
WHEEL CONT. PRESS							21	28.6	23.8												
STEP-on				47	19.1	12.8										859	15.7	5.2			
TOGGLE	26	15.4	15.4	4	25.0	50.0				1	100.0	100.0	26	15.4	15.4	4	25.0	50.0	4		25.0
ROCKER	18	11.1	0.0	9	0.0	0.0							13	7.7	0.0				1	0.0	0.0
THUMBWHEEL	2	0.0	50.0																		
USUAL																			455	.9	5.5
DUAL/MULT.	326	10.1	7.4	330	9.1	10.3	5	20.0	20.0				6	0.0	33.3						
BAN							131	6.9	16.0												
MANUAL																			291	1.7	11.0

four stalk configurations present: 1 left stalk (1L), 2 left stalks (2L), 1 left plus 1 right stalk (1L, 1R) and 2 left plus 1 right stalks (2L, 1R). The one-left-stalk configuration (1L) occurred most frequently. The number of functions/stalk varied between one and seven. Shown in Tables 18, 19, and 20 are the summaries of the 130 finding and operating problems reported by configuration. Mourant et al. (1977) concludes that if functions are to be stalk-mounted, it is better to add them to existing stalks than to install additional stalks for them. Frankly, those differences, when based on problems/function, are not statistically significant. In several cases the differences in the percentages are in the wrong direction.

Other general conclusions drawn by Mourant et al. (1977) include: (a) labeling decreases reported problems (but the difference was not statistically significant), and (b) there was no interaction between any of the driver characteristics (driving experience, sex, mileage, hand size, etc.) and reported problems.

The Mourant et al. study contains considerable detail regarding reported difficulty with each switch type and stalk location configuration for each function. These data are presented in Tables 18, 19, and 20. As Mourant et al. correctly note (p. 35), drawing conclusions about a particular switch design from these data is difficult. While the total number of problems reported is large, the number for each combination is small. For example, three vehicles with (1L, 1R) stalk configurations had a hand switch, which when pushed in, turned on the wiper. One driver reported a problem finding that control, thus yielding a 33% complaint rate. Clearly such a figure is meaningless. Only for flash-to-pass control are there samples of any respectable size (the largest being n = 79) and in those cases the differences between designs are slight.

Table 18. Problems of Finding and Operating the Wiper Control. Reported by Mourant et al. (1977).

Problem and Control (configuration)	Wiper On/Off: Switch Types: Lever Lift Up		Lever Pull Down		Hand Switch In		Hand Switch Rotate Toward Driver		Hand Switch Rotate Away from Driver		Slide Switch Right		Wiper Speed: Switch Types: Lever Lift-Up		Lever Pull Down		Rocker Switch		Slide Switch	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Finding Problems																				
Left Stalk (1L)					5	20.0			0	0	2	10.5					3	13.6	1	4.2
Left Stalk (1L, 1R)					1	33.3														
Left Stalk (2L)									0	0										
Right Stalk (1L, 1R)	6	10.3	5	10.9			1	33.3					2	3.5	4	8.5				
Right Stalk (2L, 1R)			2	8.3																
Operating Problems																				
Left Stalk (1L)					1	4.0			1	5.6	0	0					0	0	0	0
Left Stalk (1L, 1R)					0	0														
Left Stalk (2L)									2	18.2										
Right Stalk (1L, 1R)	9	15.5	4	8.7			1	33.3					2	3.5	1	2.1				
Right Stalk (2L, 1R)			2	8.3																

Table 19. Problems of Finding and Operating Washer Control. Reported by Mourant et al. (1977).

Location of Control and (configuration)	Switch Types: Lever Pull Toward #	Lever Pull Toward %	Lever Pull Away #	Lever Pull Away %	Hand Switch Push In #	Hand Switch Push In %	Finger Button Push In #	Finger Button Push In %
Finding Problems								
Left Stalk (1L)			0	0			1	2.4
Left Stalk (1L, 1R)					2	66.7		
Left Stalk (2L)					2	18.2		
Right Stalk (1L, 1R)	5	7.6			2	5.4	1	100
Right Stalk (2L, 1R)	1	4.4						
Operating Problems								
Left Stalk (1L)			1	33.3			0	0
Left Stalk (1L, 1R)					1	33.3		
Left Stalk (2L)					0	0		
Right Stalk (1L, 1R)	8	12.1			1	2.7	1	100
Right Stalk (2L, 1R)	0	0						

Table 20. Problems of Finding and Operating the Headlight Dimmer and Flash-to-Pass Controls, Reported by Mourant et al. (1977).

Location of Control and (configuration)	Switch Types - Dimmer								- Flash-to-Pass					
	Lever Lift Up		Lever Pull Toward		Lever Pull Down		Lever Push Away		Lever Pull Toward		Lever Pull Down		Hand Switch Push In	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Finding Problems														
Left Stalk (1L)			18	17.1			11	12.1	6	7.6				
Left Stalk (1L, 1R)	0	0	15	18.3			2	5.4	3	6.8				
Left Stalk (2L)	1	50	0	0	0	0			2	10.0	0	0		
Left Stalk (2L, 1R)			3	75	0	0							0	0
Operating Problems														
Left Stalk (1L)			13	12.4			4	4.4	0	0				
Left Stalk (1L, 1R)	1	100	8	9.8			3	8.1	2	4.5				
Left Stalk (2L)	1	50	2	18.2	1	25			1	5.0	1	33.3		
Left Stalk (2L, 1R)			2	50	9	42.9							1	50.0

Summary

Overall the problem surveys indicate:

1. Secondary control use has been reported by drivers to be associated with accidents and near-accidents.
2. Drivers reported roughly the same number of problems with multifunction stalk controls as with panel-mounted controls.
3. Most control use problems were associated with locating and activating them rather than reaching for them.
4. Adding functions to stalks may have made them more difficult to operate. The trade-off between adding functions to stalks and adding stalks is unknown.
5. Horn controls should be mounted on the steering wheel pad or spokes and not on a stalk.
6. Many drivers experienced difficulties with stalk-mounted wiper/washer controls.

While problem surveys can be a valuable source of information, they are a retrospective approach yielding only information about the past. The accuracy of problem surveys depends on driver recall, and may be in error.

Preference Studies

As automobiles are manufactured to be sold for a profit, it is desirable to market vehicles with features the customers want. Mortimer and Post (1973), as part of a larger study, had 10 drivers state their preferences for switches for a three-beam headlighting system. (Subjects did not have an opportunity to operate them.) Subjects chose from three designs. (See Table 21.) Column-mounting was preferred.

Kuechenmeister (1974) lent each of 24 General Motors employees a test vehicle fitted with a multifunction control for an evening. (On that control, a left stalk, was located the turn signal, dimmer, and

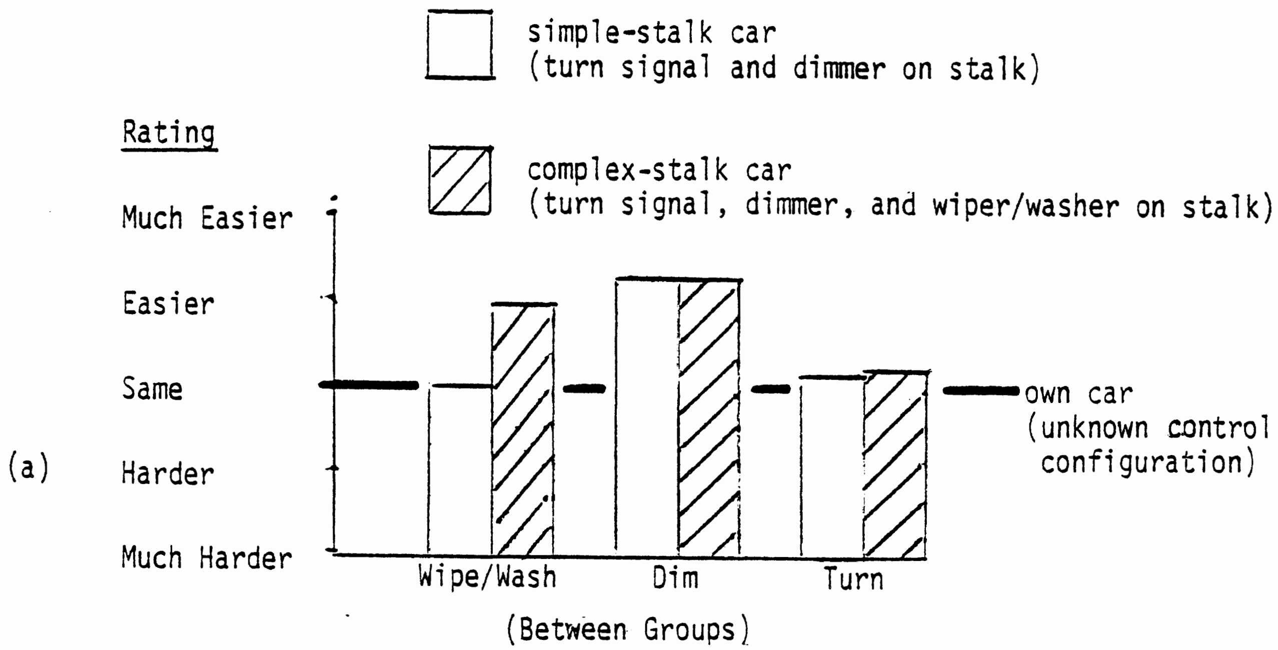
Table 21. Switch Preferences Reported by Mortimer and Post (1973).

Subjects	Preference	Method of Operation
5	stalk	push turn signal level away for low, middle, high
2	stalk (with reservations)	
2	floor-dash combination	push/push foot switch and dash-mounted pull/push beam pair selector (lower middle or middle - high)
1	cycling foot switch	push down for high (3 positions)

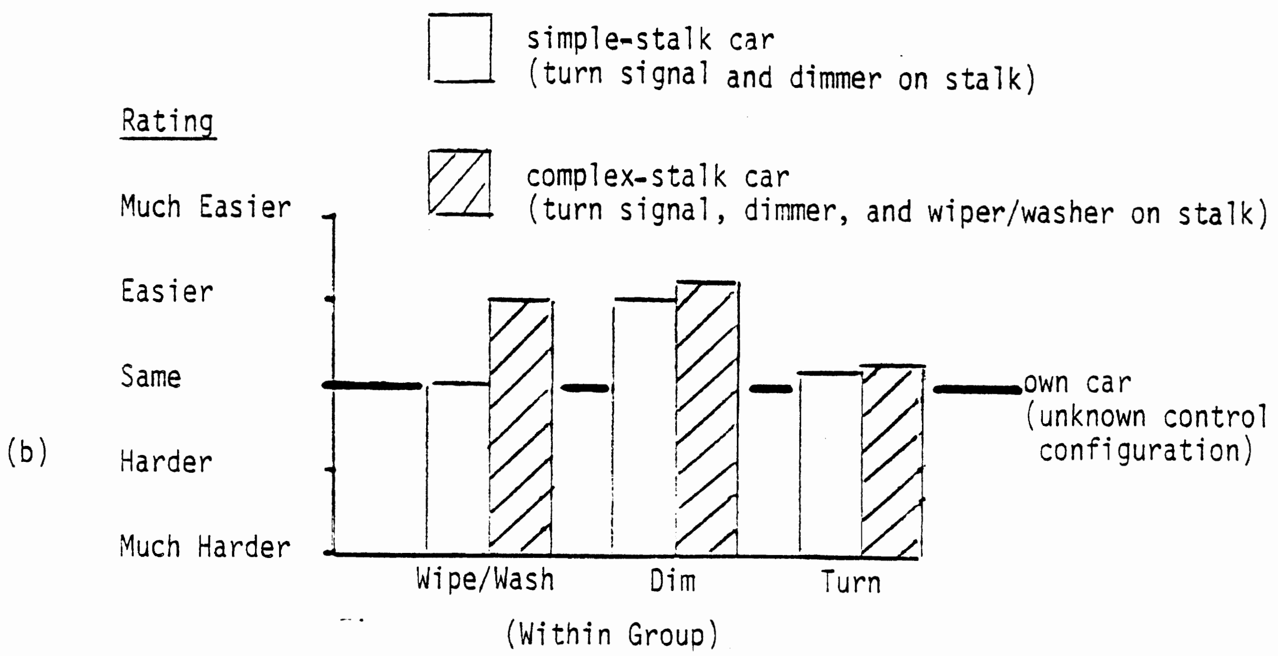
wiper/washer functions.) A questionnaire completed after returning the vehicle revealed that subjects felt the wiper, washer, and beam-switching function should be included on a multifunction control but not the headlights-parking lights on/off, hazard, cruise, or horn controls. It is possible that subjects were biased in favor of the "improved" GM product.

As part of the Mourant et al. (1977) reanalysis of the Krumm (1974) problem survey, responses concerning driver "likes" and "dislikes" for stalk controls were described. As drivers listed advantages more often, Mourant et al. (1977) concluded, "these percentages suggest that drivers prefer more functions at fingertip reach (stalk-mounted) than in conventional locations on the dashboard." (p. 104.) The author does not believe there is sufficient evidence for that conclusion.

As part of the ISO 1975 study, 16 subjects rated the ease of operation of five functions (wiper, washer, headlights on/off, dimmer, turn signal) in a vehicle fitted with a "Chevette type" stalk, relative to their own car. Another 16 provided similar ratings for a vehicle with a stalk on which the turn signal and dimmer were grouped. Shown in Figure 15 are the mean ratings. No statistical analysis of them was provided. The implication is that stalk controls are desired.

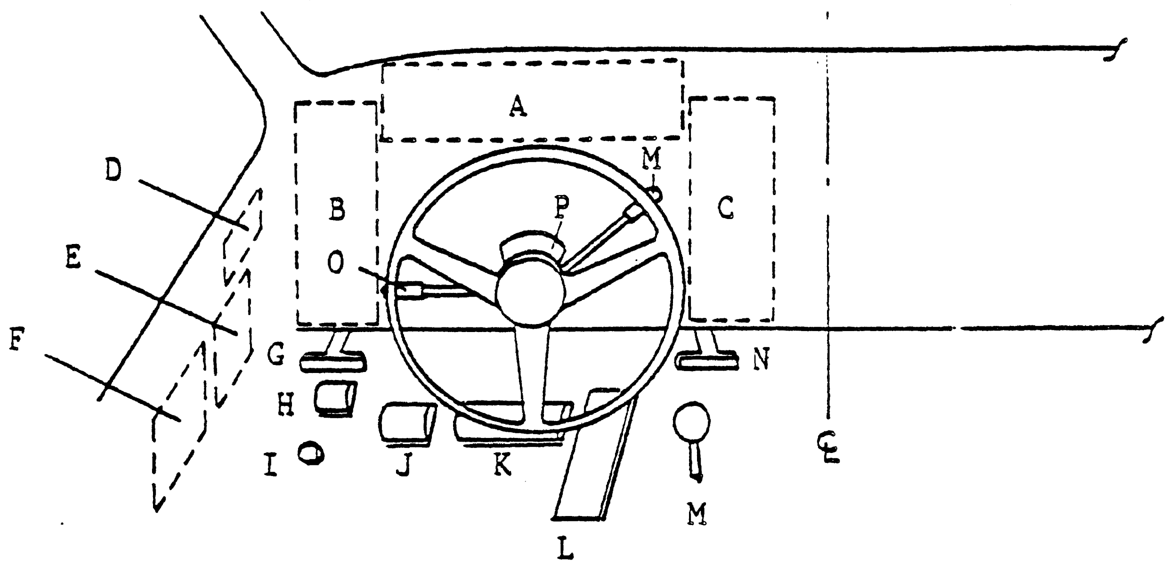


note: one group compared the simple stalk and own cars, another the complex stalk and own cars



note: same group compared simple stalk with own car and then complex stalk with own car

Figure 15. Mean Ease of Operation for Stalk Functions. Reported in ISO (1975).



A - Primary visual displays (speedometer, tachometer, oil, temperature, fuel, amps, indicator lights).

B - Lights, windshield clearing controls.

C - Radio and environmental controls/display, ignition, ash tray, cigarette lighter, choke, hand throttle.

D - Exterior mirror adjust.

E - Window lift and lock control(s).

F - Door opening control.

G - Parking brake release.

H - Parking brake.

I - Dimmer switch.

J - Clutch.

K - Service brake.

L - Accelerator pedal.

M - Gear shift lever (AUTO and/or manual).

N - Hood release.

O - Turn signal lever.

P - Gear shift position display (automatic).

Figure 16. Man Factors Panel.
Source: Woodson, Conover, Miller, and Selby (1969).

However, as the controls in the subjects' own cars were not described and the subjects may have been influenced accordingly, this implication may be incorrect.

Using subject preferences for control designs in the absence of performance data is very risky. It is well known from research on visual displays that subjects tend to prefer whatever design they were last exposed to in a test series. For these and other reasons, prererences can be misleading (see McCormick, 1970; Murrell, 1969).

It is difficult to draw conclusions from the published preference studies. The scanty evidence available indicates that drivers prefer the head-light beam-switching function to be stalk-mounted. That evidence is unreliable.

Human Factors Analyses

Several scientists have examined the extent to which various control designs are in accordance with human factors principles. Woodson, Conover, Miller, and Selby (1969) critiqued existing control designs addressing such issues as the compatibility of controls with population stereotypes, the legibility of lettering, etc. See also Conover, Woodson, Selby, and Miller (1969). Also presented was a partial draft standard for instrument panel design, a recommended panel (the "Man Factors panel" - Figure 16) and design details for the individual controls and displays. Among those details were recommendations for the labeling, sizing, and spacing of controls. For each control and display, a tradeoff rationale is presented. For the most part, the discussion of tradeoffs is very general.

While the primary emphasis of the Woodson et al. (1969) study was on instrument panel controls, this report should be examined by those interested in multifunction controls. It clearly and directly addresses many questions concerning control design.

Malone, Krumm, Shenk, and Kao (1972) performed a detailed human factors analysis of instrument panel designs for cars, trucks, and buses. (See also Kao, Malone, and Krumm, 1972.) Only the automobile work will be discussed. Unfortunately, the steps described in their main report and their Appendix B do not match, and therefore, reconstruction of their analysis process is difficult. Furthermore, they did not provide a single concise statement (page or paragraph) grouping all of the information together for each control. It is therefore difficult to determine what the decision criteria were for each control.

In developing a suggested instrument panel they stated the following were considered.

1) Current convention - Information regarding where controls and displays were then located was assembled. That information included Federal Motor Vehicle Safety Standard 101, Society of Automotive Engineers recommendations, commonality considerations with trucks and buses, the ability to accommodate options, and the right-hand rule." (The right-hand rule, a convention which they suggested, states that controls operated while the vehicle is in motion should be located to the right of the steering column.)

2) Operability - Information was assembled regarding the kind of errors that can be made in using each control and display, the workload of each item, and interference.

3) Criticality - The relationship between each item and its impact on safety was examined. All controls and displays were assigned to the criticality levels shown in Table 22.

Table 22. Criticality Scale of Malone et al. (1972).

Level	Equipment Class	Safety Impact	Safety-Related Problems	Other Major Impact
1	standard	major	high error rate, error is critical	--
2	standard or option	moderate	high error rate	--
3	↓	↓		--
4		minimal		driver performance
5				vehicle performance
6				comfort
7	↓	↓		convenience

By combining the previous criticality data with their frequency-of-use estimates, an overall priority was assigned to each control and display. Shown in Table 23 are the priorities and associated criteria. The resulting priorities for each control, its location, and the resulting panel design are shown in Tables 24 and 25 and in Figures 17 and 18, respectively. Because of its corporate origin, this design has been referred to as the "Essex" panel.

Table 23. Priorities of Malone et al. (1972).

Priority Rating	Criteria	
1	criticality rating of 1, 2, or 3 (safety)	location already standardized
2	criticality rating of 1, 2, or 3 (safety)	incidence > 10%
3	criticality rating of 1, 2, or 3 (safety)	incidence $\leq$ 10%
4	criticality = 4 (driver performance)	incidence > 10%
5	criticality = 5 (vehicle performance)	incidence > 10%
6	criticality = 6 (convenience)	incidence > 10%
7	criticality = 4, 5, 6	incidence $\leq$ 10%

Mortimer and Post (1973) also reported a human factors analysis of 13 different beam switching systems. Concepts contained in the "Reference Criteria List" (Woodson, Conover, Miller, and Selby, 1972) and the "Concept Evaluation Criteria" (Malone et al., 1972) (See Appendix B) were presented to five members of the Highway Safety Research Institute Human Factors Group. Raters identified each concept as essential, primary, secondary, not design-related, or "none of these." Later, weights of 5, 3, 1, and 0 were assigned to these terms. Of the initial concepts, four were deleted from the final list.

The total ratings (summed across the evaluators) for each concept were computed. Based on those totals each concept was assigned

Table 24. Selected Priorities and Commonality Reported by Malone et al. (1972).

Control	Priority	Code Convention Place	Arrangement	Shape	Method of Operation
Horn	2				
Gear Shift	1	2 places	X	X	X
Turn Signal	2	X		X	
Cruise	4				
Wheel Tilt	2	X	X	X	
Headlights	2	X		X	X
Panel Light	4		X		X
Parking Light	2		X		X
Hi/Lo Beam	2	X		X	X
Hazard	2				
Wiper	2				
Washer	2				

Table 25. Control Arrangement Suggested by Essex.

Control	Location	Grouped With	Arrangement Within Zone	Rational
Horn	Steering column	--	Center hub	Convention, priority
Gear Shift	Right side column	--	--	Convention priority
Turn Signal	Left side of column	Cruise	--	Convention, priority
Headlight	For upper left of panel	Panel, parking	Separated	Convention, priority
Parking light	For upper left or panel	Headlight	"	Convention, priority
Hi/lo Beam	Left side on floor			Convention, priority
Hazard	For upper right of panel		Separated	FMVSS 101, Visibility
Wiper	Upper right of panel	Washer	Central, Separated	Right hand rule, Separate from Headlight Priority
Washer	"	Wiper	Within wiper	Right hand rule, priority
Panel Light	Upper left of panel	Headlight	Separated	Convention right hand rule priority
Cruise	Left side of column	Turn signal		Convention - SAE

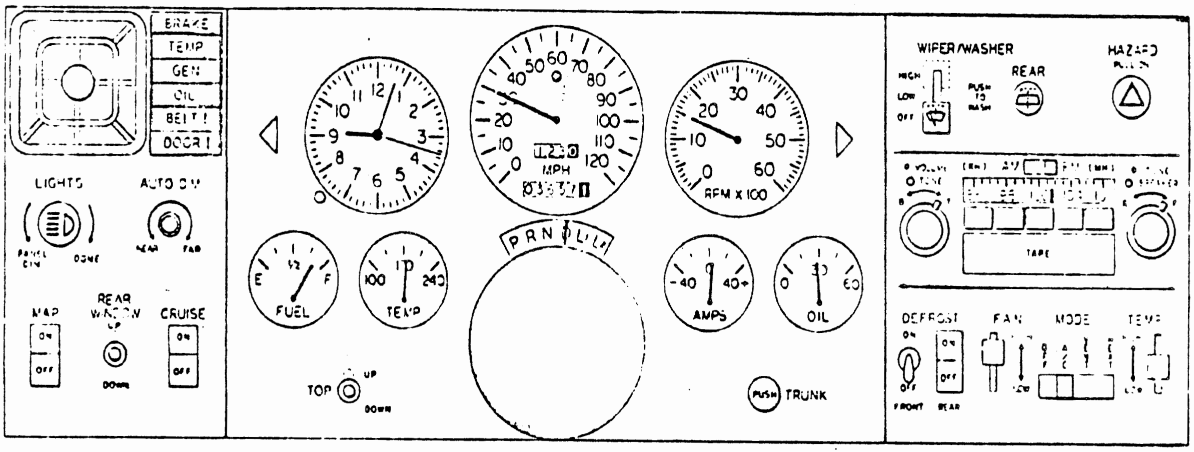


Figure 17. Drawing of Essex Car Panel.

a weight (4 = essential, 3 = primary, 2 = secondary, 1 = tertiary). The five Human Factors experts then examined each design and assigned a rating for each concept (+ = ok, - = not ok, N/A = not applicable). Based on the weighted ratings a score (0 = worst, 100 = best) was computed for each design. (See Mortimer and Post, 1973, for the calculation details.)

In those analyses the critical difference was not whether some of the controls were stalk- or column-mounted, but rather whether they permitted beam switching to occur in a single motion. The descriptions and ratings of each control design appear in Table 26.

This report is noteworthy because it is one of the few attempts to rigorously quantify the factors that are important in using controls. Its main fault is the absence of any performance measure against which the weights of the various factors can be compared. In spite of this drawback, their method deserves further attention.

Woodson and Selby (1975) examined the merits of using various fixed-seat, adjustable-controls instrument panels as alternatives to current fixed-panel adjustable-seat designs. Contained in that study is a human factors analysis of several versions of the latter design. Using a weighting scheme, the advantages and disadvantages of these versions are considered at the most general level, i.e., with regard to crashworthiness, construction costs, styling flexibility, and general controls operability issues. While considerable information is presented (e.g., anthropometric data) the location of controls and displays is not specified.

One of the few quantitative human factors analyses of control location was performed by the International Standards Organization (1975). A total error score for several configurations was computed. These scores were obtained by multiplying the joint frequency of use for each control pair (the product of the marginal frequencies, see Table 27) by the conditional confusion likelihoods (subjective, configuration-specific estimates on a 1 to 10 scale, see Table 28) and

Table 26. Designs Rated by Human Factors Experts in Mortimer and Post (1973).

			ACTUATOR (ON/OFF)			BEAM PAIR			BEAM SELECTOR		
DESIGN	RANK	FINAL RATING	LOCATION	SWITCH TYPE	POSITION	LOCATION	SWITCH TYPE	POSITION	LOCATION	SWITCH TYPE	POSITION
A	9	73	left panel	CW rotary	off/park/head	left panel	pull/push knob	high-mid/high-low	floor	push/pull stalk	
B	10	72	left panel	CW rotary	off/park/head	left panel	pull/push knob	high-mid/high-low	column left	pull/pull stalk	
C	8	77	left panel	CW rotary	off/park/head	left panel	pull/push knob	high-mid/high-low	column left	pull/push stalk	
D	5.5	89	left panel	pull/push knob	off/park/head	floor	push/push button	high-mid/high-low	column left	pull/pull stalk	
E	5.5	89	left panel	pull/push knob	off/park head	floor	push/push button	high-mid/high-low	coloumn left	pull/push stalk	
F	7	85	left panel	pull/push knob	off/park head	column left	pull/push stalk	high-mid/high-low	floor	pull/push button	
G	4	97	left panel	pull/push knob	off/park head				column left	3 position stalk	low = rear, mid = middle, hi = away
H	3	98	left panel	pull/push						delta stalk	up = hi, down = mid, away = low
I	12	70	left panel	CW rotary	note 1 below				floor	push/push button	
J	13	66	left panel	combined lever	pull positions: off, park, head				floor	push/push button	
K	1.5	100	left panel	pull/push knob	off/park head				column hub	3 interlocked pushbuttons	left button = low, middle = mid right = hi
L	1.5	100	left panel		off/park head				panel left	3 interlocked pushbuttons	top = hi, middle = mid, bottom = low
M	11	71	left panel		off/park head				floor	push/push button	light pressure alternate between hi & low, heavy pressure = mid

NOTE 1: off/park/L-M or M-H
left = L-M, right = M-H

Table 27. Error Frequencies for Controls.

Intended Action ↓ / Possible Error →		Freq. of Use[1]	Side Lamps On	Side Lamps Off	Head Lamps On	Head Lamps Off	Flash (opt. Horn)	Dip To High	Dip To Low	Horn	Turn Left	Turn Cancel	Turn Right	Wipe 1	Wipe 2	Wipe Off	Wash	Emergency Brake On	Emergency Brake Off
Proportion of Time Error Possible[2]			60	40	70	30	100	(60)[3]	(40)	100	90	10	90	95	98	7	100	99	1
Side Lamps	On	4		I	-	-	I	-	-	I	I	I	I	D 3.8	D 3.9	I	I	D 4	D 0.04
	Off	4	-		-	-	-	-	-	I	I	I	I	D 3.8	D 3.9	I	I	D 4	D 0.04
Head Lamps	On	4	-	D		D	-	I	-	I	I	I	I	D 3.8	D 3.9	I	I	D 4	D 0.04
	Off	4	-	-	I		I	-	-	I	I	I	I	D 3.8	D 3.9	I	I	D 4	D 0.04
Flash (optical horn)		(5)	I	D 2	-	D 1.5		-	-	-	I	I	I	D 4.7	D 4.9	I	I	D 4.9	D 0.05
Dip	To High	5	I	D 2	-	D 1.5			-	-	I	I	I	D 4.7	D 4.9	I	I	I	D 0.05
	To Low	5	I	D 2	-	D 1.5		D		-	I	I	I	D 4.7	D 4.9	I	I	D 4.9	D 0.05
Horn		2	D 1.2	D 0.8	D 1.6	D 0.6	I	D 1.2	D 0.8		D 1.8	D 0.2	D 1.8	D 1.9	D 2	D 0.1	D 2	I	D 0.02
Turn	Left	35	I	I	I	D 10.5	I	D 21	I	I		I	D 31.5	D 33	D 36	I	I	D 36.6	I
	Cancel	70	I	I	I	D 21	I	I	I	I	D 63		D 63	D 66	D 69	I	I	I	I
	Right	35	I	I	I	D 10.5	I	D 21	I	I	D 31.5	I		D 33	D 36	I	I	D 36.6	I
Wipe	1	(8)	-	I	I	D 2.4	I	D 4.8	-	I	I	I	I			D 0.6	I	I	I
	2	(2)	-	I	I	D 0.6	I	D 1.2	-	I	I	I	I	-		I	I	I	I
	Off	10	-	I	I	D 3	I	D 6	-	I	I	I	I	-	I		I	I	I
Wash		3	-	I	I	D 0.9	I	D 1.8	-	I	I	I	I	I	D 2.9			I	I
Emergency Brake	On	(1)	-	I	-	D 0.3	-	I	I	-	-	-	-	D 1	D 1	I	I		D
	Off	(1)	-	I	-	I	-	I	-	I	-	-	-	-	-	-	-	D	

'D' represents possible danger, 'I' inconvenience, and '-' no real consequence.

Source: International Standards Organization, 1975

Notes:
1. Values are based on data collected for 71 cars in normal use in Germany, Sweden, Finland and the U.K. for one year. The frequencies listed are 50th percentiles at 80,000 km, reduced by a factor of 1000.
2. The proportion estimates are relative to the time the engine is running.
3. Figures in brackets are estimates.

Table 28. Confusion Likelihood for Two Configurations of Controls.

Proposal A	Possible Error	Side Lamps	Headlamps	Optical Horn	Dip	Horn	Turn	Wipe	Wash	Emer. Brake
Intended Action	Side	L(P)	L(P)	L	L	L	L	R	R	R/L
Side Lamps	L(P)							2		1
Headlamps	L(P)	10						2		1
Optical Horn	L	4	4					2		1
Dip	L	4	4					2		1
Horn	L	4	4		10		10	2	2	1
Turn	L		10		10			2		1
Wipe	L		2		2					
Wash	L		2		2			10		
Emer. Brake	R/L		1					1		

Total Relative Error Number = 1865.7

Proposal B	Possible Error	Side Lamps	Headlamps	Optical Horn	Dip	Horn	Turn	Wipe	Wash	Emer. Brake
Intended Action	Side	L	L	L	L	L	L	L	L	R/L
Side Lamps	L							10		1
Headlamps	L	10						10		1
Optical Horn	L	10	10					10		1
Dip	L	10	10					10		1
Horn	L	10	10		10		10	10	10	1
Turn	L		10		10			10		1
Wipe	L		10		10		10			
Wash	L		10		10			10		
Emer. Brake	R/L		1					1		

Total Relative Error Number = 4344.5

Note: L = control located on the steering column to the left of the reference plane.

L(P) = control located on the instrument panel to the left of the reference plane.

R = control located on the steering column to the right of the reference plane.

1. These subjective estimates do not represent "official" estimates (neither of the author nor ISO) but rather values generated for discussion only.

Source: ISO, 1975.

then summing those values across all possible pairs of controls. Because the confusion likelihoods are opinions, often obtained from only one or a few individuals, the total error scores are often inaccurate. Employing objective confusion likelihoods would improve accuracy.

Probably the clearest human factors analysis of control design is contained in Black, Woodson, and Selby (1977). Controls were assigned into three priorities based on their frequency of use, requirements for viewing the controls, and a critical incident analysis. In this analysis, hazards whose elimination required the operation of a control were described along with the outcomes. Also considered were difficulties in coordinated operation of each control with other controls and displays. For each control a single summary page is provided. Included in that summary are research results, expectancy for location and duration of operation, and a subjective estimate of the frequency of use. That estimate was obtained by multiplying the installation probability (1 = all cars, 2 = many, 3 = some) by the frequency of use if installed (1 = frequently, 2 = occasionally, 3 = rarely). While this computation has its shortcomings, the manner in which the suggested locations and methods of operation emerge from the evidence is straightforward. The conclusions and other evidence in Black et al. were merged and presented in the form of a suggested future draft for Federal Motor Vehicle Safety Standard 101. (See Figure 18.) Their proposal was extremely detailed and includes all sorts of human engineering minutie (knob sizes and the like). Its style (do this, don't do this) was similar to that of Woodson and Conover (1964).

With regard to controls that might be stalk-mounted, Black et al. concluded:

"1. Headlights On/Off: Fingertip reach for this control is not required. Drivers expect it to be located to the left of the instrument panel and pull on to operate. Therefore a control of this type (or a rotary variant) is recommended.

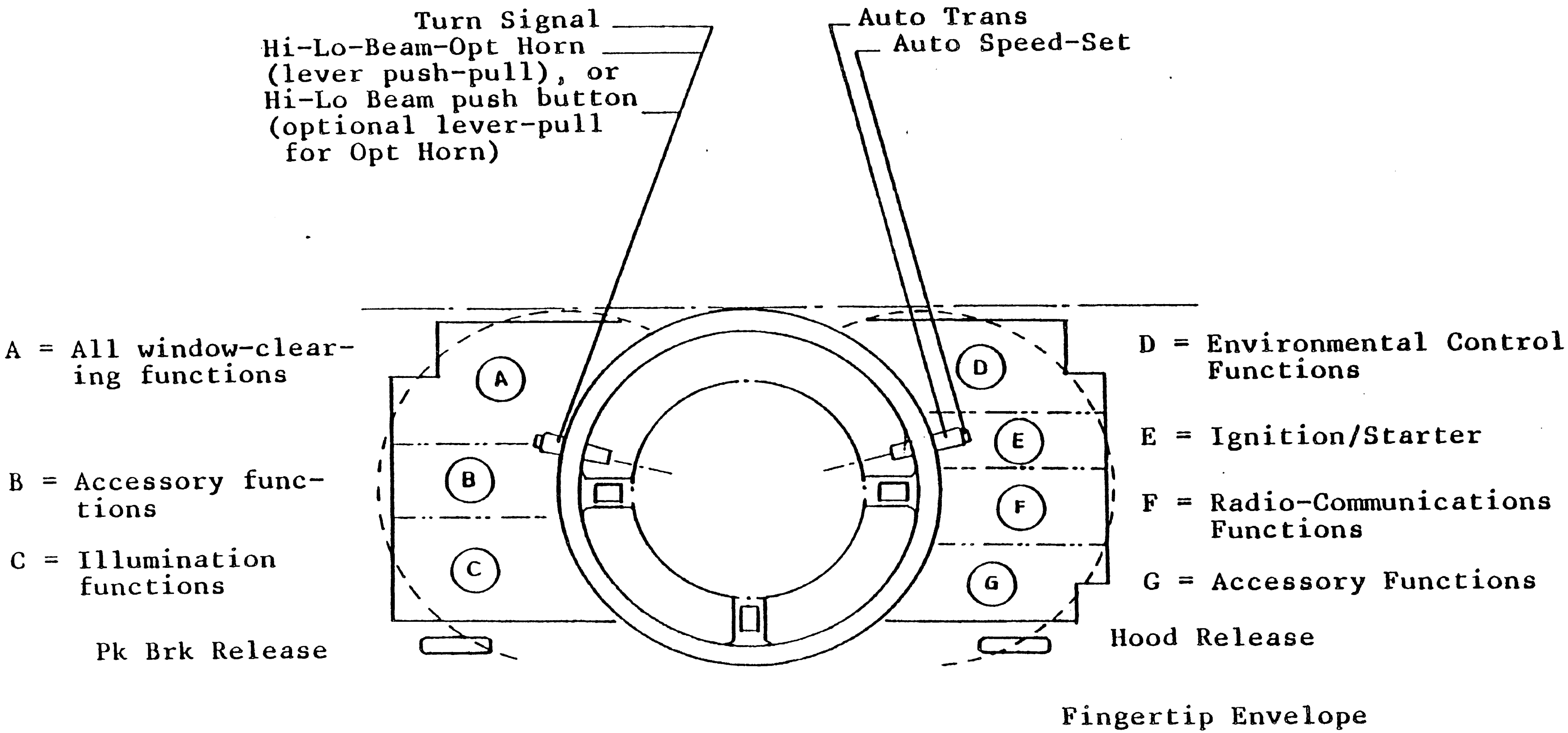


Figure 18. Proposed Controls Location Standard of Black, Woodson and Selby (1977).

2. High-Low Beam and Optical Warning: Drivers perform equally well if the control is push away or pull towards for either purpose. They suggest the positions should be high beam - push forward, low beam - mid position, flash-to-pass pull towards (spring loaded to return to low beams).

3. Gear Selector: To facilitate restarting in an emergency, a fingertip reach location (right stalk) is suggested. Driver expectancies and the Federal Motor Vehicle Safety Standard support such a choice.

4. Cruise: Locate the cruise either at the end of the right stalk (because it is associated with vehicle control) or on the right side of the panel. There is little research evidence to favor one location over another.

5. Acoustic Horn: Expectancy dictates the horn should be mounted on the steering wheel spokes or hub. Research has shown stalk-mounted horns to be error prone.

6. Wiper: Both Mourant et al. (1977) and Anacapa Sciences (1976) found problems with left-side vs. right-side locations. The left-side location is expected, while research supports fingertip location. A panel-mounted rotary switch is suggested.

7. Washer: Again a left-side location is expected. A panel-mounted push button is recommended."

Also reported within the human factors literature are approaches similar to that of ISO (1975) that were developed to predict human errors in the fabrication and delivery of nuclear weapons. A somewhat historical introduction to the problem is contained in Swain (1978). Meister (1971) describes 19 models of potential application to the problem of control design. (A briefer overview is given in Meister, 1966.) Shown in Table 29 (reproduced from Meister, 1971) are analytic models of operability which are described in the following section. The simulation models are described later in conjunction with the response time index.

Table 29. Human Reliability Models listed in Meister (1971).

A. Operability Prediction Models

1. Analytic Methods

   a. American Institute for Research (AIR) data store
   b. THERP—Technique for Human Error Rate Prediction
   c. TEPPS - Technique for Establishing Personnel Performance Standards
   d. Pickrel/McDonald
   e. Berry/Wulff
   f. Throughput ratio
   g. Askren/Regulinski model
   h. DEI-Display Evaluation Index (Siegel model)
   i. Personnel Performance Metrix
   j. Critical Human Performance and Evaluative Program (CHPAE)

2. Simulation Methods

   a. Digital Simulation Model
   b. TACDEN
   c. Boslean Predictive Technique
   d. Human Operator's Simulation (HOS)
   e. ORACLE - Operations Research and Critial Link Evaluator
   f. Personnel Subsystem Effectiveness Model

B. Maintainability Prediction Models

1. ERUPT - Elementary Reliability Unit Parameter Technique
2. Personnel reliability index
3. MIL-HDBK-472 Prediction Methods

The AIR (American Institutes of Research) Data Store (Meister, 1965; Payne & Altman, 1962) is a compilation of performance data from 164 psychological studies listing response times and error rates as a function of control and display design. The base provides considerable information about the operation of simple controls (toggle switches, rotary switches) and displays. Person/equipment reliability is computed by multiplying the probabilities for each task characteristic together. For reference purposes, a sample table drawn from the AIR Data Store is presented (Table 30). Unfortunately, not much effort has gone into updating that data base. In many areas it is deficient. No data are provided for discrete multidirectional levers (or combined levers). Because the information was collected for single-task performance, it is uncertain how relevant that data base is to a time-sharing activity such as driving. In addition to flaws of the supporting data, this approach (and several others) assumes that a simple multiplicative model is adequate. Interactions are absent. It is not known how valid that assumption is (Swain, 1968).

THERP (Technique for Human Error Rate Prediction) is an extension of the AIR Data Store. It differs primarily in permitting both continuous and discrete behaviors and allowing for both independent and dependent operator activities.

TEPPS (Technique for Establishing Personnel Performance Standards) differs from THERP in that it deals only with discrete tasks and relies entirely on expert judgments of task performance reliability. The weakness of TEPPS is that inter-judge reliability is low. This also casts doubt on the merits of the ISO (1975) approach.

Other models are listed in Table 29 for the sake of completeness and are of secondary importance for control design. (For example, DEI is concerned only with displays.) For further information on these and other models see Blanchard, Mitchell, and Smith, 1966; Meister, 1971; Rigby, 1967; and Swain, 1963.

Table 30. Sample Table from the AIR Data Store.

LEVER

(Bar control which moves in a single plane; includes use of wrench or pliers to make adjustment.)

BASE TIME = 1.15

Time added	Reliability	
		1. Length
0	.9990	a. Long lever with arm movement, <u>or</u> short lever with wrist or finger movement
0	.9920	b. Short lever with arm movement
		2. Support of operating member
0	.9990	a. Present
.50	.9950	b. Absent
		3. Plane of movement
0	.9992	a. Vertical
0	.9999	b. Horizontal
		4. Control movement amplitude (Extent of movement from one extreme to the other.)
0	.9964	a. 5-10°
.20	.9970	b. 10-20°
.40	.9975	c. 30-40°
.60	.9985	d. 40-60°
		5. Control resistance
		a. Hand operation
0	.9999	(1) 2-5 lbs.
.50	.9992	(2) 10-20 lbs.
		b. Arm operation
0	.9990	(1) 2-5 lbs.
0	.9999	(2) 10-20 lbs.
.50	.9995	(3) 20-30 lbs.
		6. Control/display movement relationship (direction of movement)
0	.9999	a. Direct
1.00	.9985	b. Reverse
		7. Control/display movement ratio (Usually defined in terms of distance.)
1.50	.9957	a. 1:1
1.50	.9970	b. 1:3
1.00	.9983	c. 1:6
.50	.9975	d. 1:15
0	.9985	e. 1:30

Source: Munger, Smith and Payne (1962).

These models, especially AIR, THERP, and TEPPS, provide insight into the problems of multifunction control design and evaluation. They address many issues (e.g., the need for objective error estimates, the frequency, nature, and independence of multiple errors, etc.) yet to be resolved in the automotive human factors literature.

Summary

Human Factors analyses of automobile control design vary from general discussions of various configurations (e.g., Woodson, Conover, Miller, and Selby (1969)) to structured evaluations (e.g., Mortimer and Post (1973), ISO (1975)). Except for the latter two studies, unifunctional panel-mounted controls have been favored. Most of the studies performed so far have collected expectancies, problem reports, and performance data for American drivers. As Americans have more experience with panel controls than multifunction-stalk controls, these conclusions are not surprising.

Most noteworthy of these efforts is that of ISO (1975). If that analysis could be based on entirely objective error estimates, it, along with the Mortimer and Post approach, could very well point to the "best" design. Research has shown that where evaluations were loosely structured (checklist-based), the correlations between those human factors evaluations and system performance were low (Meister and Farr, 1966).

Conclusions Regarding the Literature

To recap, the literature makes several points:

1) There have been several previous literature reviews of automotive human factors research; none has been very critical. Research concerning control design is briefly described in those reviews. As they are short on detail, they are of secondary importance.

2) Only Perel (1976) has examined the relationship between accident reports and control design. He found a number of

instances in which hand controls were associated with accidents, especially the horn.

3) There have been 13 major experiments in which control operation performance has been examined. They do not suggest a simple rule favoring either stalk- or panel-mounted controls. Several factors cause this state of affairs. Panel-mounted controls are expected by American drivers. As long as controls were within five inches (the author's interpretation) of their expected location, performance did not suffer. Stalk controls were usually located closer to drivers than panel controls. As the time to reach for a control is about half of the time to use it, stalk controls were responded to more rapidly once their location becomes well known (after practice). Stalk controls were at a further disadvantage early in practice because their small surface area makes labeling difficult. The absence of labeling tripled error rates early in practice. Those errors added an average of two seconds to the time to use a control.

4) Except for the Mourant et al. (1977) and ISO (1975) reports in which alternative designs for a single left stalk were compared, the role of the number of stalks and their design has not been evaluated. In an independent manner, the location of the horn control has been considered. Hub or spoke locations were found to be far superior to stalk-mounting.

5) Methodological issues have been resolved for studies of panel-mounted controls. Laboratory and on-the-road performance were well correlated. The recommended procedure has been to have the driver timeshare between tracking and operating controls on real instrument panels or touch controls shown on slides. Dependent variables have included measures of tracking skill, reaction time, errors, and the number of direct looks to the control. These measures were related.

6) Most of the surveys of control expectancy have examined American drivers. Americans expected panel-mounted controls. Europeans had stronger expectancies for stalk controls, especially the French and Italians for the beam switch and the French and British for the horn.

7) There have been five major studies of problems and near accidents in using controls. All surveyed American drivers. Those studies showed that most problems were with finding and operating as opposed to reaching for controls. One cannot draw any sweeping conclusions about stalk design from them, though difficulties with stalk-mounted horns were often reported. While all of those studies questioned at least 300 drivers, the number of drivers reporting on each design configuration was small (often 10 or less). In many cases, therefore, conclusions regarding specific designs are tenuous. For the purpose of international standardization, more information about foreign drivers is needed.

8) From the limited evidence collected, drivers are reported in favor of stalk controls. The author considers that evidence unreliable.

9) A number of individuals have completed general human factors analyses of control design. Factors usually considered were: existing design stereotypes, driver expectancies, the need for a control to be operated quickly, the frequency of operation, and the relationships among controls. Those analyses have generally favored panel-mounted controls.

10) Somewhat more quantitative analyses have also been performed. Those included ratings based on lists of concepts and error counts based on judgments of control confusability. Approaches popular in the nuclear weapons industry show that those judgments can be unreliable. Human factors analyses should be based on objective error estimates.

Thus, the literature does not provide a sound basis for any recommendations concerning stalk control design, though it does indicate how those questions should be researched.

HARDWARE REVIEW (DESIGN STEREOTYPES)

Previous Hardware Reviews

In developing a standard for the design of controls, knowledge of how controls are arranged on existing vehicles is valuable. To minimize costs, it is desirable to avoid redesigning instrument panels where feasible. Woodson, Conover, Miller, and Selby (1969) (see also Conover, Woodson, Selby, and Miller (1969)) sampled, based on sales volume, all 1969 model cars sold in the United States in excess of 500 units/year (this constraint was later relaxed). Roughly 80% of the 100 vehicles examined were of domestic manufacturer and 20% of foreign manufacturer. With regard to controls, their survey revealed a large variation within and between manufacturers with regard to the location, identification, and accessibility of controls. For the lights (on/off) and wiper/washer switches, only panel-mounted controls were found. Details regarding their location (tabular summaries or dot density diagrams) are not provided. Because of its age and the number of interim design changes, the hardware review of Woodson, Conover, Miller, and Selby (1969) is of only historical interest.

Malone, Krumm, Shenk, and Kao (1972) surveyed roughly 90% of all American 1971 cars and 76% of the imports (87% total) by model (37 model categories). The locations of 19 controls and 14 displays were tallied using a system of 49 zones.

Typically, controls were found in an average of five zones. Both the wiper/washer and headlights controls were found in many locations. In regard to stalk controls, only the turn signal was such with any consistency (100%). None of the vehicles had stalk-mounted wiper/washer or headlights controls. The only other stalk-mounted control was the dimmer switch (on left stalk in 24% of all vehicles examined--all of foreign origin).

As part of his 1974 study, Krumm presented design stereotypes for a sample of 392 (or 391, the total varies) foreign cars. Included were

61 control-stalk combinations distributed among 25 vehicle types. There were four stalk configurations present: 1 left, 1 left plus 1 right, 2 left, and 2 left plus 1 right. Unfortunately, details of the designs encountered were not presented. The design stereotypes he found are presented in Table 31.

Reported by Anacapa Sciences (1974) (see also Anacapa Sciences, 1976) were data on the location of 12 controls (only 10 are shown in Anacapa Sciences, 1974) in 77 American and 38 foreign-made 1973 models. These data were intended to check changes that occurred since the Malone et al. (1972) survey of the 1971 model year. Aside from the turn signal, stalk locations are reported only for the dimmer. (Of 52 models examined for this feature, 44 had footswitches, 6 were on the left stalk, and 2 were elsewhere.)

Unlike the Malone et al. report, Anacapa Sciences reports the actual location and not the location within an arbitrary zone. As Anacapa Sciences notes, this avoids the problem of "gerrymandering" zones to fit the experimenter's views. Furthermore, the dot density diagrams are more informative than the zone probabilities.

Anacapa Sciences (1976) notes there were minor differences between the Anacapa Sciences (1974) and Malone et al. (1972) studies due to the two samples not being matched by model. As the Malone sample is more comprehensive, Anacapa Sciences suggests that sample is preferred. The pictorial presentation in Anacapa Sciences (1974) report makes it more useful.

Contained in the McGrath (1974) study (see also Anacapa Sciences, 1974) are control location data for 69 models of European automobiles. McGrath reports the original data was supplied by ISO. It appears (but there is no confirmation) that a summary of that data is in International Standards Organization document ISO/TC22/SC13/WG2 (Secr.-2)2. (That document in turn was circulated as part of document ISO/TC22/SC (WG2-6)218.)

While generally found on the left of the instrument panel in American cars (92%), the headlight switch was found there in only 62%

Table 31. Design Stereotypes Reported by Krumm (1974).

Configuration	Left # 1	Left # 2	Right # 1	# Functions
	Stalk			
one left (1L) n = 278	(nearest driver) turn signal			1
	turn signal + dimmer			2
	turn signal + dimmer + optical horn			3
one left-one right (1L-1R) n = 83	turn signal		headlights on/off	1
	turn signal + dimmer		wiper & washer	2
	turn signal + dimmer +optical horn		wiper + wiper mist + washer or headlights on/off + wiper + washer	3
two left (2L) n = 13	turn signal	dimmer		1
		dimmer + optical horn		2
		headlights + dimmer + optical horn		3
two left-one right (2L - 1R) n = 17	turn signal	dimmer	wiper	1
		dimmer +optical horn	wiper + washer	2
		headlights + dimmer + optical horn	wiper & wiper mist washer	3

of European left hand drive cars. In 25% of these cars, the headlight switch was found on the right side of the panel. For right-hand drive cars, left and right panel-mounting occurred equally often.

The wiper and washer switches were usually located on the left side of the instrument panel in American cars. In European left-hand drive cars these controls occurred equally often on the panel (usually left) or a stalk (usually right). In right-hand-drive cars, panel-mounting (usually left) was most commonplace.

Finally, McGrath (1974) found the hazard switch on the instrument panel (usually on the right) in most European cars. American practice was to mount it on the right side of the steering column.

Shown in Table 32 are the number of vehicles (31 car makers) sampled by Mourant et al. (1977) with each switching configuration. It should be noted that Mourant sampled users and not manufacturers. Therefore, some vehicles were tallied more than once and others not at all. The composite figures thus represent a random vehicle that a user might encounter. Stalk configurations encountered included (1L)-222 cars, (1L, 1R)-133 cars, (2L)-24 cars, and (2L, 1R)-26 cars.

For wiper switch, the most prevalent stalk location was on the right side. The motion required to turn on or increase wiper speed was split roughly evenly between lifting the lever up or pushing it down. In addition, left-stalk mounting was also found, with methods of operation including pushing in a hand switch, rotating the left stalk toward the driver, and operating a switch on the left stalk face. Left-stalk locations were half as likely as right-stalk locations.

Most often, the washer was operated by pulling a right stalk towards the driver. Almost equally often it was operated by either moving the entire right stalk in or pushing a button on its end.

Headlighting controls were always found on a left stalk. Almost without exception beam flashing (optical warning) is achieved by pulling the lever towards the driver. Beam changing, however, included

Table 32. Number of Vehicles with Each Switching Configuration in Mourant et al. (1977) Sample.

FUNCTION	LEVER				HAND SWITCH						Stalk Location	Stalk Configuration
	Lift Up	Push Down	Pull Towards	Push Away	Push In	Rotate Away	Rotate Towards	Push-Button (on end)	Side Switch (on face)	Rocker Switch (on face)		
Wiper on/off					25		18		19		left	1L
					3							1L, 1R
							11					2L
	58	46				3					right	1L, 1R
		24										2L, 1R
Wiper speed									24	22	left	1L
												1L, 1R
												2L
	57	47									right	1L, 1R
												2L, 1R
Washer on/off				3				42			left	1L
					3							1L, 1R
					11							2L
			66		37						right	1L, 1R
			23					1				2L, 1R
Flash-to pass			79								left	1L
			44									1L, 1R
			20									2L, 1R
					2							2L
Beam Changes			105	91							left	1L
	1		82	37								1L, 1R
	2	4	11									2L
		21	4									2L, 1R

Note: This table was constructed from Tables 3.6-1.10 in Mourant (1977). These values were estimated by dividing the number of problems reported for each configuration by the problem rate (percentage/100). Because they were calculated, these numbers may differ slightly from Mourant's original values.

a mixture of that configuration (a pull-pull switch) and a 3-position lever (toggle-like) switch (center = low beam, push away = high beam, pull towards = momentarily switch to high and spring back to center when released).

The author feels a bit uneasy about the Mourant et al. study, because the means by which vehicles were sampled was not specified. A "random" strategy is suspected. In addition, the model years of the vehicles sampled is not given beyond the remark that 90% were "post-1970 models." It is quite likely that Mourant et al. hardware review reflects the state-of-the-art of 1974 and not 1977.

Six previous studies have reported original design stereotypes. Except for the McGrath (1974) and Mourant et al. (1977) studies, previous hardware reviews provide little guidance, because of the absence of multifunction controls. Even then the reviews are concerned primarily with foreign vehicles. Those studies do, however, convey a tendency of the beam-switching function to be located on the left stalk (pull toward the driver to operate) and the wiper/washer on a right stalk (method of operation inconsistent).

Design of 1977-1979 Automobiles

Shown in Appendix D are the results of the hardware survey performed as part of this study. Examined were all vehicles of the 1977-1979 period for which information could be obtained. Excluded were reproductions of historic vehicles (Stutz, Bearcat, Model T Ford, etc.) and vehicles thought to be neither innovative nor of importance to the world market (e.g., East German Warthog). Because of the time available to perform this study, the survey is far from complete, particularly for vehicles manufactured overseas and not sold in the United States. (An exception is VW, which was extremely cooperative in supplying information about their non-U.S. products.) Nonetheless, the survey does provide a reasonable picture of the stalk configurations in use during this period. A summary of the survey for 1979 cars with stalk-mounted (wiper/washer controls) is shown in Table 33.

Table 33. 1979 Cars with Stalk-Mounted Wiper/Washer Functions.

Configuration	Manufacturer
(1L)	Mercedes
	Fuji (Subaru)
	Chrysler/Dodge (Omni, Horizon, St. Regis, New Yorker Newport, Arrow, Colt)
	Ford (Versailles, Monarch, Granada)
	GM (Chevette)
(1L,1R)	Peugeot (504,604,2CV,Dyane, LN)
	BMW
	VW (except for Audi 100-Germany)
	Maserati
	Toyota
	Nissan (Datsun)
	Toyo Kogyo (Mazda except for GLC)
	Honda
	Saab-Scania
	Volvo
	Lotus
	British Leyland
	GM (Opel)
(2L)	Alfa Romeo
	Ford (Fairmont, Zephyr, Mustang, Capri, Futura)
	Toyo Kogyo (Mazda GLC)
(2L,1R)	Citroen (GS)
	Fiat (including Lancia, Ferrari)
(1L,2R)	Ford (Fiesta)

Note: On most Citroen products (CX, Visa, and GSA) controls are pod-mounted.

This survey is not completely reliable. Most of the information was obtained by calling manufacturers and asking them to describe their products over the phone. While some were willing to check owner's manuals they had on hand, others checked their memories. (Letters to them often were unanswered.) Where possible, owner's manuals and/or actual vehicles were examined to confirm or correct responses.

Five major stalk configurations were observed. In foreign vehicles the most popular was the one-left plus one-right stalk configuration with the beam switching control mounted on the left and the wiper/washer control on the right. Shown in Figure 19 is an example of this design. (See also Figure 20.) Among others, this configuration was found in Saab, Volvo, Toyota, Datsun (Nissan), Mazda (Toyo-Kogyo), Honda, Lotus, and British Leyland products.

There was considerable variation among one-left plus one-right stalk designs. While the tendency has been to mount beam-switching controls on the left and the wiper/washer control on the right, there are numerous exceptions. For example, in the Toyota Corona the headlights on/off control were on the right stalk. Likewise in the Mazda, the right stalk operated the headlights, the left stalk controlled both beam switching and the wiper/washer. Control operation was inconsistent even when the beam-switching control was found on the left stalk and the wiper/washer control was found on the right. For example, in the Saab the beam switch was operated by pushing away for low beam and pulling towards the driver for high beam. In the Volvo the switch was a pull/pull type. Similar conflict is found in the operation of the right stalk wiper. For example, in the Renault R12 one lifted the right stalk up to operate the wiper. In the R17 the opposite motion was used; the lever was pushed down. In the older Datsun (Nissan) 510's and 810's, one twisted the right stalk to operate the wiper. Thus, even where there was agreement in regard to which control operated each function, the method of operation across vehicles were often opposite.

Also observed were a number of models in which a single left stalk was fitted. (See Figures 21 and 22 for examples.) In this case both the headlight beam switch and wiper/washer controls were all on the same stalk. Vehicles having this design included some Datsun (Nissan) products, Suburu, and most notably Diamler-Benz (Mercedes). This design is often referred to as the Mercedes design.

The two-left plus one-right stalk design is used by Fiat and has appeared in Peugeot vehicles of the past. (See Figure 23 for an illustration.) Peugeot is phasing out this design.

Also observed was a one-left plus two-right stalk design, found only on the Ford Fiesta (Figure 24).

Vehicles having two left stalk designs included many Ford (U.S.A) products (See Figure 25 for an illustration) and the Mazda GLC.

It is the author's view that American manufacturers, with the exception of Ford, are moving towards adopting a multidirectional left stalk design. Production by the Saginaw Steering Division of columns both for the parent firm (GM) and Chrysler and AMC, has caused this shift. While Chrysler and AMC have modified the GM design, they have, in a sense, adopted it.

This change began several years ago with the movement of the dimmer from the floor to the turn signal lever. In most cases the dimmer is a pull/pull switch and an optical warning capability is absent. More recently a wiper/washer element has been added. (At General Motors this design is known as the Chevette design. Chrysler calls it a "smart switch.") In this configuration the wiper function is operated by twisting the stalk away from the driver, and the washer by pushing an end button in towards the column. Also in this configuration, two variations of the cruise control have been noted: either combined (set switch on the end of the stalk, slide switch (resume, on, off) on the face of the stalk) or separated (a second short stalk mounted behind (with respect to the driver) the primary stalk.

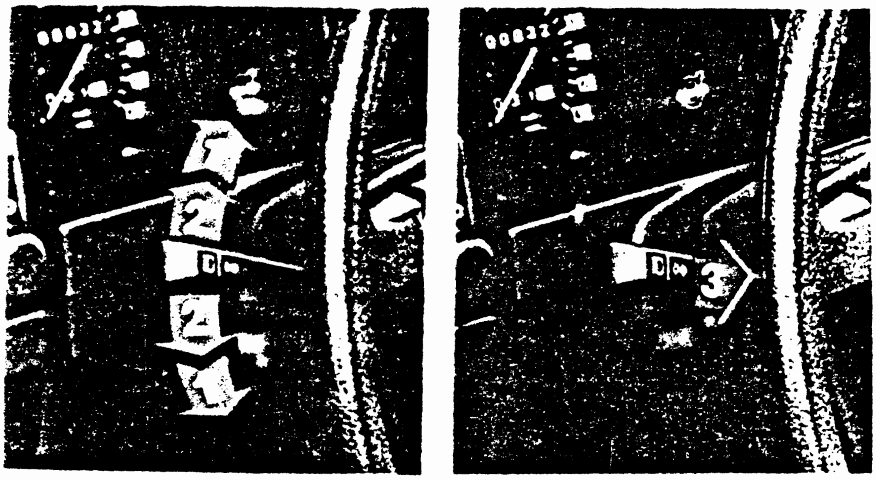
The exception to this practice is the Ford two-left-stalk configurations for which the near stalk operates the turn signal, the dimmer, and the horn (push button on the end of the lever) and the far left stalk operates the wiper/washer. The washer is operated by pulling the stalk towards the driver, the wiper by pushing the lever up.

In addition to combined levers supplied as original equipment are some that can be added later. Sears, Heathkit, J.C. Whitney, and others sell cruise controls designed to be mounted piggyback on or replace the turn signal lever. (See Figure 26.) While not examined in detail, the only design noted was one in which the set button is on the end of the lever and a slide switch was on the face (push towards column - resume, on, off).

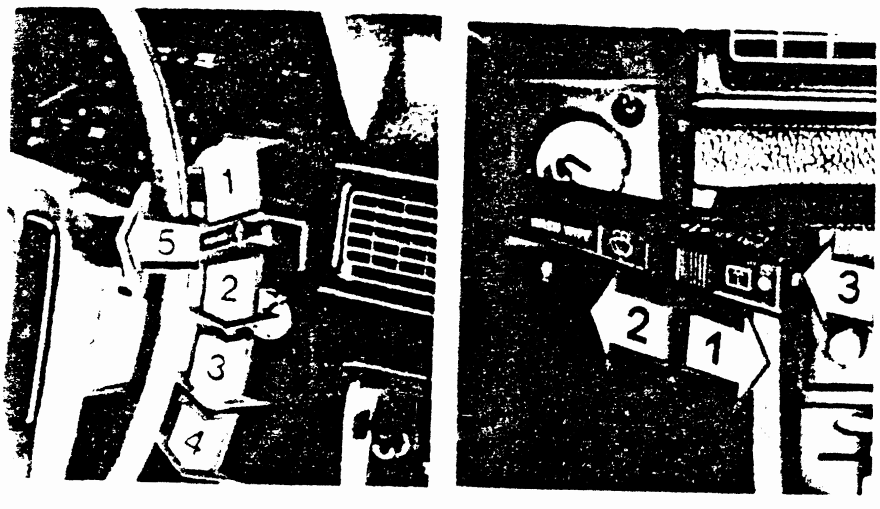
While not the focus of this report, several unusual alternative types of controls noted were on Citroen vehicles. In the past, Citroen has used stalk designs similar to those of other European manufacturers. One example of a novel design is that of the Citroen CX. (See Figure 28 for illustration.) On the CX there are two fingertip-reach pods, one to the left at 10 o'clock and one to the right of the steering column at 2 o'clock. Mounted on these pods are slide, rocker, and push button switches. A second interesting alternative are the controls found on the Citroen Visa and Citroen GSA (see Figures 29 and 30 for pictures). In these vehicles a cylinder mounted on an arm extending from the instrument panel is located within fingertip reach. Twisting the top of the cylinder operates the wiper, twisting the bottom turns the headlights on and off. Beam switching is accomplished by pushing a tab on the bottom. The turn signal is a slide rocker switch. The horn is operated by squeezing the cylinder. Both the CX and Visa/GSA designs, while unique, may be viable alternatives to stalk mounting. They need to be considered further.

Thus, a number of control designs were uncovered. Virtually every possible combination imaginable of one to three stalks, operating motions (pull or push (up or down, forward or backward, in or out) or twist (towards or away from the driver)) and functions (lights on/off, beam switching, wiper/washer, horn, cruise) was found. Only the turn signal was located or operated in a consistent manner, except, of course, in new Citroen products.

Turn signals

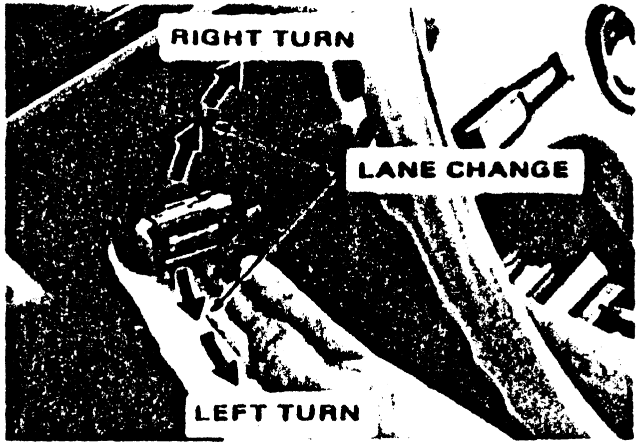


1979 Volvo 242/244/245



1979 Volvo 242/244/245

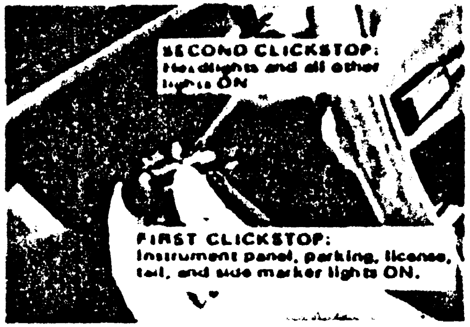
Figure 19. One Left plus One Right Stalk Configuration in Volvo Products.



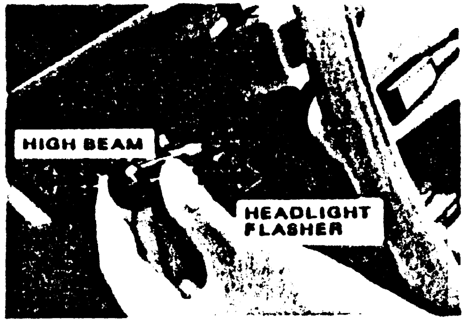
For signaling turns, move the switch up or down in the conventional manner.

1979 TOYOTA COROLLA

Combination headlight, dimmer, and turn signal switch



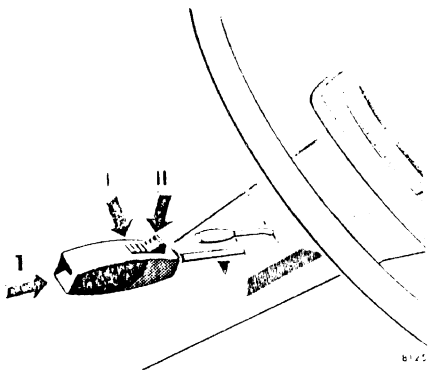
To turn the lights on, twist the knob on the end of the switch.

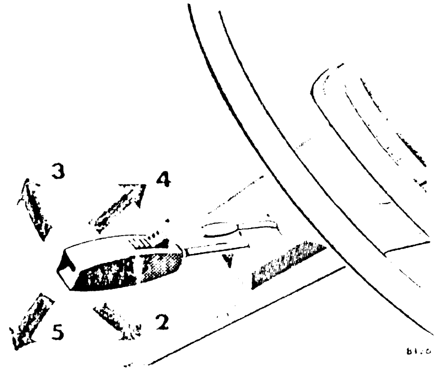


For high beams, push the switch forward. Pull back for low beams. For headlight flasher, pull further back.

1979 TOYOTA COROLLA

Figure 20. Left Stalk of 1979 Corolla ((1L, 1R) Design).





Combination Switch

1 Windshield wipers (push knob once = wipers on, push once more = wipers off)
  I Normal wiper speed
  II High wiper speed
2 Turn signals, left
3 Turn signals, right
4 Headlight flasher (high beam available independent from light switch position)
5 Windshield washer pump

Hints

Turn the steering lock key to position "2" to cut off power to standing lights.

When the windshield wipers are disengaged, the toggle switch returns to position "I" automatically.

MERCEDES
(old design)

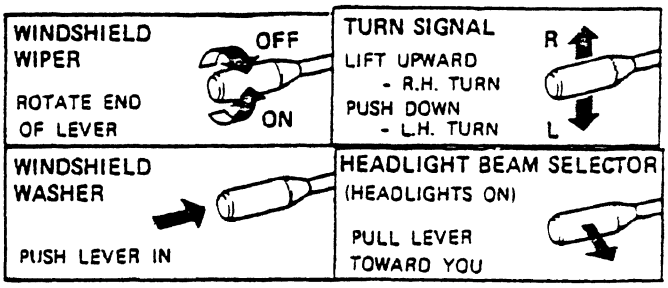
Figure 21. (1L) Stalk in Mercedes (Old Design).

Turn Signal And Multi-Function Lever

The turn signal lever located on the left side of the steering column also controls the headlight low beam or high beam selection, and windshield wiper/washer operation.

The accompanying illustration shows the proper movement of the lever to control these functions.

- **Turn Signal** - The lever is moved upward to the second stop to signal a right turn and downward to the second stop to signal a left turn. When the turn is completed, the signal is automatically canceled and the lever returns to horizontal.



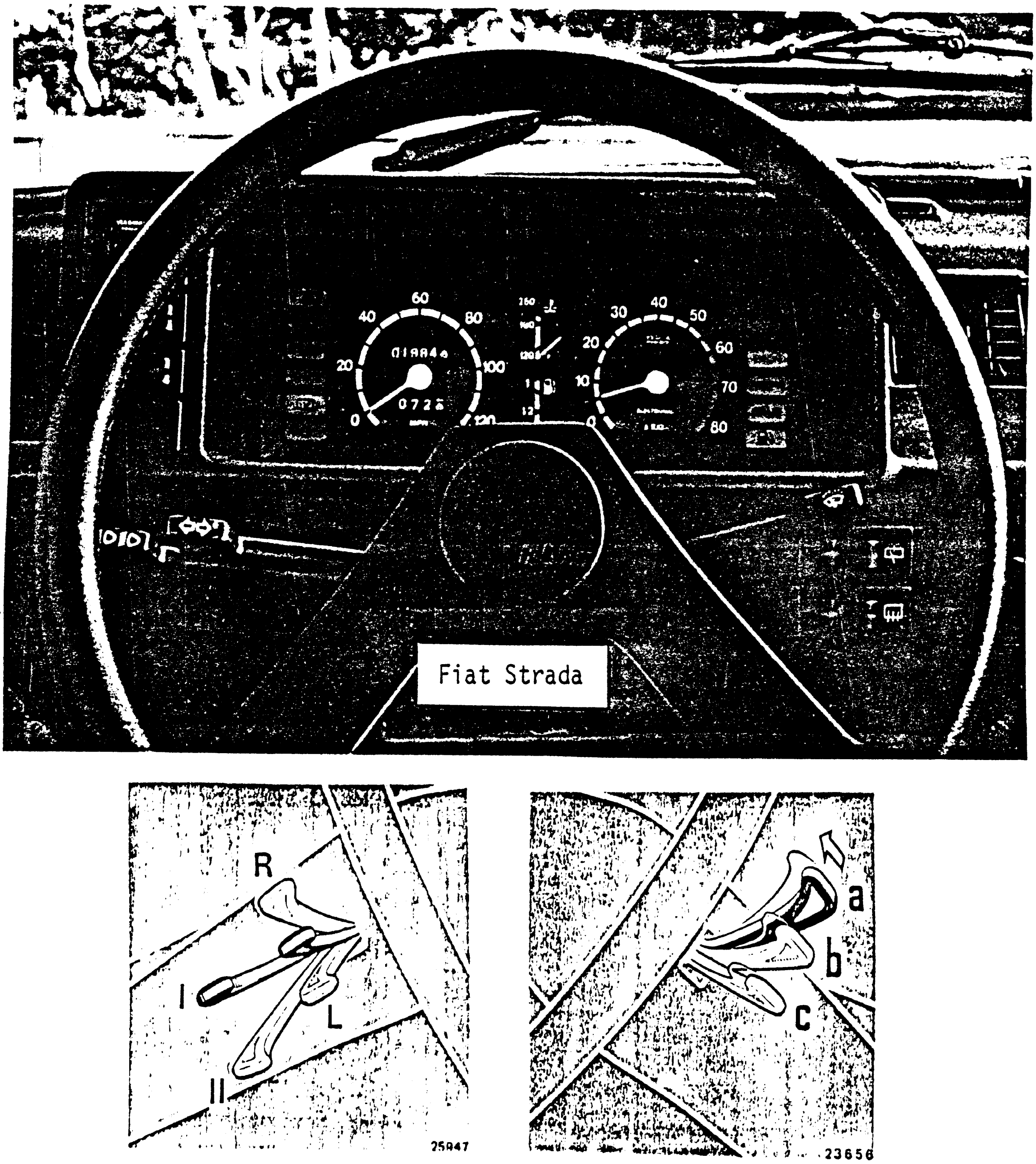
- **Windshield Wiper** Rotate the end of the lever counterclockwise to the detent position for low speed wiper operation; for high speed wiper, continue rotating end of lever to the next detent position.
- **Windshield Washer** - Push in on the end of the lever (toward the steering column) to operate the windshield washer. The washer pump is designed to operate as long as the lever is held in; when the lever is released, the washer pump is designed to stop.
- **Headlight Beam Selector** - With the headlamps already on (controlled by light switch shown on page 2-16), pulling the lever toward the driver until a "click" is heard, then releasing it, will switch the lights from high-beam to low-beam or from low- beam to high-beam. When the high-beam is on, an indicator light will appear on the instrument panel.

The ignition switch must be in the "on" position in order for the turn signals to be operational. This feature prevents battery draining if the lever is left in an "on" position when your car is not in use.

- **Lane Change Signal** - In some turns, such as changing lanes on an expressway, the steering wheel is not turned far enough to automatically cancel the turn signal. For convenience, the driver can flash the turn signals by moving the lever part way (to the first stop) and holding it there. The lever returns to the horizontal position when the driver releases his hold.

A green light on the instrument cluster flashes to indicate proper operation of the front and rear turn signal lamps. If the indicator lamp remains on and does not flash, check for a defective lamp bulb. If the indicator fails to light when the lever is moved, check the fuse and indicator bulb.

Figure 22. 1978-1979 Chevrolet Chevette (single left stalk).



Beam Change = Forward Lever
I = Low
II = High
Turn Signal = Rear Lever
R = Right
L = Left

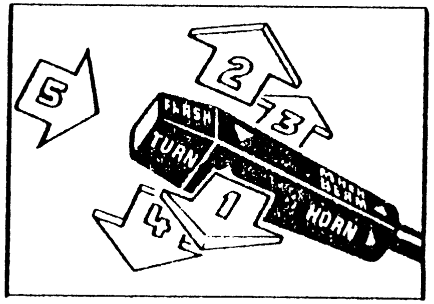
Windshield Wiper
a = Off
b = Low
c = High
Windshield Washer
Pull Towards Driver

Figure 23. Fiat: One Right Plus Two Left Stalk Design.

Steering Column Levers

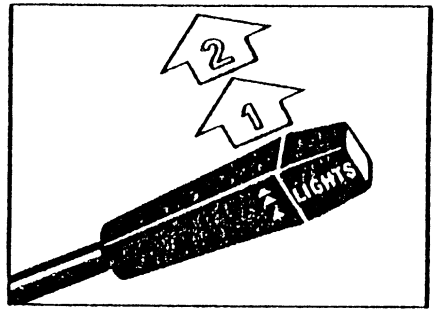
Multi-Function Lever

1 -- Headlight flasher (high beam when moved toward driver, when headlights are on OR off)
2 -- Right turn indicators
3 -- High beam (when headlights on)
4 -- Left turn indicators
5 -- Horn



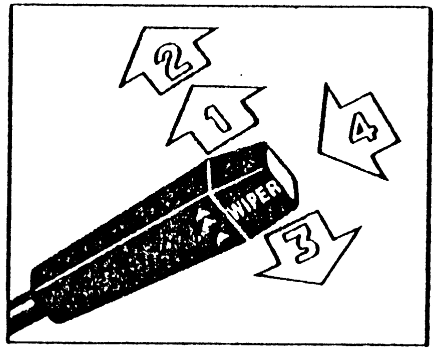
Lighting Lever

1 – Side and tail lights on.
2 – Headlights, side and tail lights on. The headlights will be on high or low beam depending on the position of the multi-function lever.



Wiper/Washer Lever

1 – Normal wiper speed.
2 – Fast wiper speed–for extreme conditions.
3 – Single wipe or intermittent wipe function, depending on option. Use in light rain or mist.
4 – Windshield washers–keep button depressed for prolonged washer operation.



1977-1979 Ford Fiesta

Figure 24. 1977-1979 Ford Fiesta.

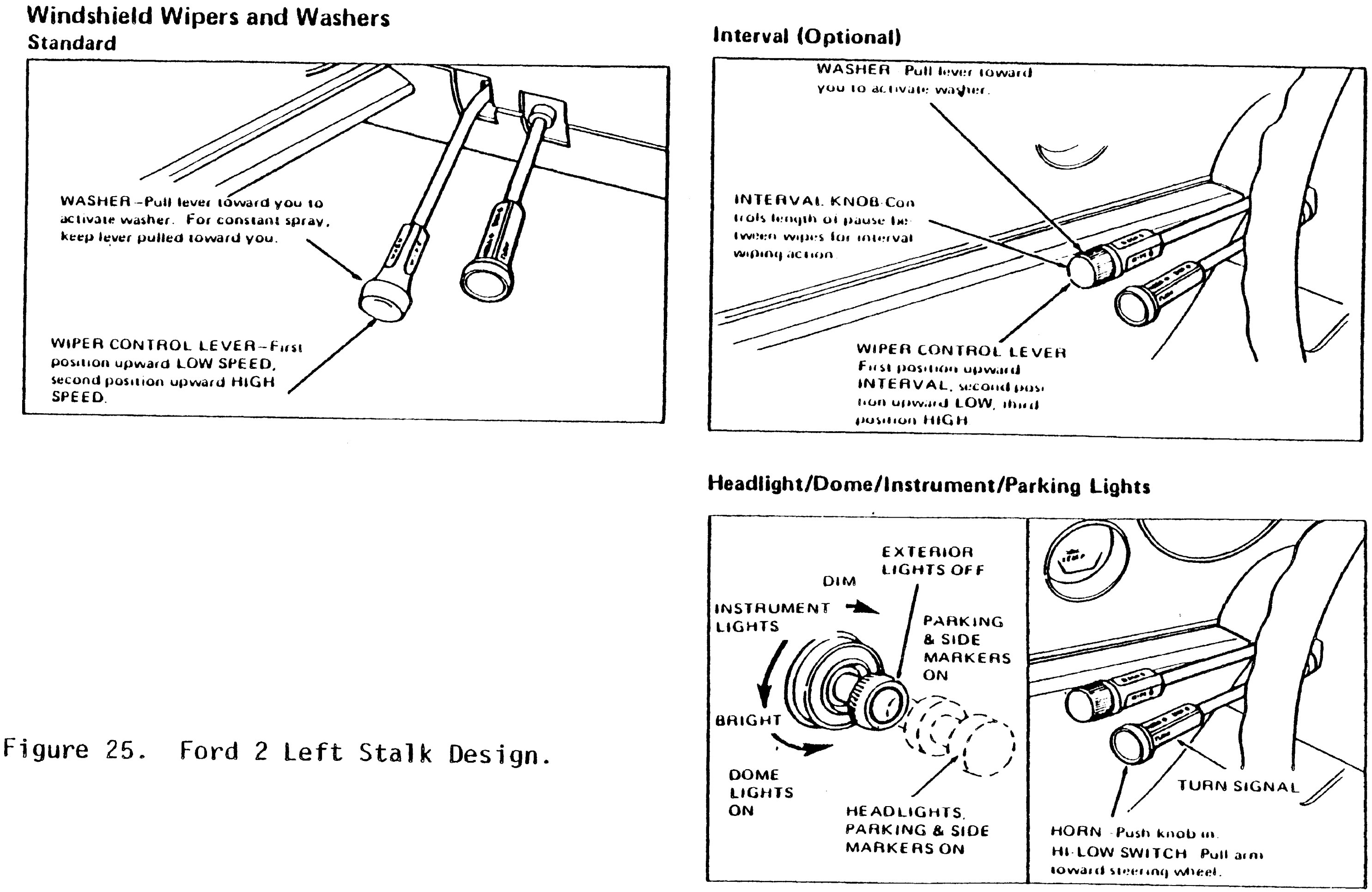
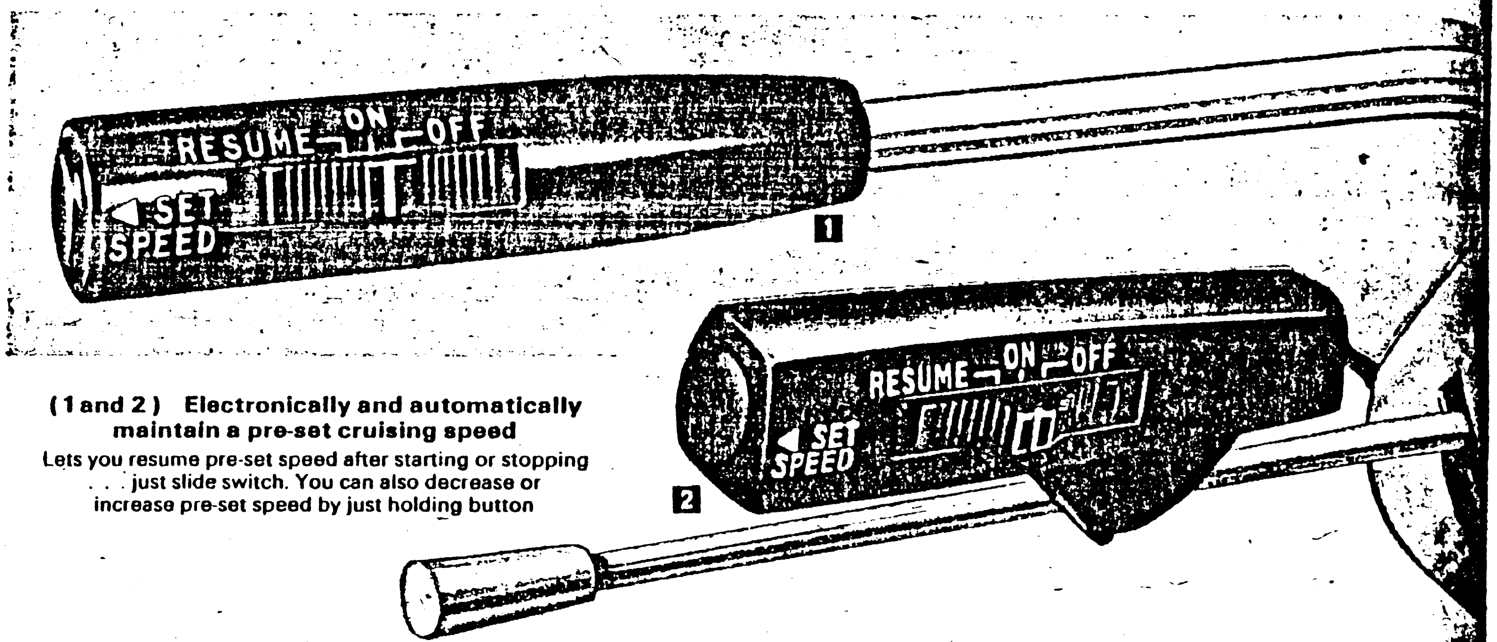


Figure 25. Ford 2 Left Stalk Design.

Electronic Speed Controls watch your speed while you watch the road

For U.S. cars, light trucks, vans with automatic or standard transmissions

- **Accurate:** Regulate road speed, not engine speed . . . provide constant motion, up hill or down
- **Reliable:** Solid-state electronic design
- **Pleasant, relaxing drive:** Helps relieve driving tensions . . . keep operator comfortable and alert
- **Operating Economy:** Just set legal, gas-saving speed for maximum gas mileage



(1 and 2) Electronically and automatically maintain a pre-set cruising speed

Lets you resume pre-set speed after starting or stopping . . . just slide switch. You can also decrease or increase pre-set speed by just holding button

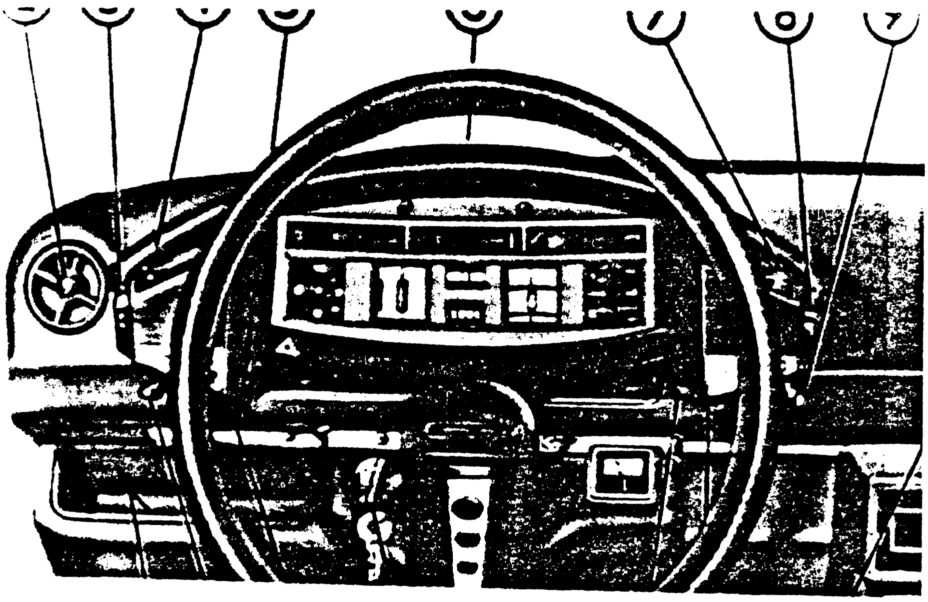
HOW THEY WORK: Turn to "On". Accelerate to desired speed. Press "Set Speed" button. Unit holds steady speed by monitoring vehicle speed, not engine revolutions. Automatically disengages when you apply brakes. To resume speed, just slide switch to "Resume" and vehicle accelerates to previously set speed. To coast, hold "Set Speed"—vehicle slows down . . . release to set lower speed. To increase speed, move slide switch to "Resume" and hold . . . speed will increase. Upon release, vehicle will slow—control takes over at previously set speed.
CONTROLS: On/off/resume switch. Set Speed engage pushbutton at tip of control.
COMPONENTS: Engagement switch, black molded plastic—1x3 in. long. Servo mechanism. Magnetic pickup assembly. Solid-state regulator, hoses, wiring, hardware included.

(1) Original equipment-type Speed Control
INSTALLATION: Unscrew knob or saw off (depending on your vehicle) the end of the turn signal lever . . . looks like original equipment. Servo mounts on the engine or firewall. Magnetic pickup mounts near the drive shaft. All components connect to the regulator via lead-in wiring. Mechanical knowledge is required to install this unit . . . drilling is also required. Installation instructions are included. Professional installation is available at most Sears Retail Automotive Centers at an additional charge.
ORDERING INFORMATION: For most U.S. cars, light trucks, vans with automatic or standard transmission, except cars with washer control or other controls on turn signal lever. Not for use with imported vehicles. For front-wheel drive vehicles, order Front-Wheel Drive Adapter Kit, below, right. See Warranty on facing page.
Shipping weight 5 pounds 1 ounce.
28 G 20543 .... $97.99

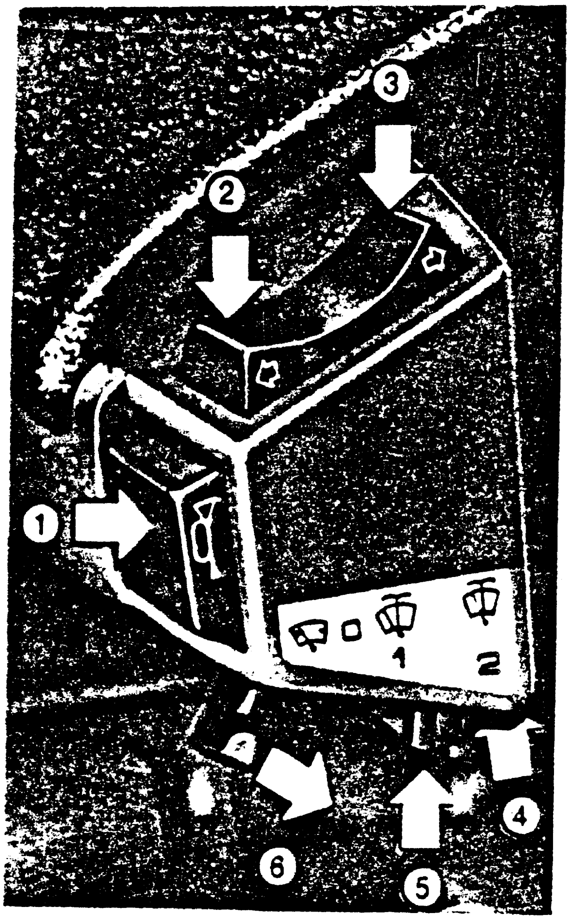
(2) Turn signal-mount Speed Control
INSTALLATION: Engagement switch snaps on to turn signal lever. Servo mechanism mounts on engine or firewall, magnetic pickup near drive shaft. All components connect to regulator via lead-in wiring. Mechanical knowledge required; drilling necessary. Professional installation available at most Sears Retail Automotive Centers at an additional charge.
ORDERING INFORMATION: For most U.S. cars, light trucks, vans with automatic or standard transmission, except front-wheel drive. For front-wheel drive vehicles, order Front-Wheel Adapter Kit below. Some imported and domestic-named imports require adapter kit sold in table below. Kits permit attachment to throttle linkage; help insure proper hookup. See Warranty on facing page.
Shipping weight 5 pounds 1 ounce.
28 G 20545 .... $97.99

Figure 26. Some cruise controls sold by Sears.

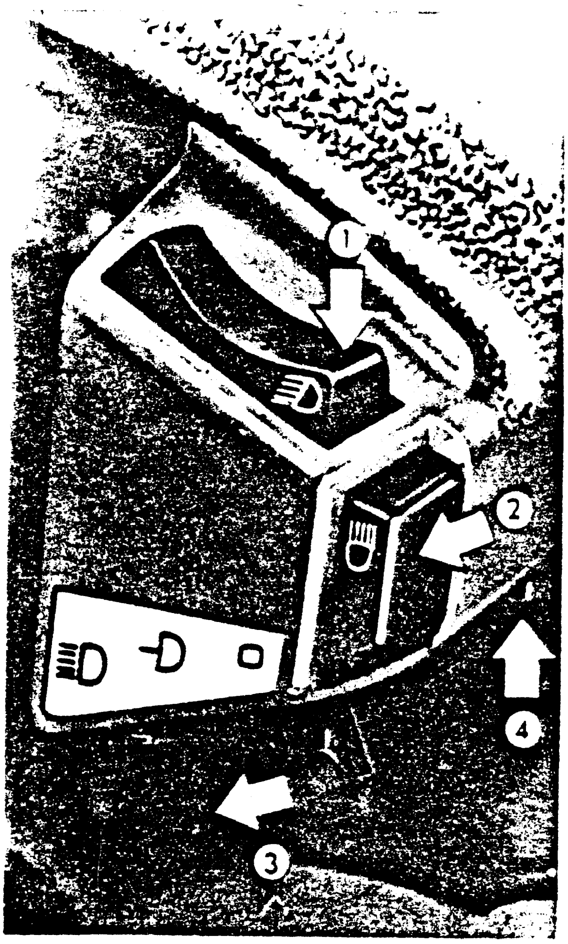
Source: Sears, Roebuck and Co., <u>Sears Fall/Winter 1979 Catalog</u> (Midwest, Edition 259G), Chicago: Sears, 1979, p. 776.



1979 Citroen CX

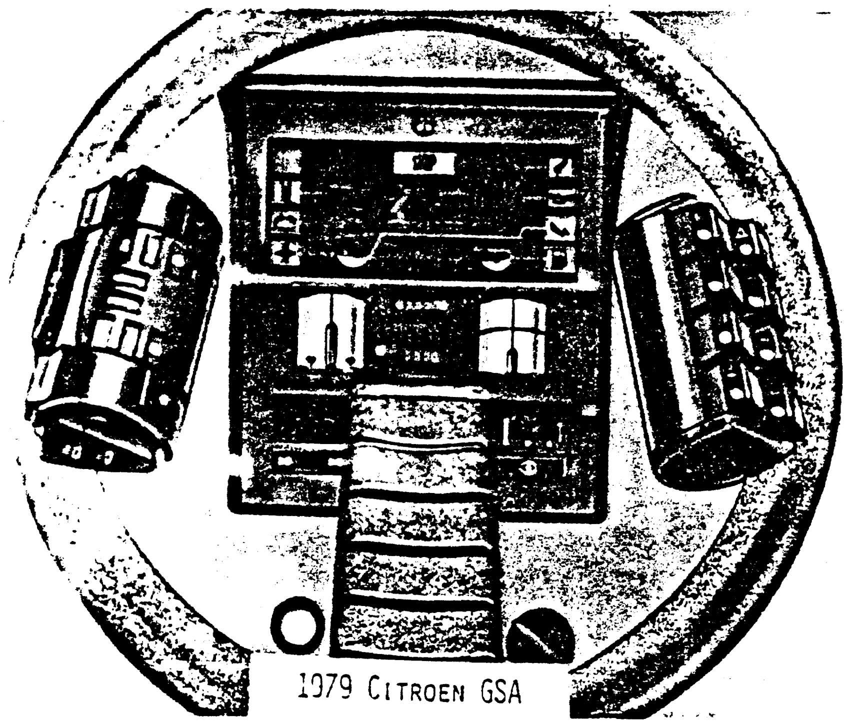


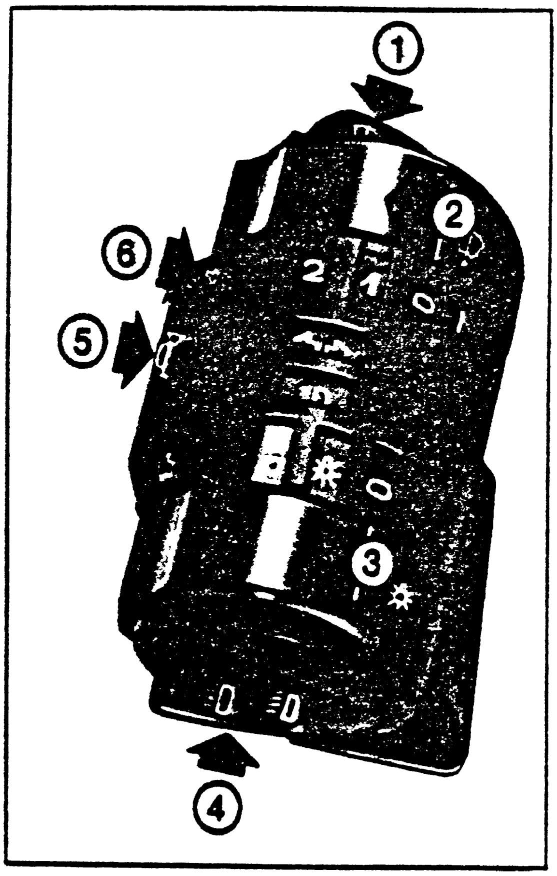
1979 Citroen CX



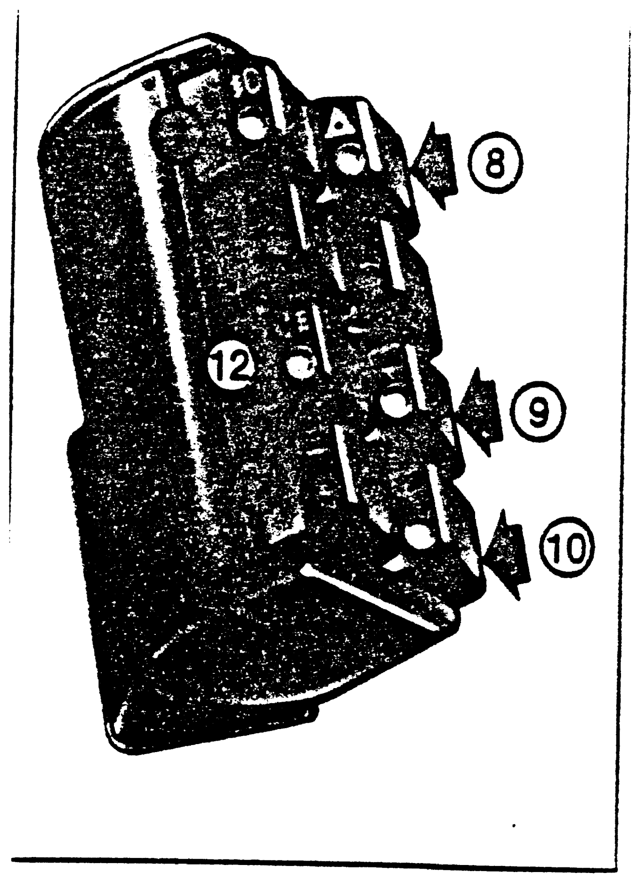
1979 Citroen CX

Figure 27. Citroen CX Controls.





1979 CITROEN GSA



1979 CITROEN GSA

Figure 28. Citroen GSA Controls.

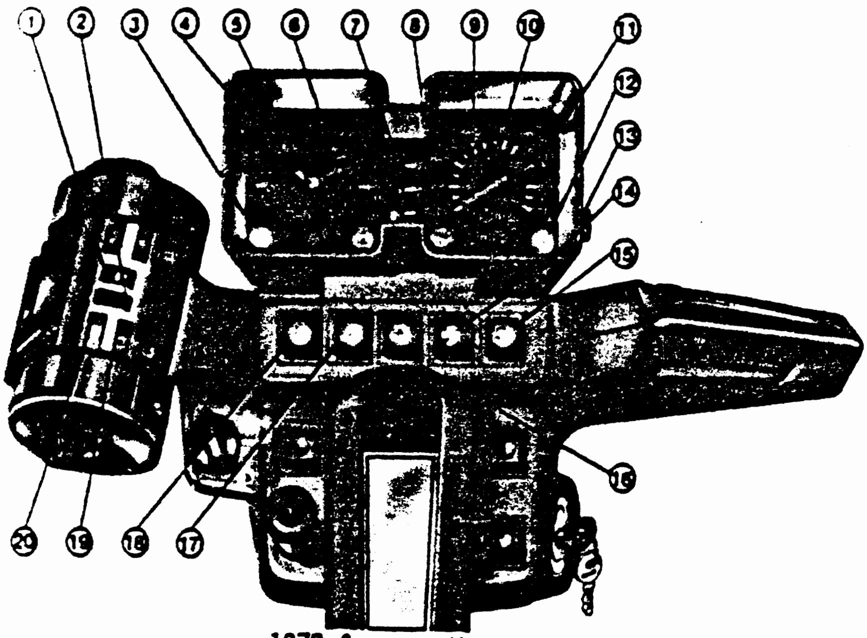


Figure 29. Citroen Visa Controls.

STANDARDS FOR CONTROLS

The following section describes the efforts of the U.S. government, professional societies, international economic cooperatives, and most importantly, standards organizations directed towards standardizing the location and method of operation of automobile controls. Readers unfamiliar with the general scope and structure of organizations involved in standardization should review Appendix E before reading the remainder of this section.

International

ISO

International Standards Organization Technical Committee 22, Subcommittee 13 (ISO TC22/SC13); "Ergonomics of Road Vehicles," has worked towards international harmonization in the design of controls and displays since the late 1960's. Particularly important are the activities of Working Group 3 (WG3); "Controls and Displays Location," one of the six groups reporting to SC13.

WG3 and SC13 have generated numerous documents on controls location, some of which have been discussed previously.

Resulting from the efforts of WG3 and SC13 has been the development of ISO Standard 4040 - 1977(e), "Road Vehicles - Passenger Cars - Location of Hand Controls, Indicators and Tell-tales," first issued May 5, 1977 (International Standards Organization, 1977b). A copy of that standard is contained in Appendix F. The standard requires the horn to be either in the center of the steering wheel or on a left stalk, and the following controls to be left of the steering wheel centerline: driving lights, marker lights, beam switching, optical warning, turn signal, and emergency brake (right-hand drive only).

Since that time there has been considerable discussion of revising ISO Standard 4040. The latest proposal (distributed as ISO document SC13(WG3-85)283 (International Standards Organization, 1978)) reflects the discussion generated at the 1978 Technical Committee 22, Subcommittee 13 meeting. The proposed revisions extend the scope of the standard considerably both in terms of displays and controls location. The proposal maintains the requirements for the location of the horn, driving lights, marker lights, and emergency brake controls (right-hand drive only). Proposed additions include:

1. If there is a stalk to the right (other than the gear selector) it will operate the wiper/washer. If there are two, the forward stalk will be for the windshield wiper/washer. The wiper/washer control will not be mounted on the right side of the instrument panel.
2. The headlight beam switching, optical warning, and turn signal controls will be located on the left side of the instrument panel close to the steering wheel.
3. The wiper and washer must be operated by the same control. So, also, must the optical warning and beam switching functions.
4. Ruled out are combinations of the master lighting switch with either a control used to operate the wiper/washer or one in combination with the turn signal.
5. Some restrictions of the directions in which controls move are offered. (See Figure 6 of document 283.)

The author believes that the following points should also be addressed by a revised standard:

1. The standard assumes that a car's direction will be controlled by a steering wheel and secondary controls will be located with respect to the steering wheel. Other types of primary driving controls (e.g., a joystick) should also be considered (Tejmar, 1972). Such controls are often provided for handicapped drivers (Anger and Wayne, 1978) and may be provided in future mass-produced vehicles because they allow more space for an airbag. Specifications are needed for secondary control location where the steering wheel is absent.
2. The standard assumes that the driver is seated (and positioned) directly behind the steering wheel. There are some cases where the vertical centerline of the steering wheel and the vertical centerline of the driver's seat are not aligned. Adjustments to the control location restrictions are needed in such instances.

3. The locations permitted for currently standardized controls should be more specific. As noted in the Anacapa Sciences (1976) report, even if the side of the instrument panel is specified, location time is markedly affected by the expectation for control design (panel- or stalk-mounted).
4. To avoid inadvertant operation, the location of many controls sometimes placed close to the steering wheel should be specified (e.g., cruise control, backlite wiper/washer, etc.). As the problem surveys (e.g., Burger et al. (1977) demonstrate, drivers have difficulty with these controls.
5. Additional details regarding the size and direction of operation should be included. Only very general limits are offered for direction of operation. For example, the standard permits a right turn to be indicated by pushing a left stalk down. In light of the Burger et al. study (many problems in operating controls), direction of operation should be limited for all controls.
6. The definition of "fingertip reach" from the steering wheel should be based on research not judgment.

In addition to the work of TC 22/SC 13, the work of other ISO Committees needs to be mentioned. Technical Committee 23 (TC23) is concerned with tractors and machinery for agriculture and forestry. While a document list for TC 23/SC 14 (Controls) is not available at this time, a copy of their draft standard for controls has been obtained (document TC 23/SC 14 N49 DIS 3789/I/II/III - Tractors and Machinery for Agriculture and Forestry, Powered Lawn and Garden Equipment - Operator's Controls - Location and Method of Operation). That document does not deal with multifunction controls.

Several other Technical Committees are concerned with vehicles, including TC 20 (Aircraft and Space Vehicles), TC 96 (Cranes, Lifting Appliances and Related Excavator Equipment), TC 110 (Industrial Trucks), and TC 127 (Earthmoving Machinery). Because of time constraints, they were not contacted.

Finally worthy of note is the work of TC 159/SC 4 (Ergonomics - Signals and Controls). Unfortunately this Committee has not been very busy nor well-supported. For several years there have been attempts to find an American professional society willing to serve as the Secretariat for TC 159/SC 4. At one time the Society of Automotive Engineers served as such. At their October annual meeting, the Human Factors Society indicated a willingness to provide support for the Secretariat.

It is the author's understanding that TC 159/SC 4 has been working on a general guidance for control design (Juptner, 1979). The guidance document is reportedly an extension of a proposed standard (ISO Standard 1503, "Geometric Orientation and Direction of Movements," an enclosure in International Standards Organization (1977a).) It should be examined closely because the preferred direction-of-operation for some automobile stalks may differ from the general rules.

ECE (Economic Commission for Europe)

While WP29 was the most active in the early seventies, the efforts of this Geneva-based UN group have taken a backseat to those of ISO TC 22 (Cutting and Teesdale, 1974; Pocci, 1975). Current information regarding ECE activities is difficult to obtain. At one time (1974) Geneva issued a Draft Regulation concerning the "Arrangement of Hand Controls" (ECE Draft GRSG/R16). The current state of that document is unknown (Cutting, 1978; Cutting and Teesdale, 1974).

EEC (European Economic Community)

For the most part, the Brussels group (EEC or Common Market) has tended to adopt Geneva (ECE) Regulations as their own Directives. EEC also has tended to defer to ISO for Regulations regarding controls and displays (Cutting and Teesdale, 1974; Pollard, 1976; Schlosser, 1972).

ANSI (American National Standards Institute)

Unlike other areas, there is not an active ANSI Committee working on automobile controls and displays. In this instance, information is passed on directly from the appropriate professional organization, the Society of Automotive Engineers, to ISO.

Society of Automotive Engineers (SAE)

Responsibility for multifunction controls within the Society of Automotive Engineers (SAE) rests with the Multifunction Control Task Force. That group reports to the Controls and Displays Subcommittee that in turn reports to the Human Factors Engineering Subcommittee.

Resulting from SAE efforts are a Recommended Practice (SAE J1138, Design Criteria - Driver Hand Controls, Location for Passenger Cars, Multipurpose Passenger Vehicles, and Trucks (10000 GVW and Under) (Society of Automotive Engineers, 1979a)) and an Information Report (SAE J1139, Supplemental Information - Driver Hand Controls, Location for Passenger Cars, Multipurpose Passenger Vehicles, and Trucks (10000 GVW and Under) (Society of Automotive Engineers, 1979b)). There are no SAE Standards for controls location or design that affect automobiles.

The recommendations of SAE J1138 are slightly more restrictive than the current version of ISO Standard 4040. Specifically, SAE J1138 calls for a number of controls to be within the drivers' reach while wearing a lap and shoulder belt, within easy view, and requires them to be labeled with simple words. With regard to location, the following are recommended to be left of the steering wheel: turn signal, headlight dimmer, wiper/washer, headlights switch, and optical warning. The following are to be to the right: gear shift, ignition, defroster, hazard, climate controls, radio, lighter, and ashtray. Multifunction controls are not dealt with directly in this SAE Practice.

The second item, the SAE Information Report, contains little detail. Its primary purpose it to relay some of the results from the Anacapa/McGrath studies. The SAE Information Report highlights the importance of locating controls so that their positions agree with driver expectancies. Both of these SAE documents have been included in the Appendix (G and H respectively).

Manufacturers and Distributors

Neither the MVMA (Motor Vehicle Manufacturers' Association) Human Factors Engineering Subcommittee nor the AIA (Automobile Importers' Association) Safety Committee have, or plan to develop, standards for controls because of potential anti-trust problems. Both, however, are interested in commenting on proposed standards.

U.S. Government

DOT

Parallel to these voluntary standards activities have been government regulations. The National Highway Traffic Safety Administration of the U.S. Department of Transportation (DOT) has developed a standard concerned with the design of controls and displays for motor vehicles. A copy of Federal Motor Vehicle Safety Standard 101-80 (FMVSS 101) - Controls and Displays (U.S. Department of Transportation, 1979) is in Appendix I.

FMVSS 101 does not directly address multifunction controls. It requires only that a number of hand-operated controls currently being considered for stalk mounting, such as the wiper/washer and headlamp on/off switches, be within the driver's reach when the driver is restrained by whatever crash protection is installed, and that they be labeled. Beyond the original rule, a notice has appeared in the Federal Register in regard to petitions for reconsideration of the original standard. None of those petitions deals with multifunction controls. Also appearing has been a correction to the standard (see Appendix I).

Future directions that DOT will take have been outlined in its five-year plan and the appendix to that plan (Department of Transportation, 1979a,b). The basic plan (U.S. Department of Transportation, 1979a, p. 34) states:

> "Controls and Displays: Amend FMVSS 101 to specify location and method of operation for certain controls on the instrument panel and steering column of passenger cars, light trucks, vans, and multipurpose passenger vehicles, and to specify the location and visibility of certain displays on the instrument panel.
> NPRM (Notice of Proposed Rule Making 1982
> Rule 1983
> Effective model 1985."

Further amplification is given in the appendix to that document. It (U.S. Department of Transportation, 1979b, p. 24-25) states:

RULEMAKING ACTION

TITLE: FMVSS NO. 101 CONTROLS AND DISPLAYS

DESCRIPTION: Standardized Location of Controls and Displays on the Instrument Panel and Steering Column

APPLICABILITY: Passenger Cars, Light Trucks, and Multipurpose Vehicles

PROBLEM

The more attentive the driver is to the roadway environment, the greater the chances of avoiding a mishap. A driver can devote more time to roadway events if an excessive amount of time monitoring the instrument panel or gaining access to and operating controls is not required. Data from tests performed in both cars and trucks indicate that drivers are about three times faster in locating controls and displays in their own vehicles than in unfamiliar vehicles. In the same way, standardization would facilitate faster location and operation of these instruments and thus reduce the amount of the driver's time diverted from the roadway.

Safety requirements for padded instrument panels, the downsizing of vehicles and the need for space to install air cushions have contributed to the competition for usable panel space in the vehicle and this competition will increase as panel size decreases. One answer to this problem is to use "finger tip" or stalk mounted controls. There are now over 27 different configurations available on current models and because they are not standardized as to the number and type of controls and modes of operation, safe vehicle operation is further degraded.

APPROACH

This amendment will standardize the zone location of critical controls and displays on the instrument panel and specify which controls, in addition to the turn signal, may be located on steering column stalks. This commonality will improve the driver's ability to find and operate these controls, especially when the driver is in an unfamiliar vehicle.

No additional research will be required for specifying the zone locations on the instrument panel since previous research by the NHTSA and the work of the SAE and ISO committees in this area have provided much data that can be used for these requirements. Because many light trucks and vans are being purchased for personal use and since many of these owners will be switching back and forth between them and passenger cars, NHTSA believes that there is sufficient reason to extend these initial requirements to include these vehicles. A brief review indicates that the instrument panels of light trucks and vans are essentially the same as passenger cars in regard to control and display layouts. During the preparation of the NPRM, a review of instrument panels on light trucks and vans will be made to assure that no major problems will occur as a result of including these vehicles in this amendment. Data will also be obtained from the users to determine the proportion and frequency of use of these and other vehicle types.

The major research effort will evaluate possible combinations and modes of operation of controls mounted on steering column stalks or on pod extensions from the instrument panel. This research will include an analysis of whether the controls should be on the instrument panel or on a stalk (pod).

Another approach that manufacturers are considering in order to maximize the utilization of the decreasing area of instrument panels is advanced concepts using new technology for these instruments. In order not to be design restrictive, research will identify the state-of-the-art in these new areas and consider their potential impact on requirements for a control and display standard.

SCHEDULE

NPRM		1982
RULE		1983
EFFECTIVE	Model	1985

Several authors have proposed revisions of Federal Motor Vehicle Safety Standard 101. (See for example, Woodson, Conover, Miller, and Selby (1969).) The only proposal that is relevant to the current standard is that of Black, Woodson, and Selby (1977). Their proposal was based on driver expectancies, reports of problems, the analysis of driver performance, and other factors. Draft versions of their proposal were reviewed by a panel of experts. For the sake of brevity comments will be confined to issues concerning multifunction controls.

Their proposed requirements for multifunction controls follow:

"b. Stalk-Mounted Grouping
The following control function combinations are permitted:
1) Left-Hand Stalk
    a) Turn Signal Selector Function - Lever motion shall be parallel to the axis of the steering wheel rim; a clockwise lever movement shall activate the right-turn signal, a counter-clockwise lever movement shall activate the left-turn signal. The lever shall return to neutral as a consequence of steering centering.
    b) Headlight Hi-Lo Beam Selector (dimmer) Function - The left stalk control (forward for high beam and back for low beam) or a push button extending from the end of the lever shall alternately switch the headlights from low to high beam by successive push button actuations.
2) Right-Hand Stalk
    a) Automatic and/or Manual Gear Selector (when this function is not located between the two front seats) - Lever motion shall be parallel with steering wheel rim axis; a clockwise motion of the lever shall effect gear changes from PARK, to REVERSE, to NEUTRAL, to DRIVE, to LOW in successive, detented steps. A mechanical detent and/or change of direction to minimize accidental REVERSE positioning while the vehicle is in forward motion shall be provided.
    b) Automatic Speed Control Set (Cruise), when provided shall consist of a push button extending from the end of the lever handle. Operation of this system shall be as follows: Driver accelerates to the desired speed; presses the push button to cause the cruise control system to secure at the selected speed; release is accomplished by a slight pressure on the service brake pedal.
    Note: In the event the vehicle in question has an automatic speed control option but the gear selector is mounted on the floor, a fixed stalk shall be used with the speed control push button mounted as indicated in (b) above."

The proposed configuration is very similar to that of many 1980 cars (dimmer and turn signal on the left stalk). It should be noted that in their design, the wiper/washer is panel-mounted. The author believes that operating the dimmer switch by pushing a button on the end of the left stalk should not be permitted. Several other functions are often mounted there (washer, cruise set, horn, etc.). To permit one more possibility would only add to confusion. (Later Black et al. also suggest that mounting the horn on the left stalk and/or the back of the steering wheel spokes should be permitted as an option. The author considers both proposals unwise.)

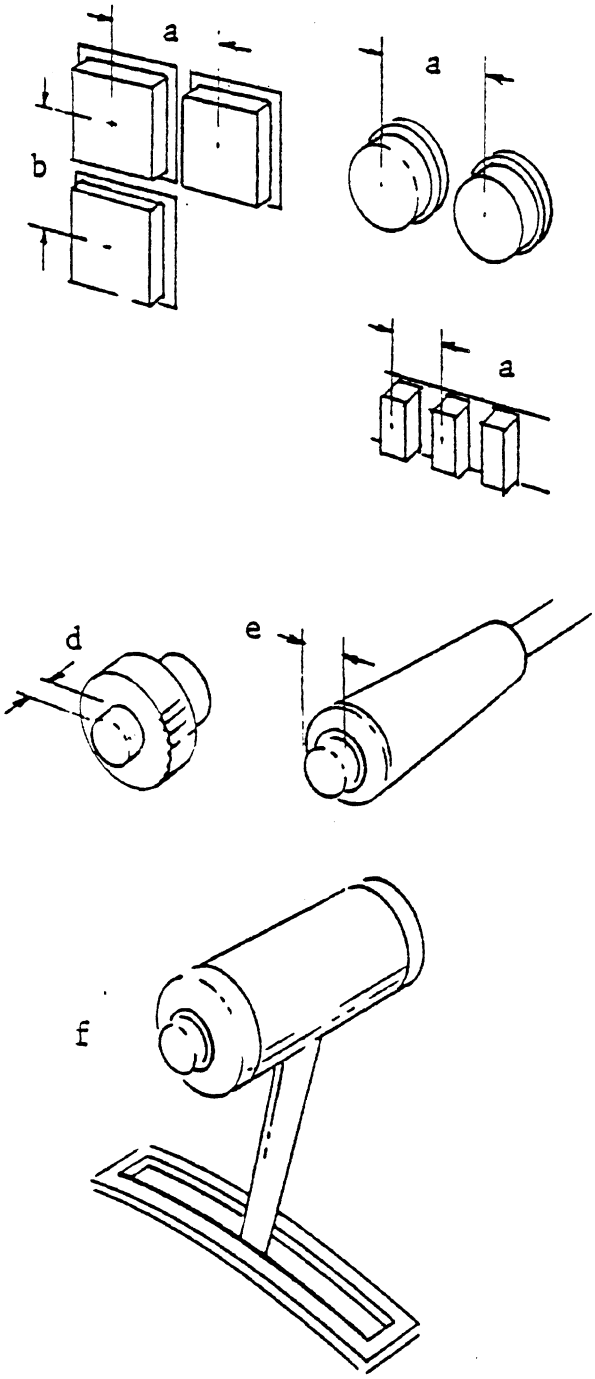
In addition to the basic proposal, specifics regarding control design were presented. (See Figure 30.) At first glance they seem reasonable. The author has an additional suggestion. Where part of a stalk twists, the detent names should be on the fixed part of the stalk and the arrow (or pointer) on the the part that moves. (See Figure 31.)

DOD

With regard to the design of vehicles for the U.S. Department of Defense (DOD), there are two appropriate documents. The best known is Military Standard 1472B, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities" (U.S. Department of Defense, 1974). Also of importance is Military Handbook 759, "Human Factors Engineering Design for Army Material" (U.S. Army, 1975). That document replaces HEL Standard S-6-66 (U.S. Army, 1966). When the Defense Department buys vehicles, it generally specifies they be in accordance with the Military Standard. The Handbook is primarily for reference purposes.

Although most military vehicles are of a somewhat specialized nature, there is considerable interest in employing civilian vehicles in a military role where possible as a cost-saving measure. As it is intended to do this both in the United States and for U.S. forces in Europe, foreign manufacturers will be increasingly concerned with Military Standard 1472B in the future. For that reason, it is important that ISO TC 22/SC 13, responsible for ISO Standard 4040, and those responsible for the Military Standard, ensure that the two documents are in agreement.

Military Standard 1472B contains far more detail than any of the other standards mentioned in this section. There is considerable information on the size, spacing, labeling, force limits, etc. for toggle switches, push buttons, rotary knobs, cranks, thumb wheels, and so forth. Little, however, is said concerning the location of controls.



PUSH BUTTONS:

Center-to-center separation of push buttons shall be sufficient for forefinger operation of a single button surrounded by other buttons, either above or below the switch to be pushed.

a = 0.75 in. (1.9 cm)

b = 0.75 in. (1.9 cm)

Push buttons should extend (d) from the panel (not be recessed even after the button is activated. The extension difference between depressed and non-depressed should be at least 0.125 in. (0.32 cm) but no more than 0.25 in. (0.64 cm).

The diameter of round pushbuttons should be a minimum of 0.50 in. (1.27 cm).

Thumb-operated push buttons should be larger where practical (f) e.g., approximately 0.75 in. (1.9 cm).

Figure 30. Push Button Design Suggestions of Black, Woodson and Selby (1977)

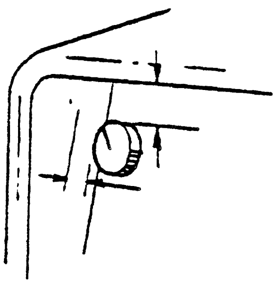
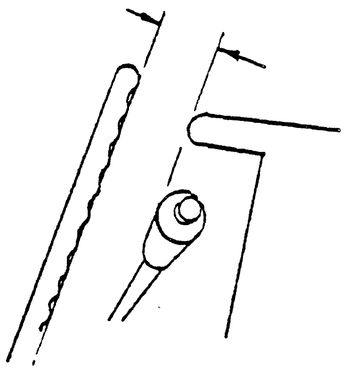
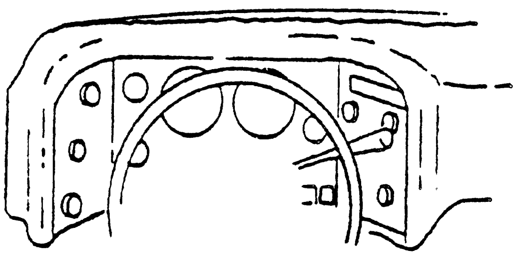
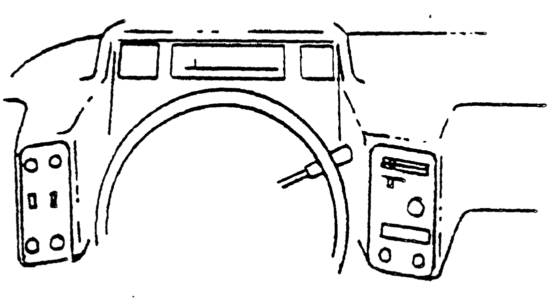
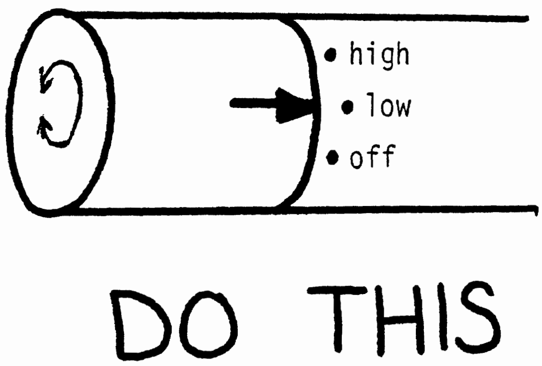
	Structural Interference; Controls must not be placed too close to a door panel, glare shield, etc. and thus interfere with operation of the control. Minimum spacing is 1.50 in. (3.81 cm).
	Interference with Steering; Because of the frequent, rapid manipulatory requirements in emergency steering, no interfering structure, and/or control shall be closer than within 2.0 in. (5.08 cm).
 Unacceptable  Preferred	Controls should not be laid out so that driver has to reach around or in between steering wheel rim and adjacent door panel in order to reach a panel, stalk, or column-mounted control. The extra time it takes and the possibility of snagging a cuff on an intervening control make it undesirable to place any control behind the steering wheel.

Figure 30. (cont.)



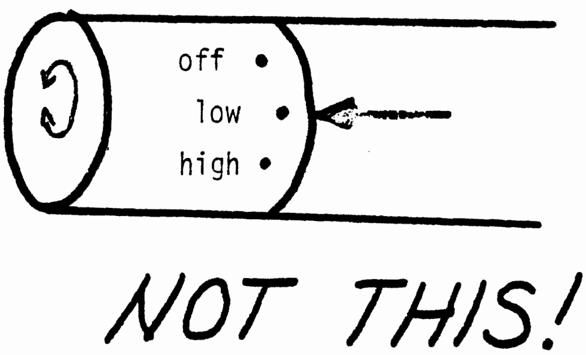


Figure 31.

Labeling of Stalks That Twist

Summary

Several standards are concerned with controls location and the design of multifunction controls. The current ISO Standard states which will be located to the left or right of the steering column. The proposed revision would add many restrictions regarding stalk movement directions and combinations of functions that might appear together. The current SAE Recommended Practice stipulates where controls will appear. It is only slightly more restrictive than ISO Standard 4040. Finally, FMVSS 101 has little to say about multifunction controls now, though it will be far more restrictive in the future.

Estimating Accident Frequency

A well-designed instrument panel is simple to operate and ultimately is designed not to induce accidents. If such could be quantified, the automotive engineer would have a valuable tool with which alternative designs could be compared.

Estimating the frequency of such accidents or any similar measure of utility, is most difficult. Instrument panel design-induced accidents may result from inadvertent operation of controls or delayed operation of desired controls. Influencing such are the frequency of use of each control, the time required to correctly operate each control, the probability that each added delay will result in an accident, the confusion probabilities for each control with every other control, the time required to correct each error, and the conditional probability for each control that an accident results, given inadvertent operation. A simple expression for the expected number of accidents for a particular control arrangement is formula (1). That formula assumes only first-order errors occurring, that is that correcting one error does not lead to another. It is a sum of the contributions due to delays and errors.

$$E(accid) = \sum_{i=1}^{n} (fr)_i \Bigg[(Paccid)_i \Big((RT)_i + (Perror)_i (CT)_i \Big) \quad \Big\} \text{exposure due to to delayed operation}$$

$$+ \sum_{j=1}^{n} (Perror)_{ij} (CT)_j (Paccid)_j \Bigg] \quad \Big\} \text{exposure due to error} \qquad (1)$$

E(accid)	= expected number of accidents for an arrangement
$(fr)_i$	= frequency of use of i^{th} control
$(Paccid)_i$, $(Paccid)_j$	= probability that operation of i^{th} or j^{th} controls results in an accident
$(RT)_i$	= response time for "corrects" for the i^{th} control
$(CT)_i$, $(CT)_j$	= time to correct an error for i^{th} or j^{th} control
$(Perror)_{ij}$	= probability that when operating control i, control j is operated (confusion probability)

To compute the expected number of accidents for a control configuration, a great deal of information is required. The frequency of use estimates for controls (Tables 16, 35, and 36) exist. So, too, do correction times for a number of controls (see Anacapa Sciences (1976)). On the other hand, the remaining information needed is extremely difficult to obtain. Confusion error probabilities for each control pair ($Perror_{ij}$) could be collected in a driver performance study, but the number of trials required for accurate estimates are enormous. (Errors are discrete, not continuous values.) Such a study would be extremely costly. Finally, the accident probabilities ($Paccid_i$) would have to be estimated by experts because objective data do not exist. Recent research has shown that in the absence of actual frequencies, people are very poor estimators of the probabilities of accidents (Lichtenstein, Slovic, Fischoff, Layman, and Combs, 1978; Shanteau, 1978; Svenson, 1978). These difficulties are similar to those of the ISO (1975) error analysis and the TEPPS procedure noted earlier. These difficulties make this utility measure not worth pursuing at this time.

Response Time Model Overview

Thus, while error and accident data are difficult to obtain, response time data are not. Response time is a key factor in accident estimation (formula (1)). Response time is highly correlated with error rates. Furthermore, because of the ease with which it is measured, it is the most appropriate measure of driver performance in using a set of controls. (Note: Because they occur in every response time experiment, error rates should also be reported.)

What Factors Influence the Time to Use a Control?

Subject Factors - It is reasonably well known that individual differences influence the time to use a control. Generally, males tend to be faster than females. Performance improves up to about age 25 or 30 (a gain in experience in operating controls) and then declines with age.

Environmental Factors - Freezing temperatures decrease finger dexterity and interfere with performance. So does having the driver wear heavy clothing. This is especially true for gloves or mittens. Though the Essex reports have not shown such differences, clearly lighting levels should influence performance. Control location performance at night should be somewhat slower than that during the day.

The time to use a control can be partitioned into three intervals. (See Figure 32.)

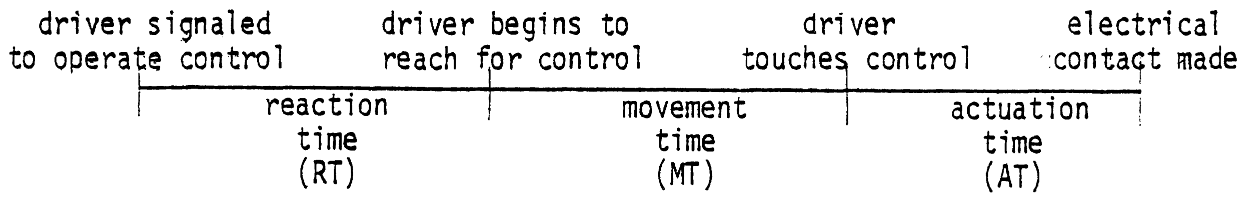


Figure 32. Intervals Comprising the Time to Use a Control

(1) Reaction Time (RT) - the time from when the driver has signaled to operate a control until the movement toward it starts, (2) Movement Time (MT) - from when the movement begins to the control until it is touched, and (3) Actuation Time (AT) - from when the control is first touched until switching is completed. Ignored in this model is the time required to return to the steering wheel. While this return time has some consequence for controls located far from the driver (for example, sometimes the radio), usually it is the former three intervals that demand the most attention and present the greatest distraction to the driver.

Reaction Time

A basic underlying model of human performance (formula (2)) is Hick's Law (Hick, 1952). It states that response time is a function of a constant plus a second constant times the logarithm to the base two of the number of alternatives.

$$RT = K_1 + K_2 \log_2 N \qquad (2)$$

where

K_1, K_2 = constants

N = number of choices

Some have argued that Hick's Law should be presented as

$$RT = K_1 + K_2 \log_2 (N+1) \qquad (3)$$

since when only one alternative is present, the subject must choose between responding and not responding. As a result of later work, it was found that Hick's Law as presented above is true only where the choices are equally likely. Where that is not true, N must be replaced by the H, the information the subject handles (Alluisi, 1970; Garner, 1966; Hyman, 1953; Sheridan & Ferrell, 1974; Smith, 1968). (See formula (4).)

$$H = \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i} \qquad (4)$$

Substituting into formula (2)

$$RT = K_1 + K_2 \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i} \qquad (5)$$

While the relationship is quite robust, the values for the constants K_1 and K_2 are situation specific. Among other items, they depend upon practice, stimulus-response (S-R) compatibility, and individual differences (Fitts & Posner, 1967).

Not as much effort has gone into modeling learning or practice effects in conjunction with Hick's Law. Several models of learning alone, however, have appeared. The most popular, known as "replacement theory," claims that old habits are replaced by new ones, and that is what constitutes learning. Shown as formula (6) is one mathematical expression intended to represent that approach (Mazur & Hastie, 1978).

$$\text{(a)} \quad y = K(1 - e^{-t/R})$$

or (6)

$$\text{(b)} \quad y = K - Ke^{-t/R}$$

where

y = performance (for example, response time)

K = constant

R = learning rate parameter

t = amount of time or number of trials

A second model often used is an accumulation model. This model assumes the hyperbolic form shown in equation (7). This model treats learning as an accumulation of habits (Mazur & Hastie, 1978).

$$y = K\left(\frac{t}{t+R}\right) \qquad (7)$$

where

y = performance

K = constant

R = learning rate parameter

t = amount of time or number of trials

In practice, both of these models are equally effective in accounting for performance (Restle & Greeno, 1970; Hilgard & Bower, 1975).

The extent to which controls and displays are properly labeled varies significantly between vehicles. Its effect on performance is well documented (Anacapa Sciences, 1976). The primary effect of labeling is to cause performance to improve more rapidly in the early stages of practice. That suggests that formula (6b) should be changed to appear as formula (8). In that formula L, the labeling factor, is a continuous value.

$$RT = K_3 L(1-e)^{-t/R}) \quad (8)$$

where

RT = reaction time

K_3 = constant

L = labeling factor

t = number of trials

R = learning rate parameter

Combining formulas (5) and (7)

$$RT = K_1 + K_2 \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i} + K_3 L(1-e^{-t/R}) \quad (9)$$

As K_1 and K_3 are arbitrary constants, they can be combined, yielding

$$RT = K_1 + K_2 \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i} - K_3 (L)(1-e^{-t/R}) \quad (10)$$

As was noted previously, reaction time is markedly affected by compatibility. There are two kinds of S-R compatibility effects: within-ensemble effects, and between-ensemble effects (Fitts & Deininger, 1954; Fitts & Seeger, 1953).

Between-ensemble differences are due to the type of material serving as the signal (stimulus) and how the subject responds (e.g., is the stimulus array a collection of lights and the response array a collection of buttons; or, is the subject asked to name visually presented numbers; or, is some other combination used?). The effect of altering between-ensemble compatibility is to change the value of K_1. For controls, varying the design (panel versus stalk-mounting) will alter K_1.

Within-ensemble differences are those due to altering the mapping of a particular set of stimuli onto a particular set of responses. In the number-naming example, such could be achieved by asking the subject to name a number other than the one shown. (When I show a "1" say "2"; when I show you a "2" say 3"; when I show you a "3" say "1.") Altering within ensemble compatibility changes the value of K_2 in formula (5). For a particular control configuration, altering the direction of motion of controls (push the right stalk down (not up) to operate the wiper) is a within-ensemble manipulation. This suggests modifying formula (10) as follows:

$$RT = K_1(C_b) + K_2(C_w) \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i} - K_3(L)(1-e^{-t/R}) \qquad (11)$$

where

RT = reaction time

K_1, K_2, K_3 = constants

C_b, C_w = between- and within-ensemble compatibility

P_i = probability i^{th} function is actuated

L = labeling factor

t = number of trials

R = learning rate parameter

Movement Time

Motions made in reaching for controls have two distinct phases, a ballistic movement to get the hand near the control, and final positioning and grasping of the control. Predictions of the time to complete ballistic movements have been expressed in many ways, the most common of which is Fitts' Law (equations (12) and (13)). Fitts' Law states that movement time is linearly related to the logarithm to the base two of two times the movement amplitude divided by the target width.

$$\text{Movement Time} = MT = K_5 + K_4(ID) \tag{12}$$

where

K_5, K_4 = constants

$$ID = \text{Index of Difficulty} = \log_2 \frac{2A}{W} \tag{13}$$

where

A = amplitude of movement distance

W = width of target or accuracy

As with Hick's Law, Fitts' Law is robust and somewhat immune to speed-accuracy tradeoffs (Robinson & Leifer, 1967) and environmental changes (Kerr, 1973) though the constants do change with the experimental conditions. Generally, where accuracy is uncontrolled, W is the 2 sigma error limit. Welford (1968) presents a somewhat modified form (equation (14))

$$MT = K_5 + K_5 \log_2\left(\frac{A}{W} + .5\right) \tag{14}$$

He argues that subjects distinguish the near and far edges of the target, using something resembling a Weber fraction and not an information metric, for which Fitts argues. Distinguishing between the two models is difficult and it is not unusual for them to account for over 90% of the variance in a simple movement time task. Predictive differences between these models are insignificant.

A third model has been suggested by Beggs and his colleagues (equation (15)). (Kerr & Langolf, 1977)

$$E^2 = E_0^2 + K^2 \sigma_\sigma \left(\frac{t_u}{T}\right)^{2.8} \qquad (15)$$

where

E^2 = mean square error

E_0^2 = residual error (attributed to tremor)

K = movement deceleration constant

σ_σ = angular accuracy of the movement

t_u = time after last correction (taken to be 290 ms)

T = total movement time

It is not clear if this relationship is appropriate for the controls reach problem. This relationship was validated using a dart throwing-like movement which permitted timing (and corrections) to be easily scheduled.

While the ballistic motion to a target has been carefully examined in the psychological literature, the final positioning and grasping motions have not been considered. That is not true of the industrial engineering literature. Industrial engineers have taken great interest in predicting movement time, the main factor in determining the time to do work. As a result, they have developed substantial data bases for such. Primary application of those predetermined time systems have been to factory assembly operations. (Barnes, 1968; Crossan & Nance, 1972; Green, 1979; International Labor Office, 1973; Maynard, 1971; Niebel, 1976; Quick, Duncan & Malcolm, 1962; Whitmore, 1976.) Because of the intended application, it is assumed that the movements are performed repetitively, that the worker is reasonably well practiced, and that the movements are made with visual guidance. Furthermore, it is assumed that the movements are made at a normal speed, a pace that could be maintained for an entire day and not at the quickened rate that occurs while driving. It is an accepted practice to compute times for other paces by multiplicatively scaling the normal times (i.e., reducing or increasing them by some percentage).

The most commonly applied pre-determined time system family is Methods-Time Measurement (MTM). For the controls reach problem, the relevant version is the detailed form, MTM-1. This system was constructed by analyzing films of drill press operations in the 1940's. In MTM-1 there are 13 elements. They are: Reach - the motion of the hand toward an object; Move - a similar action involving transporting a weight; Turn; Apply Pressure; Grasp; Position; Release; Disengage; Eye Movements; and Body, Leg and Foot Movements. Times for those movements are shown in Table 34. For short-cycle activities (e.g., using controls) the round-off error introduced by tabular values as opposed to a continuous relationship (formula) can introduce substantial errors into the computation. This is a weakness common to most predetermined time systems. It should be noted that the times in those tables are not in seconds or fractions of a second, but TMU or Time Motion Units. One TMU equals .036 seconds, .0006 minutes, or .00001 hours. In other words, there are roughly three TMU per second (Barnes, 1968; Maynard, 1971; Niebel, 1976).

In transporting the hand from the steering wheel towards the control, one of two movement sequences can occur: either Release-Reach-Position-Grasp (for knobs and toggle switches), or Release-Reach-Grasp (for levers). The sequence selected and the element durations will depend on the control design and the pace of the motions. Those details will be determined in future research.

A second popular system (used about 1/3 as often as MTM) is Work Factor. As with MTM, there are several versions of the basic system, several elements (8) and tables of detailed data for each motion element (Quick, Duncan & Malcolm, 1962). Estimates of motion times based on Detailed Work Factor should approximate those of MTM-1. Further specification of the motion elements and times will be included in future work.

In addition to these predetermined time systems, there are many others that may provide useful data, including Master Standard Data (Crossan & Nance, 1972), Dimensional Motion Times (Geppinger, 1954) and MODAPTS (Colbert & Griffith, 1971). For the most part, these systems are less precise than MTM-1 or Detailed Work Factor.

Learning not only influences reaction time, but also movement time. The most comprehensive examinations of learning and movement time are

Table 34, MTM-1 Predetermined Times

TABLE I—REACH—R

Distance Moved Inches	Time TMU A	Time TMU B	Time TMU C or D	Time TMU E	Hand In Motion A	Hand In Motion B
¾ or less	2.0	2.0	2.0	2.0	1.6	1.6
1	2.5	2.5	3.6	2.4	2.3	2.3
2	4.0	4.0	5.9	3.8	3.5	2.7
3	5.3	5.3	7.3	5.3	4.5	3.6
4	6.1	6.4	8.4	6.8	4.9	4.3
5	6.5	7.8	9.4	7.4	5.3	5.0
6	7.0	8.6	10.1	8.0	5.7	5.7
7	7.4	9.3	10.8	8.7	6.1	6.5
8	7.9	10.1	11.5	9.3	6.5	7.2
9	8.3	10.8	12.2	9.9	6.9	7.9
10	8.7	11.5	12.9	10.5	7.3	8.6
12	9.6	12.9	14.2	11.8	8.1	10.1
14	10.5	14.4	15.6	13.0	8.9	11.5
16	11.4	15.8	17.0	14.2	9.7	12.9
18	12.3	17.2	18.4	15.5	10.5	14.4
20	13.1	18.6	19.8	16.7	11.3	15.8
22	14.0	20.1	21.2	18.0	12.1	17.3
24	14.9	21.5	22.5	19.2	12.9	18.8
26	15.8	22.9	23.9	20.4	13.7	20.2
28	16.7	24.4	25.3	21.7	14.5	21.7
30	17.5	25.8	26.7	22.9	15.3	23.2

CASE AND DESCRIPTION
A Reach to object in fixed location, or to object in other hand or on which other hand rests.
B Reach to single object in location which may vary slightly from cycle to cycle.
C Reach to object jumbled with other objects in a group so that search and select occur.
D Reach to a very small object or where accurate grasp is required.
E Reach to indefinite location to get hand in position for body balance or next motion or out of way.

TABLE II—MOVE—M

Distance Moved Inches	Time TMU A	Time TMU B	Time TMU C	Hand In Motion B
¾ or less	2.0	2.0	2.0	1.7
1	2.5	2.9	3.4	2.3
2	3.6	4.6	5.2	2.9
3	4.9	5.7	6.7	3.6
4	6.1	6.9	8.0	4.3
5	7.3	8.0	9.2	5.0
6	8.1	8.9	10.3	5.7
7	8.9	9.7	11.1	6.5
8	9.7	10.6	11.8	7.2
9	10.5	11.5	12.7	7.9
10	11.3	12.2	13.5	8.6
12	12.9	13.4	15.2	10.0
14	14.4	14.6	16.9	11.4
16	16.0	15.8	18.7	12.8
18	17.6	17.0	20.4	14.2
20	19.2	18.2	22.1	15.6
22	20.8	19.4	23.8	17.0
24	22.4	20.6	25.5	18.4
26	24.0	21.8	27.3	19.8
28	25.5	23.1	29.0	21.2
30	27.1	24.3	30.7	22.7

Wt. Allowance: Wt. (lb.) Up to	Factor	Constant TMU
2.5	0	0
7.5	1.06	2.2
12.5	1.11	3.9
17.5	1.17	5.6
22.5	1.22	7.4
27.5	1.28	9.1
32.5	1.33	10.8
37.5	1.39	12.5
42.5	1.44	14.3
47.5	1.50	16.0

CASE AND DESCRIPTION
A Move object to other hand or against stop.
B Move object to approximate or indefinite location.
C Move object to exact location.

TABLE III—TURN AND APPLY PRESSURE—T AND AP

Weight	Time TMU for Degrees Turned: 30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
Small— 0 to 2 Pounds	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium—2.1 to 10 Pounds	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large— 10.1 to 35 Pounds	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

APPLY PRESSURE CASE 1—16.2 TMU. APPLY PRESSURE CASE 2—10.6 TMU

TABLE IV—GRASP—G

Case	Time TMU	DESCRIPTION
1A	2.0	**Pick Up Grasp**—Small, medium or large object by itself, easily grasped.
1B	3.5	Very small object or object lying close against a flat surface.
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than ½".
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter ¼" to ½".
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than ¼".
2	5.6	**Regrasp.**
3	5.6	**Transfer Grasp.**
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 1" x 1" x 1".
4B	9.1	Object jumbled with other objects so search and select occur. ¼" x ¼" x ⅛" to 1" x 1" x 1".
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than ¼" x ¼" x ⅛".
5	0	Contact, sliding or hook grasp.

TABLE V—POSITION*—P

CLASS OF FIT		Symmetry	Easy To Handle	Difficult To Handle
1—Loose	No pressure required	S	5.6	11.2
		SS	9.1	14.7
		NS	10.4	16.0
2—Close	Light pressure required	S	16.2	21.8
		SS	19.7	25.3
		NS	21.0	26.6
3—Exact	Heavy pressure required.	S	43.0	48.6
		SS	46.5	52.1
		NS	47.8	53.4

*Distance moved to engage—1" or less.

TABLE VI—RELEASE—RL

Case	Time TMU	DESCRIPTION
1	2.0	Normal release performed by opening fingers as independent motion.
2	0	Contact Release.

TABLE VII—DISENGAGE—D

CLASS OF FIT	Easy to Handle	Difficult to Handle
1—Loose—Very slight effort, blends with subsequent move.	4.0	5.7
2—Close — Normal effort, slight recoil.	7.5	11.8
3—Tight — Considerable effort, hand recoils markedly.	22.9	34.7

TABLE VIII—EYE TRAVEL TIME AND EYE FOCUS—ET AND EF

Eye Travel Time $= 15.2 \times \frac{T}{D}$ TMU, with a maximum value of 20 TMU.

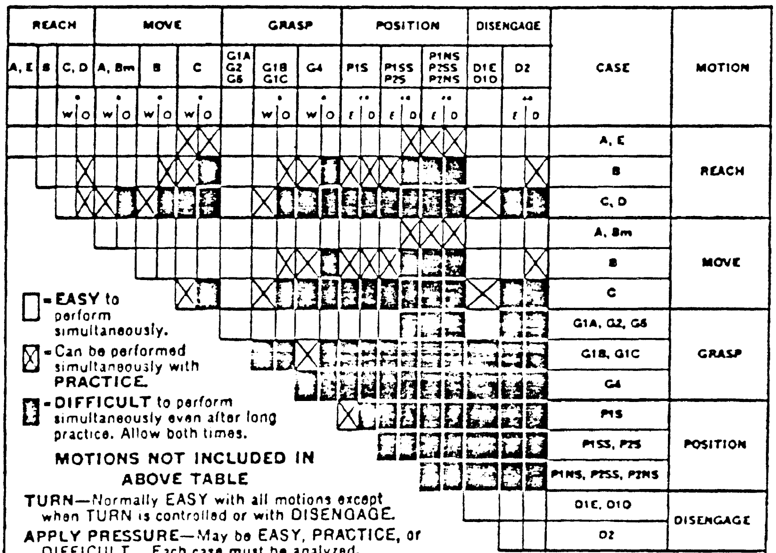
where T = the distance between points from and to which the eye travels.
D = the perpendicular distance from the eye to the line of travel T.

Eye Focus Time = 7.3 TMU.

TABLE IX—BODY, LEG, AND FOOT MOTIONS

DESCRIPTION	SYMBOL	DISTANCE	TIME TMU
Foot Motion—Hinged at Ankle.	FM	Up to 4"	8.5
With heavy pressure.	FMP		19.1
Leg or Foreleg Motion.	LM —	Up to 6"	7.1
		Each add'l. inch	1.2
Sidestep—Case 1—Complete when leading leg contacts floor.	SS-C1	Less than 12"	Use REACH or MOVE Time
		12"	17.0
		Each add'l. inch	.6
Case 2—Lagging leg must contact floor before next motion can be made.	SS-C2	12"	34.1
		Each add'l. inch	1.1
Bend, Stoop, or Kneel on One Knee.	B,S,KOK		29.0
Arise.	AB,AS,AKOK		31.9
Kneel on Floor—Both Knees.	KBK		69.4
Arise.	AKBK		76.7
Sit.	SIT		34.7
Stand from Sitting Position.	STD		43.4
Turn Body 45 to 90 degrees— Case 1—Complete when leading leg contacts floor.	TBC1		18.6
Case 2—Lagging leg must contact floor before next motion can be made.	TBC2		37.2
Walk.	W-FT.	Per Foot	5.3
Walk.	W-P	Per Pace	15.0

TABLE X—SIMULTANEOUS MOTIONS



□ = EASY to perform simultaneously.

☒ = Can be performed simultaneously with PRACTICE.

■ = DIFFICULT to perform simultaneously even after long practice. Allow both times.

MOTIONS NOT INCLUDED IN ABOVE TABLE

TURN—Normally EASY with all motions except when TURN is controlled or with DISENGAGE.

APPLY PRESSURE—May be EASY, PRACTICE, or DIFFICULT. Each case must be analyzed.

POSITION—Class 3—Always DIFFICULT.

DISENGAGE—Class 3—Normally DIFFICULT.

RELEASE—Always EASY.

DISENGAGE—Any class may be DIFFICULT if care must be exercised to avoid injury or damage to object.

*W = Within the area of normal vision.
O = Outside the area of normal vision.
**E = EASY to handle.
D = DIFFICULT to handle.

those of Hancock & Foulke (1963) and Hancock & Sathe (1969) of MTM-1. They found that performance could be modeled using both negative exponential and simple linear (i.e., $y = mx+b$) functions. The appropriate relationship varied with the motion element.

How, then, should movement time be modeled? The suggested procedure is to use Fitts' Law to determine the time of the ballistic motion, and MTM-1 (or Work Factor) to estimate the time required for the release, positioning, and grasping motions. As shown in formula (16), those predetermined times will be adjusted for the driver's pace and learning.

$$MT = K_5 + K_4(\log_2 \frac{2A}{W})(K_6 - K_7 e^{-t/R}) + PR(RL(L_1) + P(L_2) + G(L_3) \qquad (16)$$

where

K_5, K_4 = constants

A = movement amplitude

W = target width

PR = performance rating (pace)

RL = release time

P = position time } depend on control design

G = grasp time

L_1, L_2, L_3 = learning parameters of form ($L = mt + b$)

t = trial number

R = learning parameter

It may be possible to simplify this model, as the amount of learning that occurs for some of these motions (especially Release and Grasp) tends to be small. That, however, requires further investigation.

Actuation Time

The psychological literature does not provide any general models that could predict the time to activate a control. On the other hand, predetermined time systems (the industrial engineering approach) do provide some predictions. For actuating a toggle switch or lever, the motion (in MTM-1) is Move, for a knob it is Turn, and for a push-button it is either Apply Pressure or Move. The exact value of the time is dependent on the control design, operator pace, and practice. Those values will be determined in future research. Actuation time is defined as shown in formula (17).

$$\text{Actuation Time} = AT = (D)\ (PR)\ (L_4) \tag{17}$$

where

D = MTM-1 value for each control design

PR = performance rating (pace)

L_4 = learning parameter (of the form $L = mt + b$ where t = trial number)

Combining formulas (11), (16), and (17)

$$\begin{aligned} \text{Response Time} = {} & \left. K_1(C_b) + K_2(C_w) \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i} - K_3(L)e^{-t/R_1} \right\} RT \\ & \left. \begin{aligned} & + K_5 + K_4(\log_2 \tfrac{2A}{W})(K_6 - K_7 e^{-t/R_2}) \\ & + PR(RL(L_1) + P(L_2) + G(L_3)) \end{aligned} \right\} MT \\ & \left. + D(PR)\ (L_4) \right\} AT \end{aligned} \tag{18}$$

where

$K_1, K_2, K_3, K_4, K_5, K_6, K_7$ = constants

C_b, C_w = between and within ensemble compatibility

P_i = probability i^{th} function is cued

L = labeling factor

t = number of trials

R_1, R_2 = learning parameters $(R_1 > R_2)$

A = movement amplitude

W = target width

PR = performance rating

RL = release time

P = position time

G = grasp time

L_1, L_2, L_3, L_4 = learning parameters

D = base time for actuating each control design

Thus performance is influenced by the probability that a function will be operated, the design of the control, and practice. These factors are captured in a relationship that combines Hick's Law, Fitts' Law, and industrial engineering predetermined times.

Previous Models

The model described in the previous section is by no means the first attempt to model human performance. Models have been developed to describe human performance in many complex tasks. Most popular are those concerned with the workload of flying an aircraft. (See Greening, 1978 and Wierwille & Williges, 1979 for reviews.) The most appropriate of the "cockpit" models is the Human Operator Simulator (HOS) (Lane, Strieb & Wherry, 1977; Strieb, Glenn & Wherry, 1978). While HOS will generate predictions for operation times of simple switches, it lacks the necessary details to describe either multidirectional or combined lever controls. Other similar models include SWAM (Statistical Workload Assessment Model) (Linton, Jahns & Chatelier, 1977), the Siegel and Wolf model (Siegel & Wolf, 1969), and SAINT (Systems Analysis of Integrated Network of Tasks) (Hann & Kuperman, 1975; Kuperman & Seifert, 1975; Wortman, Duket, Seifert, Hann & Chubb, 1978a, b). SAINT is not a model dedicated to addressing operator performance but rather a general task scheduling model whose inputs are values obtained from human performance experiments.

Within the industrial engineering literature are a parallel set of computer models whose purpose is to automate the application of predetermined time systems. Worthy of note are ARMAN-Artificial Methods Analyst (Cremer, Towne & Mason, 1977), the Chaffin model (Chaffin, Kilpatrick & Hancock, 1970), SAMMIE (Bonney & Schofield, undated a, b), the 4M System (Martin, 1974) and MOST-Maynard Operation Sequence Technique (Maynard Company, 1974; Zandin, 1975). As all of these models are intended to describe serial repetitive tasks, reaction time is excluded. These models will therefore underestimate the time to operate a control once adjusted for pace.

Thus there are many models of human performance appropriate to predicting the time to use a control. It appears that combining several of the psychological models with the industrial engineering data will yield the most accurate predictions.

HUMAN FACTORS SUGGESTIONS

General Principles

One of the aims of the research review was to provide a basis for stalk control design recommendations. The author has interpreted this mandate somewhat broadly, and in many cases all types of fingertip-reach controls, not just stalk controls, are considered. What controls should be within fingertip reach and where should they be positioned? There are four basic factors to be considered in the arrangement of controls: (1) frequency of use, (2) the importance of the action resulting and the cost of time, (3) sequence of use, and (4) functional grouping.

1) Frequency of Use - Controls that are frequently actuated should be as close as possible to the 10 and 2 o'clock grip positions on the steering wheel without being accidentally struck while steering. One of the key factors in determining the time to use a control is movement time and consequently the movement distance.

2) Importance of the Resulting Action - The most important controls (based on what they do) should be located closest to the driver. Again, by minimizing movement distance to a control, response time is minimized.

3) Functional Grouping - Controls that are associated with the same system or subsystem should be arranged adjacent to each other. Organizing controls in such a logical manner makes them easier to find.

4) Sequence of Use - Controls that are used in sequence should be located next to each other so as to minimize movement distance (and time).

Fowler, Williams, Fowler, and Young (1968) proposed several methods for quantifying each of these principles and compared them in an experiment. Varied in a factorial manner were stress and the level of application of each principle. Each of 200 male college students operated an instrument panel that had been designed to meet some combination of these factors. The task, a simulated satellite launch, was highly sequential and deterministic. The results (time to perform the launch operation and the number of errors committed) showed that best performance was achieved when the controls were arranged according to sequence of use. When functional grouping was achieved at a high level, that arrangement was superior to those resulting from grouping by frequency of use or importance of resulting action. With regard to the other principles, no general conclusions can be drawn because of rather complex speed/accuracy tradeoffs underlying the results.

In addition to these characteristics, several other items of data have impact upon decisions concerning control location. Those other factors are: (1) accident information, (2) driver expectancy, (3) driver performance, (4) problems with control configurations, and (5) driver preferences.

1) Accident Information - It is clear that design of controls can be a causative factor in accidents. However, insufficient information is available to draw detailed conclusions as to which specific kinds of controls are conducive to accidents, at least based on the accident data at hand.

2) Driver Expectancy - Controls should be located where drivers expect them to appear and should operate in the matter expected (up and twist away for on or increase). There is more than ample experimental evidence to support this position. McGrath (1976) shows that if controls are within five inches of their expected location and mounted on the expected surface (panel or column) there is no performance decrement. In the "response time model," expectancy is reflected in the compatibility coefficients.

3) Driver Performance - There are considerable data on driver performance in using controls. With regard to stalks, few designs have been evaluated. The existing literature, however, does offer many insights as to how such studies should be performed.

4) Problems with Controls - There is vast information regarding which controls drivers experience difficulty in finding, reaching for, and operating. Information on the influence of the control design is somewhat spotty, especially in regard to stalk controls.

5) Driver Preference - There are some indications that drivers prefer stalk controls to panel controls. There is little information concerning preferences for alternative stalk control configurations. It is believed existing preference data are biased.

Suggested Configurations

The selection of controls for fingertip reach locations and the development of suggested configurations for them was performed in two steps. In the first step, controls were assigned priorities based on the previously described principles. While it would be desirable to make those assignments in a rigorous and quantitative manner, the information needed to do this (the cost of errors and, in some cases, the frequency of use) is not available. (See Tables 16, 17, and 35-37 for frequency of use and related data.) In the second step, suggestions are presented for the location and operation of fingertip reach controls. Because a de facto standard for it exists, the steering control has been excluded from this analysis. Again because there is an absence of good data on driver operation of multidirectional and combined lever controls, many of the suggestions were made based on human factors principles.

Shown in Table 38 is the list of priorities for hand controls. Controls that should be within fingertip reach are: the ignition and other engine starting and stopping controls, gear shift, parking brake set (if hand operated), beam switching/optical warning and automatic

Table 35. Anacapa Estimates of Frequency of Use of Controls.

Control	Once/day		Once/week		Once/month		Seasonally		Rarely or Never		Not in my Car		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Headlights	918	54.6	645	38.4	73	4.3	2	0.1	43	2.6	0-		1681	100
Wiper	52	3.2	370	22.2	716	43.5	4	2.5	464	28.2	2	.1	1645	100
Flasher	58	3.5	64	3.8	154	9.3	1	.1	1120	67.4	265	15.9	1662	100

(All columns from Once/day to Not in my Car are under the heading "USE".)

Source: Anacapa Sciences (1976), expectancy survey (n = 17.8 U.S. drivers), p. A-37.

Note: Other items surveyed were the radio, heater, defroster, lighter, ashtray, and vent.

Table 36. Frequency of Use Estimates from ISO

ESTIMATED

	VW	BDF	Chrysler UK	Lucas	Ford (Europe)	Overall
Main lights on/off	2	5		2.6	7.0	5
Beam selector (dip) ?	200	4		2.3	5.1 *	3
Horn	10	2	2.1	2.6	3.1	3
Wipers	30	5	4.5	12.3	9.2	10
Washers	30	5		5.0	2.9	3
Turn signal	200	10		29.3 L 38.6 R	71.2	30 Left 40 Right
Hazard warning	2	1		0.2		0.2
Parking brake release		8			13.7	14
Headlamp washer	1	5		0.9		1
Hood release		2			0.6	0.6
Restraint release		8			32	32
Cruise control		2				1
Optical horn	200	2	2.7	3.5	*	3
Front fog lamps	1	1		1.3		1.3
Rear fog lamps	1	1		0.7		0.7
Gear selector		10			245	245

NOTES: Thousands of Operations during first 80 000 km.

BDF - Qualitative estimate, 1 to 10 rating

Chrysler UK - Extrapolated from single development car used for 20 000 miles

Lucas - Calculated from 300 000 miles over 12 months, up to 7 development cars for control.

* Ford - 50%ile, 71 customer cars in UK, Germany or Scandinavia for one year; restraint releases assumed equal to drivers door openings; * beam selector operations includes optical horn; gear use estimated from clutch operations.

Source: International Standards Organization, 1976
(document ISO/TC22/SC13/WG3 (Simmonds-5) 46)

Table 37. Duration of Use Estimates from ISO

Time 'on' as a percentage of engine running time.

	Chrysler UK	Lucas	Ford(Europe)	Overall
Main lights on/off	5.9	28	38.5	30
Beam selector (dip)	10.6	2		5
Horn				
Wipers	8.3	11	7	9
Washers		1		1
Turn signal		18	10	15
Hazard warning		0.2		0.2
Parking brake release				
Headlamp washer				
Hood release				
Restraint release				
Cruise control				
Optical horn				
Front fog lamps		1		1
Rear fog lamps		2		2
Gear selector				

Source: International Standards Organization, 1976
(document ISO/TC22/SC13/WG3 (Simmonds-5) 46)

Table 38. Priorities for Hand Controls (Steering Control Excluded).

I. Controls to be Close to the Wheel	used frequently while in motion	action requiring immediate attention	part of high priority system (functional grouping & sequence of use)	remarks	stalk-mounting should be considered
ignition, other start/stop		x		emergency restart/stop	
controls, block heater,			x		
glow plug, choke					
gear shift	x	x		emergency stop	x
parking/emergency brake		x		emergency stop	
set (if hand operated)					
horn	x	x			
beam switching/optical		x	x	integrate optical warning	x
warning & auto beam				with horn	x
switch adjust					x
turn signal	x	x			x
wiper/washer & delay			x	clear windshield of spray	x
control,				from passing vehicle	x
rear wiper/washer			x		

II. Controls Within Easy Reach While Driving Position	Remarks
lighting controls (excluding beam switching)	
headlights/parking lights/fog lights on/off & headlight off delay	group together
interior lights, pnael intensity, auxiliary lights (e.g., map)	group together
hazard warning (may want to group with turn signal)	group together
headlight wiper	group together
inside mirror adjust	
outside mirror adjust & heater (group together)	
sun visor	
parking brake release	
climate controls (defroster, heater, fan, AC, & rear defogger)	group together
ventilation - windows, sun roof	
communications - radio, CB, tape, antenna, telephone	group together
lighter/ashtray	group together
driver's door lock & master lock controls	
seat adjust & heater	
steering wheel adjust	
cruise control	

III. Controls Ordinarily Not Used While Moving
hood & trunk release
glove compartment lock
clock adjust
odometer/tripmeter adjust

dimmer adjustment controls, the horn, turn signal, and wiper/washer controls (including the delay adjustment and rear wiper/washer). In light of driver expectancies, stalk locations should be considered for the gear shift, turn signal, beam switching and wiper/washer controls.

Of the remaining controls those associated with communications deserve mention. Controls for the car radio are the most frequently operated of all secondary controls. Because their operation distracts the driver from paying attention to the road ahead, special consideration must be given to where the radio is located.

Related to the radio is the car telephone. Bell Laboratories has developed a new switching system that will vastly increase the availability of mobile telephone service. They expect the car telephone to be a popular option in the near future. As a consequence, the design of its controls should be considered by the auto industry (Fantel, 1977; Grundlach, 1977; Hanson & Bronell, 1974; Ito & Matasuzaka, 1978; Kames, 1978; Mason, 1978; Smith, 1978; Walker, 1978).

Shown in Table 39 are details for five groups of controls actively being considered for stalk mounting. Two of the other controls that should be located close to the steering wheel are not described in detail. The location (on the right side of the column) and design (key switch) of the ignition is fairly standard and is satisfactory. As other controls related to starting and stopping the engine should be similar simple switches (push buttons, rocker switches, etc.) it would not be appropriate to describe their design in detail here. Likewise, the only manner in which sufficient mechanical advantage can be obtained to operate a handbrake is by a pull handle extending from the panel or a lever from the floor. Since this should not be a multifunction control, little will be said about it.

For the remaining controls for a left-hand drive car, the following is suggested.

1) If the car is equipped with an automatic transmission, the gear shift should be a dedicated, undirectional right-side lever. Moving it clockwise will shift the transmission through the standard

sequence (PRNDL). If manual, the gear shift could be either a right-side stalk or console-mounted. Attempts should be made to reduce the number of shift patterns.

2) The horn control should be a dedicated one, operated by touching either the steering wheel hub or spokes. Sounding the horn should also actuate the optical warning function.

3) The turn signal should be a dedicated multidirectional lever to the left of the steering column and operate in the currently almost standard manner.

4) The beam switch should be on the same multidirectional lever as the turn signal. The switch design (pull/pull, push/pull, other) needs to be resolved by research.

5) For the wiper/washer, two interim dedicated designs are suggested.

If the gear shift is column-mounted, twisting the left stalk away from the driver should increase the wiper speed (off, intermittent, low, high). The wiper delay would be adjusted by a knurled ring midway along the stalk length. The washer would be operated by an end push button. The rear wiper/washer would be controlled by a slide switch; depress to wash; push towards the column to increase rear wiper speed.

For a floor-mounted gear shift, the wiper/washer should be either mounted on the left stalk (as was the case for vehicles with a column-mounted shift) or controlled by a right stalk. If mounted on the right, pushing that stalk toward the ceiling would increase wiper speed (same sequence). A knurled ring on the end of the stalk (twist to change) would adjust the wiper delay. It is not clear whether the washer should be an end push button or operated by pulling the lever towards the steering wheel. The rear wiper/washer would be mounted on the face of the right stalk and operate in exactly the same manner as the left stalk version.

It must be emphasized that these suggestions are solely those of the author. They are extremely tentative. In most cases they are based on human factors principles, and in some, on conjecture. There is no research of which the author is aware where the number of stalks or their location has been varied and driver performance data collected. They should be interpreted as preferences rather than recommendations against specific configurations (e.g., (2L, 1R), (2L), and (1L, 2R)). They are a reflection of what is known now. They are certain to change when the proposed research is completed.

Table 39. Details of Human Factors Analyses of Stalk Controls.

CONTROL: GEAR SHIFT

GENERAL PRINCIPLES

Frequency of Use:

Simmonds (1974):	Anacapa	Owner	Rental Car
No data (assumed 100%)	Sciences (1976)	Survey: 100%	Survey: 100%

Sequence of Use:

Used after the ignition.

Importance of Action:

High: quick restart needed when engine stalls while moving, especially in vehicles with power brakes and/or power steering; quick down-shift action required if brakes fail.

Functional Grouping:

Used with ignition.

SPECIFIC DATA

Accident Evidence:

None published though considerable discussion in popular press concerning its relationship to accidents.

Expected Location:

Right side of column or mounted on floor between seats.

Driver Performance:

No data.

Problems Reported:

Burger et al. (1977), no data. Anacapa Sciences (1976), the complaint rate for panel-mounted push buttons was double that of lever designs.
Owner's Survey: Locate/operate 1.5/8.5%
Current trip: .5/1.9%
All renters: 2.4/3.8%

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls

Control: Gear Shift

INTERIM SUGGESTION

The gear shift should be a dedicated column-mounted, unidirectional lever on the right side for vehicles with automatic transmissions. Floor or column mounting would be permitted for vehicles fitted with manual transmissions. While this does not seem to be very restrictive, it would eliminate several designs (for example, the 1959 Ford Edsel had a push button selector mounted on the steering wheel hub).

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls

CONTROL: HORN

GENERAL PRINCIPLES

Frequency of Use:

Simmonds (1974): No data	Anacapa Sciences (1976)	Owner's Survey: 19%	Rental Car Survey: 47%

Sequence of Use:

May be used prior to foot control (brake/accelerator).

Importance of Action:

High: Need to warn other drivers of impending danger.

Functional Grouping:

Associated with optical warning.

SPECIFIC DATA

Accident Evidence:

Of the controls examined by Perel (1974), the horn was most frequently associated with accidents.

Expected Location:

McGrath (1974). Foreign drivers - steering wheel location expected by Italian, Swedish, English, and Japanese drivers. French drivers expect stalk mounting, primarily left. U.S. drivers expect steering wheel mounting.

Driver Performance:

Malone, Krumm, Shenk, and Kao (1972); Krumm (1974); Faust-Adams and Nagel (1975); and the work of Anacapa Sciences (1976) point to superiority of steering wheel mounting over stalk mounting. Distinguishing between spoke and pod mounting alternating is difficult. Performance data indicate location within rim is unexpected.

Problems Reported:

Burger et al. (1977): The horn was the most likely of all controls to be associated with near-accidents. Detailed analysis indicates problem is mainly due to stalk-mounted horn. Fewer problems occur with other designs. Krumm (1974): There is a greater problem incidence for stalk and rim mounted horns.

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls.

CONTROL: HEADLIGHT BEAM SWITCH/DIMMER AND OPTICAL WARNING

GENERAL PRINCIPLES

Frequency of Use:

Simmonds (1974): Dip to high - 5, dip to low - 5. Optical horn - 5.
Anacapa Sciences (1976): Own car survey: 10%; Rental car survey 44%

Sequence of Use:

Beam switching optical warning may be associated with using horn.

Importance of Action:

Signaling: high. Other actions - moderate. Functional grouping associated with headlight on/off control.

SPECIFIC DATA

Accident Evidence:

None.

Expected Location:

Anacapa Sciences (1976): Strong U.S. preference (85%) for floor-mounted dimmer switch. In general, Italian and French expect stalk mounting of headlights (left side). Swedish, UK, and Japanese drivers expect panel mounting.
Black, Woodson, and Selby (1977): When control is not floor mounted it should be a lever. Moving a lever towards the driver is preferred to moving a lever away 3:1 for high/low beam switching.
Elsholz and Bortfeld show stalk mounting preferred to panel mounting for high-beam switching.

Driver Performance:

Faust-Adams, and Nagel (1975) report stalk-mounted locations responded to more rapidly than floor-mounted location.

Problems Reported:

Burger et al. (1977) reports a fair number of problems with the dimmer. Most were associated with finding and operating it as opposed to reaching for the control. The number of problems associated with reaching it, however, is greater than those for any of the other secondary controls.
Anacapa Sciences (1976) own car survey locate/operate 15.2/7.0%, rental car survey 6.0/3.3%. In comparing the various control designs, the problem rate for the floor design was less than the stalk-mounted designs.
Mourant et al. (1977) - insufficient evidence to favor one method of operation over another, though problem rates for moving a lever up and down to operate the dimmer are considerably greater than those to move it forward or back.

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls.

Control: Horn

SPECIFIC DATA: Continued

Problems Reported: (cont.)

Anacapa Sciences (1976): Own car survey 9.8/12/6%. Rental survey - 18.2/10/1%. Note: largest of all controls. Most frequently reported of all controls; large number of problems with multifunction control, push buttons, and pod-mounted device. Few problems with pod-type designs.

Driver Preference:

No data.

INTERIM SUGGESTION

As the complexity model shows that increasing the area of certain types of controls decreases movement time, the active area of the horn control should be both the steering wheel hub and spoke faces and those areas should be dedicated solely for that purpose. Both should be labeled. Because of possible confusion with washer, cruise, beam switching and other controls in existing vehicles, left stalk-mounting of the horn is not suggested. Further, the horn and optical warning should be integrated. Sounding the acoustic horn should flash the headlights. When the acoustic horn is sounded by itself, one often cannot determine which vehicle is the source, especially in traffic. Likewise, when the optical horn is operated during daylight hours, simultaneous activation of the acoustic horn could be valuable in alerting other drivers.

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls.

Control: Headlight Beam Switch/Dimmer and Optical Warning - (cont.)

SPECIFIC DATA: Continued

Driver Preference:

Mortimer and Post, 1973. Stalk mounting preferred.

INTERIM SUGGESTION

The beam switch should be on a dedicated multidirectional lever extending from the left side of the column or pod. There are two possible modes of operation which are suitable: (forward = high beam, pull towards driver = low beam, or pull towards driver to switch beams). The optical warning function and horn should be integrated. Sounding the horn should also flash the headlights.

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls.

CONTROL: TURN SIGNAL

GENERAL PRINCIPLES

Frequency of Use:

Simmonds, 1974. Left: 35, Right: 35, Cancel: 70
Anacapa Sciences (1976): Own car survey: 87%; Rental car survey: 89%

Sequence of Use:

Just prior to turning steering wheel.

Importance of Action:

High - need to signal other drivers.

Functional Grouping:

Associated with steering wheel.

SPECIFIC DATA

Accident Evidence:

None

Expected Location:

No data (left stalk up for right turn, down for left turn assumed).

Driver Performance:

No data.

Problems Reported:

Burger et al., no data. Anacapa Sciences (1976): Own car survey: locate/operate - 2.17.4%; Rental car survey: 1.3/2.6%.
Low problem rates were associated with lever designs. Greater problem rates were reported for pod switches. The Elsholz and Bortfeld, 1978 study indicated drivers had problems with novel control designs.

Driver Preference:

No data.

Table 39. (continued) Detail of Human Factors Analyses of Stalk Controls.

Control: Turn Signal (cont.)

INTERIM SUGGESTION

The turn signal should be either a dedicated multidirectional lever extending from the left side of the steering column or from a left-side pod. The direction of operation should be up for right turn, down for left turn.

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls.

CONTROL: WINDSHIELD WIPER/WASHER

GENERAL PRINCIPLES

Frequency of Use:

Simmonds (1974) - wiper, first position 8, second position 2, off 10, washer, 3. Anacapa Sciences (1976): Own car survey, 11%; Rental car survey, 35%.

Sequence of Use:

Wiper used after washer if not automatic, generally not used with other controls.

Importance of Action:

High - passing vehicle and changing weather patterns can suddenly obscure the windshield.

Functional Grouping:

Wiper and washer associated. Some association with defogger.

SPECIFIC DATA

Accident Evidence:

Perel (1974) cites instances where operating the wiper was distracting.

Expected Location:

McGrath (1974). American made sedan: U.S. - left panel, European nations including Japan - right panel. European made sedan: Japan and Sweden - right panel, Italy - right stalk, UK - left panel, France - mixed.
Anacapa Sciences (1976). (later study) wiper/washer - left side of panel.
Black, Woodson, and Selby (1977) - roughly 3 or 4 to 1 preferences for panel over stalk location.
Elsholz and Bortfeld (1978) left column location for wiper and washer not expected. Problems with left panel location.

Driver Preference:

Kuechenmeister (1974,1975). Put wiper/washer on stalk.

Table 39. (continued) Details of Human Factors Analyses of Stalk Controls.

Control: Windshield Wiper/Washer (cont.)

SPECIFIC DATA (cont.)

Problems Reported:

Burger et al. (1977): Moderate number of problems reported for finding and operating wiper/washer. Anacapa Sciences (1976): wiper - own car survey, problem locate/operate 10.1/7.3%; rental car survey - 6.9/8.6%. Washer - owner car survey 8.6/9.9%, rental car survey - 8.3/19.2% (somewhat greater number of problems with wiper and washer than other controls. Reported problem rates for multifunction controls are roughly equivalent to those of rotary knobs (panel mounted)). Mourant et al. (1977): Insufficient information to draw conclusions about direction of operation of wiper/washer controls.

INTERIM SUGGESTION

The response time model suggests that a right-side stalk location would be superior to a left location because a right stalk could be operated by a quick sweeping motion of that hand. On the left stalk, only the motions associated with twisting it remain uncommitted. To twist it, the stalk must first be grasped, an additional motion. Problems would arise, however, when the gear shift is column-mounted (on the right side). (It is suspected that two stalks on the opposite side of the wheel can be operated more rapidly than two stalks on the same side.) While these questions can only be resolved by research, the following interim solution is suggested.

When gear shift is column-mounted or floor-mounted:

Twisting the left stalk would increase the wiper speed (off, intermittent, low high). The wiper delay would be adjusted by twisting the middle of the stalk. Pushing an end button would operate the washer. On the stalk face would be a secondary switch for the rear wiper/washer. Depressing it would turn on the washer. Sliding that switch toward the column would increase the rear wiper speed.

When gear shift is floor-mounted:

Lifting up (towards the ceiling) a dedicated right stalk would increase the wiper speed. Either pushing an end button in or pulling the lever towards the driver (the exact design is undecided) would operate the washer. The rear wiper/washer would be a secondary switch on the lever face identical to the left stalk arrangement.

PROPOSED RESEARCH

General Information Requirements

In examining automobile controls, the author found tremendous diversity in the way controls were arranged and operated. On the other hand, except for the pod and other unique controls of Citroen products, the stalk- and panel mounted switches found in production vehicles were quite conventional in their design. The author suspects there were many other novel designs that did not come to his attention.

One possible source of information regarding novel control designs could be custom and show car dealers and manufacturers. It is suspected that they have marketed vehicles with controls the major auto manufacturers have not thought of, which might be suitable for mass production. A second potential source of information is industrial designers. One means of eliciting their ideas would be for MVMA to sponsor student projects to design "new and unusual instrument panels and controls." Both sources could be tapped for fairly low cost. The author's concern is that a design standard will be developed based on existing designs. In many cases, those designs were constructed under circumstances in which the creative talents of the industrial designers were highly constrained. A good standard should both enhance driver safety and provide the customer with an attractive-looking product.

Of higher priority are several other suggestions. Clearly, the relationship between control design and accident statistics can be most revealing. The author would like to suggest that MVMA draft a letter to NHTSA encouraging them to update the Perel (1976) study. It is suspected that sufficient accident cases have been added to the University of North Carolina Highway Safety Research Center (HSRC) files to make that data informative. As NHTSA has dealt with HSRC before, NHTSA is in the best position to obtain the needed information economically.

The author also suggests that a problem survey of European and Japanese drivers be conducted through ISO. Little is known about the experiences of non-American drivers with controls. Survey techniques similar to that of Burger et al. (1977) should be employed (where accidents, near accidents, and problems are considered). However, in this instance, more precise frequency of use statistics should be collected along with more exact information about each respondent's car. To perform this study properly, at least 1000 responses per country should be obtained. This survey, along with the other research proposed here, would serve as converging evidence for standardization.

There is little information available to engineers from which driver performance in operating controls can be predicted. In addition, interest has been expressed in developing a performance standard as an alternative to a design standard for controls. Therefore, the author proposes a series of specific experiments to determine the parameters of the response time model in the previous section. This series was described somewhat more briefly in the proposal submitted to MVMA for the 1979-1980 fiscal year (HSRI, 1979). Of the projects proposed here, this one has the highest priority. The only other current outline of automotive control design research requirements appears in Black, Woodson, and Selby (1977). Some of the author's proposals are similar to those of Black, et al.

Several stalk control configurations similar to those noted in the hardware survey ((1L), (1L,1R), (2L,1R), (2L), (1L,2R)) will be examined in conjunction with both floor and column-mounted transmission shift levers. Also, for comparison purposes, "pod-type" controls will be evaluated, though not extensively. It is envisioned that a few variations for each configuration will be considered (e.g., wiper = twist away, dim = push lever away vs. dim = twist away, wiper = push lever away). The specific variations selected will depend on hardware availability.

Experiment 1 - Population Stereotypes

Two parameters in the movement-time relationship reflect control-response compatibility. These parameters are not only important in their own right for the definition of the model, but ISO has already taken the path of including preferred directions of operation in Standard 4040.

Subjects will be shown either drawings of an instrument panel with column-mounted stalk controls or a sandwich board similar to that of Black, Woodson, and Selby (1977). Pilot research now scheduled will indicate the best method. For each control configuration (single left stalk, one left and one right stalk, etc.), subjects will be asked to state how functions should be assigned to stalks and how they should operate.

Functions for which direction of operation stereotypes will be collected include: beam switching, wiper washer (both front and rear), horn, optical warning and cruise control, among others. In addition, subjects will be asked to state which of several stalk configurations and control designs they prefer (e.g., should the dimmer be a pull/pull or push/pull switch).

As Anacapa Sciences (1976) has shown, long-term experience has an important influence on population stereotypes. While students are easier to obtain, they lack experience with a widely varying range of vehicles. Consequently, emphasis will be placed on sampling the driving population as a whole.

Potential test protocols include laboratory and field procedures. Potential field sites include shopping centers and the Rouge Plant (as part of "the Incredible Ford Factory Tour"). This approach has been used previously with success (Jack, 1972). It is hoped that Ford would be willing to cooperate in such an experiment.

Experiment 2 - Movement Time

A second set of studies will attempt to further specify the movement-time parameters and the parameters associated with activating various kinds of controls. Subjects will begin with their hands resting on the steering wheel. Two types of experiments will be performed. In the first, subjects will reach a variety of short distances to targets under conditions of fixed target size (e.g., reach to a one-inch target five inches away). Time and error data for touching the target in response to visual cues will be collected. The experiment will be controlled and timing measured by a minicomputer (Digital Equipment Corporation LSI-11). Preliminary design work on a special computer-compatible response device for this purpose has been completed and the design is undergoing revision.

In the second kind of experiment, subjects will be asked to reach for specific kinds of controls and operate them (for example, rotary knobs, push buttons, toggle switches, etc.). This second study will help estimate values for the grasping time for each kind of control and also will provide estimates of the activation time. In this study not only will movements be recorded by computer, but they will be videotaped as well. The purpose of this study is to further develop the functional relationship between movement time, distance, accuracy, and specific control designs (Fitts, 1954; Fitts and Peterson, 1964). In addition, estimates of movement time from the videotapes will be compared with those from several predetermined time systems developed by industrial engineers (Green, 1979; Maynard, 1971) and with values obtained from specific studies of controls (Lanterman, Schultz, and Douglas, 1962; Lanterman, Siegel, and Schultz, 1972; Schultz and Siegel, 1962; Siegel and Schultz, 1962; Siegel, Schultz, and Lanterman, 1962). In addition, an attempt will be made to model the learning process.

For this experiment, the author would probably use student subjects only. Adding age to the model could double or triple the sample size required.

Experiment 3 - Final Test

Finally, a third set of studies will be collected in which drivers will reach for controls on instrument panel mockups. Their primary task will be to perform a tracking task similar to that of steering an automobile. Concurrently, subjects will be shown the names of functions either on slides or a cathode-ray tube and will be asked to operate those functions as rapidly and as accurately as possible. For example, the words "high beam" would appear and the subject's task would be to turn on high beam function. The experiment will be controlled by a minicomputer. Response time, errors, and possibly measures of eye-off-the-road time and tracking performance will be collected. In addition, great care will be used in examining learning. The subjects will consist of a wide range of drivers obtained from the Ann Arbor community.

Refinement of the response time index coefficients is part of the next phase and will be described in future reports. To assist HSRI in developing the research plan just described, the relevant basic research was sampled. Key documents are listed below for MVMA guidance. A number relate to more than one phase of control operation.

REACTION TIME

Beggs, Graham, Monk, Shaw and Howarth, 1962
Brainard, Irby, Fitts and Alluisi, 1962
Fitts and Deininger, 1954
Fitts and Seeger, 1953
Frowein and Sanders, 1978
Hilgendorf, 1969
Kamlet and Boisvert, 1969
Pachella, 1974
Poulton, 1956
Smith, 1968
Symington, 1971
Teichner and Krebs, 1972
Topmiller and Sharp, 1965
Wade, Newell and Wallace, undated

MOVEMENT TIME

Battig, 1954
Bilodeau, 1954
Beggs and Howarth, 1972
Brown, Knauft, and Rosenbaum, 1948
Brown and Slater-Mammel, 1949
Carron, 1971
Davis, Wehrkamp, and Smith, 1951
Fleishman, 1958a, b
Glencross, 1972, 1973
M. Green and Muckler, 1958
Herbert, 1957
Kerr and Langoff, undated, 1977
Knight and Dagnall, 1967
Kvalseth, 1976
Loockerman and Berger, 1972
Robinson and Leifer, 1967
Semjen and Requin, 1976
Siddall, Holding, and Draper, 1957
Smith, 1968
Wallace, Newell, and Wade, 1978

ACTUATION TIME

Bradley and Stump, 1965a, b

Bradley and Wallis, 1958a, b

Jenkins, 1947

Lanterman, Siegel and Schultz, 1962a, b

Mehr and Mehr, 1971, 1973

Muckler, 1961

Schultz and Siegel, 1962

Schultz, Siegel and Lanterman, 1962

Sharp and Hornseth, 1965

Siegel and Schultz, 1962

Siegel, Schultz and Lanterman, 1962

In this report the research on the design of automobile controls focusing on multifunction controls has been reviewed. The research indicates that drivers experience difficulties in operating and locating controls, especially when they are more than five inches from their expected location. Most of the previous research has emphasized panel-mounted controls. To expand that data base and provide engineers with a means to compare alternative multifunction control designs, a model to predict response time for controls is offered. Also described is the research necessary to validate that model. It is important that vehicle controls be safe and easy to operate. The means to precisely determine such is within reach.

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Anonymous, "Four More Subcompacts", Consumer Reports, July 1979(d), 44(7), 420-425.

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APPENDIX A

Abstracts

Anacapa Sciences, SAE Study of Vehicle Controls Location, Anacapa Sciences progress report 182-11, Santa Barbara, CA, March 1974.

This study reports eight different investigations. Two surveys of problem incidence were conducted. In a large field study 1140 drivers were queried concerning difficulties in using 20 different controls. In a related survey, 342 rental car drivers were asked about 21 controls. Those studies revealed drivers experienced difficulty in locating and operating a number of the controls including the vent, dimmer, climate, flasher, wiper, horn controls and so forth. There were substantial differences in problem report rates as a function of control design. In addition, frequency of use data were collected.

In another set of studies expectancies were obtained for control location. In one case 100 drivers were asked about seven controls in their own cars, and in another 98 drivers. The results of those studies are presented as dot density diagrams. Most important was the finding that drivers expect that the headlights on/off and wiper/washer switches will be on the left side of the instrument panel.

From 28 drivers recall data for controls in their own cars were obtained. Typically three to five inch errors were found.

Finally, 53 different vehicles were examined in regards to the location of ten different controls. Somewhat standardized were the locations reported for the headlight on/off switch (left), the radio (right), the dimmer switch (floor), the lighter (right), the flasher (right side of the column), and ignition (right side of column). Other controls were fairly diverse in their location.

Finally, two performance studies were conducted. In the first, 24 drivers located eight controls on slides from 30 different vehicles. In a followup study 12 drivers located 20 controls while driving one of three cars (one of which was their own). There was good agreement between the laboratory and the performance. Finding controls in expected locations sharply reduced response time with first trial response times averaging roughly two seconds. Also, labeling had a powerful effect on drivers' ability to locate controls with the absence of labeling tripling error rates.

Anacapa Sciences. "Driver Expectancy and Performance in Locating Automotive Controls." Society of Automobile Engineers Special Publication SP-407, February 1976.

This report summarizes a series of studies done for the SAE Human Factors Engineering Committee. In the first study 1140 motorists were surveyed as to what problems they encountered in finding and operating controls in their own cars. An additional 342 were asked about rental cars. Problem incident rates are presented for roughly 20 controls in both cases. Presenting the greatest difficulty were the vent, horn and climate controls although difficulty was also experienced with the lighter, dimmer, parking brake and washer controls among others. Also obtained were commonality data for control location in 77 US and 38 1973 foreign cars.

In a second set of studies, several methodological issues were examined. Using both paper and pencil, and in-car methods 100 motorists indicated where they expected to find 7 controls. The resulting distributions were very similar.

To assess their ability to remember control locations, 28 drivers were asked to recall where 7 controls were located in their own cars. While the recall method appeared promising, limited resources prevented it from being explored more fully.

In a third study 24 drivers were shown slides of the instrument panels from 30 vehicles. The time to locate (touch the screen) 8 controls were collected. In parallel with this study location time for 20 controls were obtained in 3 different vehicles for 12 drivers. Overall the 2 methods yielded similar findings. Conclusions regarding the role of numerous interacting variables (sex, age, vehicles, labeling, prior expectation, etc.) were drawn.

In a larger study, control location expenctancies were obtained from 1768 drivers for 14 controls. Based on that information, 2 vehicles were modified such that 30 systemtically varied arrangements of 8 controls in one and 15 arrangements in the othere were obtained. Control location times and errors were calculated. In general, these data showed that performance did not suffer as long as a control of interest was within 5 or 6 inches of its expected location.

Finally, based on all of these data, suggestions for the location of several controls are offered.

T.L. Black, W.E. Woodson, and P. H. Shelby. "Development of Recommendations to Improve Controls Operability." U.S. Department of Transportation report DOT-HS-803-456, final report of contract DOT HS-6-01445, Washington, D.C., November 1977.

Automobile driver controls locations and operational modes and expectancies were studied in order to develop recommmendations for modifying Federal Motor Vehicle Safety Standard No. 101. Study phases included: (1) a field investigation of driver controls operation expectancies; (2) derivation and review of proposed rule-making recommendations; (3) analysis of current control option provisions in domestic and foreign vehicles; and (4) preparation of recommendations for modification/improvement of FMVSS No. 101 and future research standards. Results include: (1) the analysis of control operation expectancy data to support specific reommendations for improved driver-controls interface; (2) the identification of several areas for rule-making in which current information is inadequate; (3) development of a preliminary draft of a modified standard relative to FMVSS No. 101; (4) the application of human engineering principles to identification, location, operation and illumination for automobile controls; and (5) recommendations for needed research to enlarge the data bank.

(author supplied abstract)

William J. Burger, Russell L. Smith, John E. Queen, and Graham B. Slack. Accident and Near Accident Causation: The Contribution of Automobile Design Characteristics. U.S. Department of Transportation report DOT-HS-802-714, final report of contract DOT-HS-5-01216, Washington, D.C., November 1977.

A study was conducted to (1) determine the frequency and severity of driver/vehicle design mismatch problem contribution to accidents and near accidents, (2) related driver and vehicle characteristics to severity and frequency of problems experienced by drivers, (3) develop and validate the method used to measure mismatch problems, and (4) identify vehicle design countermeasures which would reduce problem frequency or severity. Based upon recommendations by experts, literature reviews, focus panels and preliminary question testing, five direct mail questionnaires were developed and pilot tested on a sample of 800 U.S. Government employees. Results were analyzed and a modified questionnaire recommended for a large scale survey of drivers. The questionnaire contained questions on vision, controls, steering, braking, shifting, and seating. Subsequently, a direct mail survey was conducted by three private institutions which surveyed 10,000 drivers from California and New Hampshire. The 3500 returns citing 1691 near accidents or accidents for various mismatch questions were analyzed by driver and vehicle demographic variables. Results strongly indicate that the survey approach is valid and that driver/vehicle design mismatch problems are not trivial as contributors or causes of accidents. Most frequent and severe problems experienced are vision related, e.g., oncoming headlight glare, window obscuration due to weather, and mirror information and glare. Steering and braking problems were also significant. Driver height, age, weight, sex, experience and exposure, and vehicle age, size (type), and model are uniquely related to specific mismatch problems experienced.

(author supplied abstract)

Donald W. Conover, Wesley E. Woodson, Peter H. Selby, & Gerald E. Miller. Location, Accessibility & Identification of Controls & Displays in 1969 Passenger Automobiles. Society of Automotive Engineers paper 690458, Warrendale PA, 1969.

A human engineering survey of the control/display arrangements in 1969 passenger automobiles was conducted under contract to the National Highway Safety Bureau. Survey rationale, methodology, and preliminary findings are presented. Marked variability was noted between various control/display arrangements and certain important driver compartment dimensions. This and other findings suggest need for development of human engineering design criteria against which to base future design standards for the driver vehicle interface.

(author supplied abstract)

Joachim Elsholz and Manfred Bortfeld. "Investigation into the Identification and Interpretation of Automotive Indicators and Controls." Society of Automotive Engineers paper 780340, Warrendale PA, 1969

The identification of present indicators and controls were tested in several series with 100 subjects having varied demographic backgrounds and their statements evaluated as to the individual technical functions. In tests with another 50 persons, we measured the learning effects as functions of both the individual labels and the various demographic groups. Evaluation of these test series shows the influence of the different demographic data among the persons tested. With 150 subjects tested in European cars the driver's expectations as to where a specific control is located and what specific manipulation he associates with this control was investigated.

(author supplied abstract)

A.S. Faust-Adams & R.J. Hagel. "Choice Reaction Time and Location of Vehicle Controls." Perceptual & Motor Skills, 1975, 40, 181-186.

The reaction time of 24 nondriver Ss was measured to six controls in each of two cars, one with an "American" style layout, the other with a "European" style layout. Ss uniformly reached for and touched the controls in the European style car faster, a finding which has implications for the design and layout of motor-vehicle controls. Implications of the further finding that reactions to immediately repeated stimuli were uniformly faster are also mentioned.
(author supplied abstract)

R.L. Fowler, W.E. Williams, M.G. Fowler and D.D. Young. "An Investigation of the Relationship Between Operator Performance and Operator Panel Layout for Continuous Tasks." U.S. Air Force Aerospace Medical Research Laboratory technical report AMRL-TR-68-170, Wright-Patterson AFB, Ohio, December 1968.

This study defined and evaluated four principles of control panel layout: sequence of use, functional grouping, optimum location by frequency of use and optimum location by importance. The four principles were evaluated by factorial experiments which included stress conditions and three levels of application of each of the arrangement principles. Systematic procedures for applying each principle in the layout process were developed. Analysis of the final trials indicated that when optimized, sequence of use leads to consistently superior performance. Stress disrupts performance on control panels layed out on the basis of optimum location by frequency of use and on the basis of optimum location by importance of use, but not on panels where the layout principles sequence of use and functional grouping were used. Practical applications of the data to the panel design process are offered.

(author supplied abstract)

International Standards Organization. Ergonomic Assessment of Control Layouts in Cars. International Standards Organization document ISO/TC22/SC13/WG3 (Simmonds-3)36, Geneva, 1975.

This document presents an analysis which estimates the total number of confusions that could result from six control configurations. Those configurations were proposed by ISO delegates. Total error scores were computed by multiplying the rated confusability of control design pairs (Simmonds' own subjective values) by the frequency of use for each control and then summing over control pairs. The resulting analysis favors column mounting of controls over instrument panel mounting.

International Standards Organization. Results of Joint WG 2 + 3 Survey of Control Use, International Standards Organization document ISO/TC22/SC13/WG3 (Simmonds-5)46, Geneva, 1976.

This document summarized the results of an ISO survey on control use. In the first two questions ISO delegates were asked to rate on a scale from 1 to 10 the need for immediate action and the danger from inadvertent operation of 16 controls. The horn, wiper, turn signal and dimmer switch were all voted as needing immediate action. Errors due to inadvertent operation of the parking brake release, main light switch, dimmer, turn signal, hand release, and seat belt release were thought to be significant. In addition, presented are frequency of use data from five sources and duration of use from three.

International Standards Organization. Multifunction Control Base System Comparison. International Standards Organization document ISO/TC22/SC13/WG3(Schwarz-6)47, Geneva, November 1975.

An evaluation was conducted to compare driver performance using a multifunction control with a base (production) system. Measurements included response time, errors and subjective ratings of ease of operation. Initial response time and error data favored the base system, however, by the fourth trial there are no "practical" differences between systems. Subjective ratings are highly favorable to column-mounted washer/wiper/dimmer.

(author supplied abstract)

International Standards Organization. ISO Survey on Controls Mounted Near the Steering Wheel, International Standards Organization document ISO/TC22/SC13/WG3 (Simmonds-9) 55, Geneva, 1976.

Experts belonging to Working Group 3 were asked to respond to three questions: 1) Which controls should be located close to the steering wheel? 2) Which functions should be combined on the same multifunction control? 3) Which modes of operation should be used for each function?

The responses of those experts were tallied using a complicated voting procedure in which each nation belonging to Working Group 3 received 10 votes per question. The experts concluded that the beam switching, acoustic horn, wiper switch, turn signal, and optical horn controls must be close to the steering wheel. Headlights on/off and cruise controls may be close. The parking brake release must not be close. They also concluded that beam switching, optical horn, acoustic horn, and wiper/washer may be grouped on the same control. Some agreement was reached as to how these controls should operate.

Henry S.R. Kao, Thomas B. Malone, and Richard L. Krumm. "Human Factors Analysis of Current Automobile Control/Display Characteristics," Society of Automotive Engineers paper 720204, Warrendale PA, 1972.

This paper reports an analysis of the degree of control/display (C/D) standardization in location, operation, and coding characteristics for 1971 automobiles. For C/D location commonality, between-manufacturer and within-manufacturer and between-car-type designs were compared. For operation and coding analysis, a selected group of C/D was used. With 90% of domestic and 76% of imported cars surveyed, a great variability of C/D designs was found for all three measures. The second part of the study experimentally evaluated four alternate control concepts for passenger car three-beam headlight systems.

(author supplied abstract)

P. Robert Knaff. Man-Machine Compatibility: A Highway Safety Essential. Proceedings of the 2nd International System Safety Conference, 1975, pp. 242-251.

This paper reviews several studies funded by the National Highway Traffic Safety Administration in the late 60's and early 70's. Particular questions examined include:

a) the forces that drivers can exert to operate foot brakes

b) the role that control location plays in the time to find and operate a control (Krumm et al., 1972)

c) a Man Factors, Inc. study of factors affecting seat belt comfort

R.L. Krumm. "Effects of Passive Restraint System Design on Horn Control Location and the Location and Operability of Stalk-Mounted Controls." U.S. Department of Transportation report DOT-HS-801-232, final report of contract DOT-HS-120-3-679, Washington, D.C., September 1974.

This study was developed to assess possible effects of wheel-mounted passive restraint systems upon control and display locations and to determine the current status of stalk-mounted, multi-function controls and their operability. Analytic, experimental, and interview methods were employed. Physical measurement of a wheel-mounted passive restraint system indicated a potential loss in usable panel area ranging from 30-70% depending on vehicle size. Experiments using more than 330 drivers indicated significantly slower reaction times were to be expected for stalk-mounted horn controls or headlight dimmer controls. Interviews with nearly 400 drivers of foreign automobiles were analyzed in terms of various stalk control configurations. Sixty-one different combinations of controls and stalks were identified among 25 vehicle makes. Rated difficulty in locating a desired control and reported errors in activating a second control instead of or in addition to the desired control varied, depending on the number of stalks and the number of controls per stalk and the types of controls. Interaction effects were also noted for type of transmission control. It was concluded that despite the apparent overabundance of stalk control configurations insufficient data are available to support standardization recommendations at this time.

(author supplied abstract)

T.J. Kuechenmeister. Driver Adaptability and Acceptance of a Multifunction Control. Society of Automotive Engineers paper 741001, Warrendale, PA, 1974.

This paper reports the results of a two-phase study of steering column mounted multifunction controls. A modified Mercedes Benz multifunction control (MFC) unit was installed in a 1972 Chevrolet station wagon. Control functions included were turn signals, washer, wiper, headlight dimmer, and optical horn.

Phase 1 of the study investigated response time, error rates, and learning for this particular MFC. Phase 2 investigated subjective preferences, comparing the MFC with conventional controls and comparing alternative functions for inclusion in an "ideal" MFC unit.

High error rates were found for first time use; however, subjects quickly learned to operate the unit with performance comparable to a representative panel control. Subjective responses were highly favorable to the concept.

(author supplied abstract)

James J. McGrath. Analysis of the Expectancies of European Drivers and the Commonality of Automotive Control Locations in European Cars, Anacapa Sciences Technical Memorandum 247-1, General Motors #P.O. DS 57068, Santa Barbara, CA, September 1974.

This report contains analyses of the expectancies of European drivers (including Japanese drivers) for automotive control location and the commonality of control locations for European automobiles. The original data were collected by the International Standards Organization and forwarded to Anacapa through the Design Staff Human Factors group of General Motors. Drivers in the United Kingdom, France, Sweden, Italy and Japan were shown two sketches of automobile interiors (one American made car and one foreign car) and asked to mark where they would expect to find eight controls. Drivers expected controls to be located in European and American cars in roughly the same places when they were left-hand drive. Specifically expectancies were obtained for the

headlights on/off - (American and others - left on instrument panel, French & Italian drivers - stalk-mounted),

wiper and washer - (no centralized expectancy pattern for European drivers),

lighter - (instrument panel or console mounting),

defroster - (right of steering column),

hazard flasher - (American drivers - mostly column-mounting but 4 out of 10 expect panel mounting, European drivers - 9 out 10 expect panel mounting),

ignition - (generally to be mounted to the right)

horn - (mounted on steering wheel except for British and French drivers who expect stalk mounting).

Commonality data were collected by asking representatives of several European manufacturers to indicate on sketches where controls were located in their products.

Controls were located as follows:

headlight switch - (almost always on left panel in American cars, in more varied locations in European cars),

wiper and washer - (panel-mounted in half of European cars and stalk-mounted in others),

lighter - (right side in all left-hand drive cars),

defroster control - (right side of instrument panel),

ignition control - (right side),

hazard switch - (American cars - right side of column, European cars - panel-mounted).

Thomas B. Malone, Richard L. Krumm, Sheldon Shenk, and Henry Kao. "Human Factors Criteria for Vehicle Controls and Displays." U.S. Department of Transportation report DOT-HS- 800-746, final report of contract DOT-HS-120-1-174, Washington, D.C., September 1972.

This study was directed toward developing valid criteria for the standardization of control and display location, coding, and operation in passenger cars, trucks, and buses. Five tasks were accomplished. Task 1 comprised an analysis of the commonality of control-display design arrangements in existing vehicles, and an assessment of the degree of the nonstandardization problems. Tasks 2 and 3 were directed toward developing criteria for C/D location and coding/operation respectively. Task 4 involved a study of 3 beam headlamp system control concepts. Task 5 comprised an experimental program to support Tasks 1, 2 and 3.

(author supplied abstract)

Lorna Middendorf, Patrick W. Dineen and Stefan Habsburg. Human Factors Evaluation of Headlight Switching Systems. Society of Automotive Engineers paper 740998, Warrendale, PA, 1974.

A search for methods of switching a proposed three beam headlight system led to the evaluation of 41 possible schemes. Human factors criteria reduced the original 41 to three systems which were tested in a laboratory with a broad range of subjects.

Recordings of practice trials, learning trials, and the responses to visual cues projected on a screen were analyzed. The same test procedure was also used to compare three alternative ways of switching conventional two beam headlight systems. Summary data is presented for the six systems tested grouped by test subject age, sex, and driving experience. The most pronounced difference observed was in the subjective preference rating among two beam switching systems. All systems tested resulted in remarkably few learning and practice trials. Small differences were recorded among systems in operational response time.

(author supplied abstract)

R. G. Mortimer and D. V. Post. Investigation of Switching Modes for a 3-beam Headlamp System. University of Michigan, Highway Safety Research Institute, Report No. UM-HSRI-HF-73-16, Ann Arbor, Michigan, June 1973.

The objective of the study was to obtain information which is basic to the development of three-beam headlamp switching methods.

The conditions in which drivers used each of the beams while driving a car equipped with a three-beam headlamp system, and the sequences of switching between the beams, were measured. Questionnaires were also used to provide information of differences between two- and three-beam system beam usage, and ratings of glare and visibility. A set of statements of human factors control-display design principles were compiled to devise a rating scale for the preliminary evaluation of switching concepts.

Results showed that drivers used the mid beam as the major driving beam on rural two-lane and divided highways, where they now tend to use the low beam, with most switching between the mid and high beams. Low beam is used almost exclusively on urban streets with momentary, occasional use of high beam. Thus, a switching system must be capable of allowing quick switching between mid and high beam, and low and high beam (the latter for compatibility and other reasons); or between all three beams. Application of the rating scale on thirteen three-beam switching concepts showed that the scale discriminates between switching systems. Among the switching systems evaluated, those that were most effective employed hand-operated push-button switches, a three-position lever mouted on the steering column, and a combination of a two-position foot switch and column lever.

It is concluded that drivers consider the mid beam to offer a worthwhile increase in visibility, compared to the low beam, and would use it in many night driving conditions. Proper use of the mid beam is expected to be related to the ease with which drivers can operate the three-beam switching system. Effective three-beam switching modes consist of (1) those that allow any one of the three beams to be selected with a single motion, or (2) in which an intermediate switch is used by the driver to choose which pair of beams (low/high or mid/high) is available, one of which is selected by a single motion of another switch. Further study is needed to determine which of these modes is understood and used most correctly and easily by drivers, and which they find to be compatible when driving vehicles equipped with two- or three-beam headlamp systems.

The switching sequences recommended in this study and the rating scale provided can be used to develop potentially effective three-beam switching methods, for final evaluation of hardware in driver tests.

(author supplied abstract)

R.R. Mourant, E. Moussa-Homouda, and J.M. Howard. "Human Factors Requirements for Fingertip Reach Controls." U.S. Department of Transportation report DOT-HS 803 267, final report of contract DOT-HS-5-01192, Washington, D.C., September 1977.

This project was instituted to develop human factors recommendations for fingertip reach controls. Interviews were conducted with 405 drivers of cars equipped with fingertip reach controls. A high percentage of finding problems was reported when the horn was mounted on a stalk and also when the turn signal was on a right stalk. Drivers of configurations with two left stalks had a large percentage of operating problems for the turn signal and for the headlight beam selector.

A laboratory experiment was conducted to evaluate modes of operation for the wiper on/off, wiper speed, and washer on/off functions when these controls were located on one left stalk. Subjects performed best when wiper on/off and wiper speed were controlled by a rotating hand switch. Performance on stalk-mounted control functions was faster and required less direct looks than performance on dash mounted functions.

It was recommended that the turn signal, headlight beam selector and flash-to-pass controls be located on one left stalk. It was also recommended that the wiper on/off, wiper speed and washer controls be located to the left of the driver at fingertip reach, and if stalk mounted, on the same stalk.

Finally, it was suggested that future research be conducted on assessing the potential benefits of putting additional controls at fingertip reach.
(author supplied abstract)

L.J. Nevett. "Automotive Switches and Switchgear," in Automotive Electrical Equipment, Institution of Mechanical Engineers, Westminster, UK, 1972.

This paper set out to deal with the full range of automotive switches from the simple manual two position ON-OFF type to the complex multifunction steering column mounted assemblies. Aspects of styling and ergonomics are considered in addition to basic design criteria. Some reference is also made to electromagnetic and other switching devices which are not directly within the driver's control. (author supplied abstract)

L.J. Nevett. "Human Engineering Applied to the Design and Grouping of Electrical Controls in the Motor Vehicle." Society of Automotive Engineers paper, 720233, Warrendale, PA, 1972.

A study has been made of motor vehicle driver environment in order to determine the most desirable design features and the optimum grouping of electrical controls conducive with minimum conscious thought and physical effort in location and operation under any given set of conditions. Consideration is given to the psychological aspects of control operating noise level and action "feel," to styling and standardization of layout with the ultimate objective of driver fatigue reduction, and to a worthwhile contribution in road safety improvement. (author supplied abstract)

Robert M. Nicholson. Where Have We Been--Where Are We Going? Society of Automotive Engineers, paper 790011, Warrendale, PA, 1979.

This paper reviews some of the progress that has been made in recent years in the transportation field by behavioral scientists and human factors engineers. The major areas covered are public transportation systems, railroad systems, highway systems, and personal transportation systems. The report suggests what future problems may be encountered in these areas that will need the attention of human factors specialists.

(author supplied abstract)

Michael Perel. Controls and Displays: Problems, Progress & Priorities. Society of Automotive Engineers, paper 740994, Warrendale, PA, 1974.

Difficulties of measuring safety problems related to human factors aspects of vehicle controls and displays are discussed and illustrated with examples. A review of National Highway Traffic Safety Administration (NHTSA) sponsored control/display research dealing with some of these problems is presented. The review describes the objectives, methodology, key findings, and application of the results of the research. Finally, future research needs are outlined.

(author supplied abstract)

Michael Perel. Analyzing the Role of Driver/Vehicle Incompatibilities in Accident Causation Using Police Reports. U.S. Department of Transportation report DOT-HS-801-858, Washington, D.C. March 1976.

An analysis of police accident reports was conducted to determine whether driver problems with vehicle controls, vehicle visibility systems, and vehicle lighting contribute to automobile accidents. By enumerating the various real-world, accident-related problems experienced by drivers with these vehicle systems, the analysis reinforces the findings from past analytical and experimental studies that have identified deficiencies in the designs of these vehicle components. The major drawback with this approach is that the data base cannot be used to accurately estimate the magnitudes of the problems.
(author supplied abstract)

W.E. Woodson & P.H. Selby. Driver Workspace State-of-the-Art Analysis. U.S. Department of Transportation report DOT-HS-801-612, final report of contract DOT-HS-4-00981, Washington, D.C., 1975.

This study was conducted to determine the merits of using a fixed-seat, adjustable controls concept to provide adequate driver accomodation in production-type automobiles. It was concluded that the concept not only is feasible but that it offers certain crash-worthiness and probably cost advantages compared with current adjustable seat concepts. Although either concept could provide adequate driver accomodation, certain constraints on styling are needed in order that each realize its maximum benefit. While complete adjustment flexibility of both seat and controls may provide maximum optimization of the driver workplace, such an arrangement would not be cost-effective and there is no assurance that drivers might not mis-use the capability to their own detriment.

A completely fixed seat plus an adjustable pedal assembly appears to offer maximum cost/operability benefits. However this approach requires considerable control over other vehicle characteristics and therefore should be studied in greater detail using mockups and live subjects to determine interaction with various vehicle models and styling.
(author supplied abstract)

W.E. Woodson, D.W. Conover, G.E. Miller, and P.H. Shelby. "Instrument & Control Location, Accessibility & Identification," final report of Contract F11-11-6907, MPI report 69-106, National Highway Safety Bureau, Washington, D.C., July 1969.

This report summarizes the results of a 13-month study designed to investigate the effect of automobile control-display location, accessibility, and identification on safe driving. Reported are the results of an effort to specify a volumetric arrangement to fit a driver population range from the 10th percentile female to the 90th percentile male by use of a driver work station mockup. Results indicate that present day automobiles do not meet the needs of the general driving population adequately. Also described is a simulation experiment (using the UCLA driving simulator), the results of which confirm an initial hypothesis that displays should be located nearer the line of sight of the driver viewing the road ahead. Major conclusions of the study are as follows: (1) a majority of the presently available human engineering criteria, principles, and standards are directly applicable to the design of automobile, truck and bus driver controls and displays; (2) a relatively limited number of these criteria and principles are required to cover most problems confronting vehicle designers; (3) a series of suggestions are presented for consideration by NHSB in creating safety performance standards for automobile manufacturers, based on sound human engineering principles; (4) future research studies aimed at developing information to support preparation of design standards are described as candidates for follow-on efforts; (5) based on a limited survey of trucks and buses during the study, the recommendation is made that a more comprehensive study be conducted in the near future in order to develop adequate criteria for the creation of standards for these vehicles; and, (6) results of the study confirm the hypothesis that standardization of driver control-display location, accessibility and identification are important to safe driving and that appropriate standards should be implemented as a guide to manufacturers at the earliest possible date.

(author supplied abstract)

APPENDIX B

TABULAR SUMMARY OF THE LITERATURE AND HARDWARE REVIEWS

Documents Applicable to Automobile Multifunction Controls Design.

DOCUMENT	Literature Review	Accident Data	Expectancy	Driver Performance	Problem Survey	HF Analysis	Preference Studies	Design Stereotypes (hardware review)	Related Issues
	Approaches Used								
Fowler, Williams, Fowler & Young, 1968									X
Woodson, Conover, Miller & Selby, 1969 (also reported as Conover, Selby & Miller, 1969)						X		X	
Malone, Krumm, Shenk, & Kao, 1972 (also reported as Kao, Malone & Krumm, 1972)				X		X		X	
Nevit, 1972a, b									X
Nissley & Elliot, 1972									X
Mortimer & Post, 1973						X	X		
Anacapa Sciences, 1974			X	X	X			X	
ISO, 1974								X	
Krumm, 1974				X				X	
Kuechemeister, 1974				X			X		
McGrath, 1974			X					X	
Middendorf, Dineen & Habsburg, 1974				X					
Perel, 1974	X								
Faust-Adams & Nagel, 1975				X					
ISO, 1975						X			
Kuechemeister, 1975				X			X		
Knaff, 1975	X								
Woodson & Selby, 1975						X			
Anacapa Sciences, 1976			X	X	X			X	
ISO, 1976a, b						X			
Perel, 1976		X				X			
Burger, Smith, Queen & Slack, 1977			X		X	X			
Black, Woodson & Selby, 1977			X			X			
Mourant, Moussa-Homouda & Howard, 1977				X	X			X	
Elsholz & Bortfeld, 1978			X						
Nicholson, 1979	X								

Summary of Accident Data Studies.

Document	Data Base	Sample Size	Search Term	Results
Perel, 1976	police report narratives of University of North Carolina Highway Safety Research Center	95,897 accidents (1974) 19,017 accidents (1975)	hand controls (heater, radio, tape, horn, air conditioner, lighter, ashtray, defroster, windshield wiper)	78 "hits," 35 cases in which operating a control "distracted" the driver from the primary task

Summary of Studies of Driver Performance.

Study	Number of Subjects	Vehicles/Control Designs	Method	Findings
Malone, Krumm, Kao & Shenk, 1972 (see also Kao, Malone, & Krumm, 1972	6	1965 Chevrolet/ spoke, left stalk, right stalk, panel-mounted horn controls	pursuit tracking and control operation	spoke type fastest
	35 (series of studies)	own car, Olds, VW/ 20 controls & displays (no stalks except turn signal)	touch control on command while tracking in lab or while driving	1) RT less and fewer errors for familiar panels 2) Performance levels off after 5 trials 3) No difference--day vs. night test 4) No interaction conrol design and lab vs. road test 5) No transfer of training to later tests 6) Performance on "human factored" panel better than on unfamiliar panel not so designed.

Studies of Driver Performance (cont.)

Study	Number of Subjects	Vehicles/Control Designs	Method	Findings
Faust-Adams & Nagel, 1973	24 Australian nondrivers	1972 Holden HQ (panel controls) and 1971 Mazda Capella Rx2 (stalks)	response time to touch control after function was named	1) stalk controls sometimes faster
Krumm, 1974	336 young US adults	horn location: Fiat 124 (center), BMW 202 (3 spoke button) Taunus (360^0 ring) Austin Marina (stalk) Olds 98 (rim) Olds Cutlass (2 spoke lever)	simple and choice RT to sound horn (and other controls)	1) stalk-mounted horn slowly responded to
Kuechenmeister, 1974	30 General Motors employees	1972 Chevrolet wagon fitted with Mercedes Benz multifunction stalk	stopwatch time to reach for controls, operate, and return to wheel	1) Difference between various control actions 2) Initially, panel controls faster than stalk controls 3) Performance leveled off after about 4 blocks 4) Error and time data agree

Studies of Driver Performance (cont.)

Study	Number of Subjects	Vehicles/Control Designs	Method	Findings
Middendorf, Dineen, and Habsburg, 1974	32 General Motors employees	3 dimmer switch designs (floor, stalk (pull/pull and pull (hi)/push (low)	show slide, measure time to use control to nearest .01 seconds	pull/pull fastest, floor switch slowest but differences less than 200 ms
	32 General Motors employees and 32 Texas drivers	3 three-beam switching designs stalk (pull for low, intermediate, high), "delta stalk," panel stalk (push up for low intermediate, high)	show slide, measure time to use control to nearest .01 seconds	between design differences less than 100 ms

Studies of Driver Performance (cont.)

Study	Number of Subjects	Vehicles/Control Designs	Method	Findings
ISO, 1975	32 subjects	1975 Oldsmobiles (standard and modified Chevette stalk)	show slide, naming function, driver reaches for control then touches button on steering wheel pad	1) panel controls responded to more rapidly but difference decreases with practice
Anacapa Sciences, 1976	28 U.S. drivers	own car (7 controls)	mark on sketch location of control in own car	1) 3 to 4 inch recall error typical
	24 U.S. drivers	panels from 30 cars varying widely in design (8 controls)	time to locate and touch control on slide	1) panel controls faster 2) differences between controls 3) older drivers slower 4) between vehicle difference 5) response time and error rate correlated and both related to expectancy 6) error rates triple when labels removed
	12 U.S. drivers	1974 Pontiac Catalina, 1974 Ford Torino, and own car (10 controls)	time to touch while driving	1) panel controls faster than stalks 2) performance depends on expectancy and not where located in own car

Studies of Driver Performance. (cont.)

Study	Number of Subjects	Vehicles/Control Design	Method	Findings
Anacapa Sciences, 1976	2,088 U.S. drivers	1973 Ford Ltd. wagon and 1969 Toyota sedan (8 controls & accessories)	time to touch (static)	1) takes 2 seconds to correct a mistake 2) for panel controls, there is no decrement in performance if it is within 5 inches of its expected location 3) stalk and panel controls are categorically different
Mourant, Moussa-Hamouda and Howard, 1977	5 groups of 16 subjects	1967 Chevrolet and modified Mercedes stalk (5 designs)	reach for and operate control while performing tracking task	1) rotate design, best for wiper switch 2) time, errors, direct look frequency (to control) and tracking are correlated

Summary of Studies of Control Expectancy.

Study	Subjects	Vehicles Sampled	Method	Findings
Anacapa Sciences, 1976 (see also Anacapa Sciences, 1974, McGrath, 1974)	100 U.S. drivers	1973 Chevrolet Impala	point to place or put knob on blank panel	1. no difference between methods 2. headlights--panel left 3. wiper/washer--panel left or right 4. flasher--column right
	238 drivers (U.K., France, Italy, Sweden, Japan)	sketches of U.S. and foreign panels	mark where control expected	1. left vs right hand drive difference 2. headlights--Fr. & It. left stalk, others: mixed 3. wiper/washer--U.S.: panel left, others: mixed 4. horn--Fr. & U.K.: stalk, others: steering wheel hub
	1708 California drivers	sketches of several (full size/compact, manual/automatic, bench/bucket seats)	mail back questionnaire, mark location on drawing	1. headlights + wiper/washer: panel left 2. hazard: on right side of column 3. dimmer: floor
	2088 U.S. drivers	U.S. full size sedan, foreign compact	mark location on sketch plus rated expectancy	same as mail back questionnaire study
Black, Woodson & Selby, 1977	about 900 U.S. drivers	context of American and foreign cars	driver shown collection of controls and asked to select one most appropriate for function	1. panel locations preferred for headlights and wiper/washer 2. for stalk-mounted headlight controls--no consensus as to how it should operate 3. lack of consensus for wiper and button for washer 4. cruise (only stalk considered)--left preferred 5. dimmer (only stalk considered)--pull towards driver 6. hazard--right side of column

Summary of Studies of Control Expectancy (continued).

Study	Subjects	Vehicles Sampled	Method	Findings
Elsholz & Bortfeld, 1978	150 foreign drivers	Audi 100LS, BWW 728 Citroen CX2000 Peugeot 604SL Renault 30TS	operate the control when asked	1. right wiper stalk--should move up/down 2. washer should not be left stalk (with push away = on) 3. horn: touch control and not stalk control 4. turn signal--left lever 5. problems with several designs for headlights, parking lights and fog lights

Summary of Problem Surveys.

Survey	Sample	Technique	Question Context	Findings
Krumm, 1974	392 drivers of foreign automobile	interview	problems	1. More problems reported with stalk-mounted horns than any other designs. 2. Confusing findings regarding assignment of functions to stalks.
Anacapa Sciences, 1976	1140 drivers (own car)	interview	problems	1. Most problems were in locating and operating the horn, wiper/washer, and dimmer footswitch.
	342 car renters	mail back ques-tionnaire	problems	2. Problem report rates for multifunction controls are the same as those for other types.
Burger, Smith, Queen, and Slack, 1977	3478 drivers	direct mail survey	near accidents	1. Many reports of problems. 2. Report frequency is in middle of range of those factors associated with the vehicle (as opposed to the roadway, environment, or driver). 3. Most problems associated with finding and operating as opposed to reaching for controls. 4. Controls associated with most problems are horn (especially stalk-mounted, defogger and dimmer). 5. Increasing number of functions/stalk increases number of problems reported/function.
Mourant, Moussa-Homouda, & Howard, 1977	405 drivers (own car)	interview	problems	1. They conclude: better to add functions to stalks than new stalks...caution--all frequencies on which conclusions are based are small and many factors are con-founded with differences of interest.

Summary of Preference Studies.

Study	Number of Subjects	Task	Did subjects operate the equipment?	Results
Mortimer & Post (1973)	10	state preference for 3-beam headlight switch	no	stalk-mounting preferred
Kuechenmeister (1974)	24	state what functions should be multi-function stalk control	yes, but only 1 design	put on stalk: beam switch wiper/ washer don't put on stalk: lights on/ off, hazard, cruise
ISO (1975)	32	rate ease of operation of 5 functions (wiper/ washer, headlights on/ off, dimmer, turn signal) of Chevette and 2 function stalk relative to own car	yes	stalks appear preferred

Summary of Human Factors Analyses.

Document	Analytic Methods	Conclusion
Woodson, Conover, Miller & Selby, 1969 (also Conover, Woodson, Selby & Miller, 1969)	General discussion of trade-offs required in standardizing location, human factors literature cited only with regard to control sizing, spacing, and labeling	Two designs for instrument panels proposed, no multi-function stalk controls suggested
Malone, Krumm, Shenk & Kao, 1972	Consideration of current convention, operability, and crashability requirements made to generate priorities for each control	Standard instrument panel proposed, no multifunction stalk controls suggested
Mortimer & Post, 1973	Rigorous attempt to select best design for 3-beam headlight switch, using various weighted criteria, several designs were rated by human factors specialists	While no best design was found, one of the recommended designs was a multifunction stalk
ISO, 1975	Rigorous analysis of errors resulting from control use based on frequency of use and probility of confusion--best design minimizes total errors, does not weigh cost of error	Alternative proposal for ISO standard compared; 3-stalk design results in fewest errors
Woodson & Selby, 1975	Comparison of fixed-panel movable seat and fixed-seat movable-panel designs; some attempts to weight various factors (reliability, crashworthiness, styling flexibility, ease of entry/exit, etc.)	No specific panel layout suggested but fixed-seat movable-panel concept is feasible and has crashworthiness and cost advantages over existing designs
Black, Woodson & Selby, 1977	Consideration of frequency of use, requirements for viewing controls and consideration of control incidents in making suggestions for control location; also considered were driver expectancy and performance research in operating controls. Approach is non-quantitative. Details for size, spacing, and labeling included.	Standard instrument panel proposed--1 left multifunction stalk suggested for turn signal and beam switching; wiper/washer panel-mounted

Summary oꝼ Previous Hardware Reviews.

Study	Sample	Findings
Woodson, Conover, Miller & Selby, 1969 (see also Conover, Woodson, Selby & Miller, 1969)	1969 cars (100 total, 80% U.S., 20% foreign)	1. no stalk controls other than turn signal. 2. problems with labeling, accessability and non-standard location.
Malone, Krumm, Shank & Kao (1972)	1971 cars (90% domestic and 76% of foreign sales is U.S.)	1. no stalk controls except for turn signal and its combination with the dimmer switch (24% of foreign vehicles sampled, no domestic vehicles).
Krumm (1974)	391 or 392 vehicles (61 control-stalk combination, 25 vehicle types)	1. one left stalk n=278 one left, one right stalk n=83 two left stalks n=13 two left, one right stalks n=17
Anacapa Sciences (1974) (see also Anacapa Sciences, 1976)	77 American and 38 foreign 1973 cars	1. a few cars (< 10%) had stalk-mounted dimmer switches 2. other than the turn signal, there were no other stalk controls.
McGrath (1974) (see also ISO, 1974 and Anacapa Sciences, 1976)	69 European automobiles	1. headlight switch--left panel mounted in 62% of sample (left hand drive)--left and right panel mount (right hand drive) 2. wiper/washer - equally often on panel and stalk (usually right) for left hand drive, far right hand drive panel mounting is most common 3. hazard switch usually panel mounted
Mourant, Moussa-Homouda & Howard (1977)	31 car makes with multifunction stalk controls	1. wiper switch: right stalk most prevelant, operation split evenly between lift up or push down; left stalk locations occurred twice as often as right stalk. 2. washer: pull right stalk towards driver or push end button in. 3. headlights: left stalk, pull towards, usually operates but there was a mixture of designs.

1979 Cars with Stalk-Mounted Wiper/Washer Functions.

Configuration	Manufacturer
(1L)	Mercedes Fuji (Subaru) Chrysler/Dodge (Omni, Horizon, St. Regis, New Yorker Newport, Arrow, Colt) Ford (Versailles, Monarch, Granada) GM (Chevette)
(1L,1R)	Peugeot (504,604,2CV,Dyane, LN) BMW VW (except for Audi 100-Germany) Maserati Toyota Nissan (Datsun) Toyo Kogyo (Mazda except for GLC) Honda Saab-Scania Volvo Lotus British Leyland GM (Opel)
(2L)	Alfa Romeo Ford (Fairmont, Zephyr, Mustang, Capri, Futura) Toyo Kogyo (Mazda GLC)
(2L,1R)	Citroen (GS) Fiat (including Lancia, Ferrari)
(1L,2R)	Ford (Fiesta)

Note: On most Citroen products (CX, Visa, and GSA) controls are pod-mounted.

Summary of Standards.

Organization	Standard	Requirements and Comments
ISO (TC22/SC13/WG3)	ISO 4040	1) left: driving lights, marker lights, beam switching, optical warning, emergency brakes (right hand only) 2) center or left: horn
	proposed revisions of 4040 (document (SC13(WG3-85)203)	1) same requirements as 4040 for horn, driving light, marker lights & emergency brake 2) where there is one right stalk (other than gear selector) it will operate the wiper/washer. When there are multiple right stalks, the one for the wiper/washer will be closest to the driver. 3) the wiper/washer control will not be panel-mounted on the right side 4) close to and left of the steering wheel: beam switching, optical warning, turn signal 5) combination of controls and directions of control operation described (see text)
ISO (TC23/SC14)	DIS 3789 Tractors	1) multifunction controls not considered
ISO (TC159/SC4)	Ergonomics	1) document not available
ECE/WP29	Draft GRSG/R16	1) 1974 information, no current information availabile, copy not available
EEC	-	1) defers to ISO
ANSI	-	1) supports SAE standard
SAE	SAE Recommended Practice J1138	1) left: turn signal, dimmer, headlights on/off, optical warning 2) right: gear shift, ignition, defroster, hazard, climate control, radio, lighter 3) no additional requirement for multifunction controls
MVMA	None	1) does not issue standards
AIA	"	"
DOT	FMVSS 101	1) primary & secondary should be within reach and labeled
DOT	future plans	1) control location & method of operation to be further specified
DOD	MIL-STD-1472B	1) general requirements for control design, no mention of multifunction controls

EXPECTED ACCIDENT FREQUENCY MODEL

$$E(accid) = \sum_{i=1}^{n} (fr)_i \left[(Paccid)_i \left((RT)_i + (Perror)_i (CT)_i \right) + \sum_{j=1}^{n} (Perror)_{ij} (CT)_j (Paccid)_j \right]$$

$E(accid)$	= expected number of accidents for an arrangement
$(fr)_i$	= frequency of use of i^{th} control
$(Paccid)_i$, $(Paccid)_j$	= probability that operation of i^{th} or j^{th} controls results in an accident
$(RT)_i$	= response time for "corrects" for the i^{th} control
$(CT)_i$, $(CT)_j$	= time to correct an error for i^{th} or j^{th} control
$(Perror)_{ij}$	= probability that when operating control i, control j is operated (confusion probability)

RESPONSE TIME MODEL

$$\text{Response Time} = \left.K_1(C_b) + K_2(C_w) \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i} - K_3(L)e^{-t/R_1}\right\} RT$$

$$\left.\begin{array}{l} + K_5 + K_4(\log_2 \frac{2A}{W})(K_6 - K_7 e^{-t/R_2}) \\ + PR(RL(L_1) + P(L_2) + G(L_3)) \end{array}\right\} MT$$

$$\left. + D(PR)\ (L_4) \right\} AT$$

where

$K_1, K_2, K_3, K_4, K_5, K_6, K_7$ = constants

C_b, C_w = between and within ensemble compatibility

P_i = probability i^{th} function is cued

L = labeling factor

t = number of trials

R_1, R_2 = learning parameters $(R_1 > R_2)$

A = movement amplitude

W = target width

PR = performance rating

RL = release time

P = position time

G = grasp time

L_1, L_2, L_3, L_4 = learning parameters

D = base time for actuating each control design

APPENDIX C

Headlight Switch Evaluation Criteria of Mortimer & Post (1973)

APPENDIX C

Headlight Switch Evaluation Criteria of Mortimer and Post (1973)

Essential Importance (weight=4)

1. Controls should be so arranged that their operation does not overload one hand or foot.
2. Controls which occasionally require actuation while the vehicle is in motion should be within reach of all drivers from their normal driving position even if they are wearing optional restraints.
3. It should not be possible to inactivate the headlamps inadvertently.
4. Controls which must be reached quickly (as in an emergency) should be located near the hand or foot by which they will be operated.
5. It should be possible to get to a beam of less glare from any beam producing objectionable glare with a single motion.
6. It should be possible to get to a beam providing greater visibility from any beam producing less visibility with a single motion for safety purposes.

Primary Importance (weight=3)

1. All controls and displays should be identifiable by their shape, location, color, and/or by the labels associated with them.
2. Controls which turn a system ON should move UP, to the RIGHT, or CLOCKWISE for ON: in the opposite direction for OFF.
3. The preferred area for location of displays centers about the normal line of sight. Critical displays should be located so that the operator does not have to turn his head to see them. Horizontal arrangements are preferred for the seated operator.
4. Controls used most frequently (by the hands) should be located between waist and shoulder height.
5. Minimum problems with arm/leg reach.
6. Degree to which the operation interferes with speed control of the vehicle.
7. Controls should provide feedback while being operated, i.e. provide proprioceptive cues.
8. Controls and displays that are used most frequently should be located in prime positions relative to convenience.
9. Displays and controls should be illuminated if they are to be used at night or under low ambient light conditions.
10. Control will not be inadvertently acitvated.
11. Lower likelihood of substitution errors (confusion of one control with another).
12. If controls are not illuminate at night, they should be within blind reach.
13. Controls should be located so they are within "comfortable" reach. The operator should not have to utilize maximum reach limits unless absolutely necessary because of lack of space for locating controls in more convenient positions.

14. Foot controls should only be used where large applications of force are required, where a large amount of displacement is required, where only gross movements are required, and/or where the operator is likely to have both hands occupied.
15. All labels should be visible under all conditions of use (i.e., day or night).
16. Capable of operating beam switch while turning the steering wheel.

Secondary Importance (weight=2)

1. It should be possible to return with one motion to an original beam after dimming.
2. Controls should provide display status feedback.
3. Control activation takes minimum time.
4. Minimum requirements for removing a hand from the wheel.
5. Certain types of switch controls should have only two positions, e.g., toggle, rocker, and push button controls.
6. When practicable, all levers should be labeled as to function and direction of motion.
7. All controls should imply the manner in which they are to be operated by their appearance and/or by the labels associated with them.
8. Foot-operated push buttons should be used only for noncritical operations.
9. Amenable to positive identification coding.

Tertiary Importance (weight=1)

1. Use foot-operated controls if large force application is necessary; hand controls if fine adjustment is required.
2. Push buttons arranged in a horizontal array are preferred to a vertical array.
3. Labels should not be placed on the surface of a control if movement of the control will obscure the label or cause it to appear other than right side up.
4. Capability of being operated and monitored without direct visual access.
5. Capable of selecting any of three beams with a single motion.
6. Minimum exertion on the part of the driver.
7. Requirements for panel area for controls are minimal.
8. Controls should provide visual status feedback.
9. Controls should provide tactile status feedback.

APPENDIX D

HARDWARE REVIEW DETAILS

Hardware Review Details.

FRANCE

Manufacturer	Make/Model	Year	Remarks
Renault	Renault/R5	1977	2 left stalks close stalk - turn signal (up = R turn, dn = L turn) far stalk - lights (labeled with words) push up for hi beam, push down for low beam (on/off switch on panel) horn - push button on stalk (wiper/washer on panel) (Source - Owner's Manual)
	Renault/R12	1977	1 left, 1 right stalk left stalk - (labels unknown) turn signal - (up = R turn, down = L turn) hi/low beam - pull towards driver - pull/pull switch (spring loaded) headlights on/off on panel right stalk - wiper/washer - (labels unknown) washer - pull toward steering wheel (somewhat unclear) wiper - low speed = pull up 1 notch high speed = pull up 2 notches (Source - Owner's Manual)
	Renault/R17	1977	1 left, 1 right stalk left stalk turn signal (up = R turn, dn = L turn) hi/lo beam - pull/pull switch (spring loaded) right stalk - wiper/washer (labeled with words) washer - pull toward wheel (wipers automatic) wiper - off = fully up low speed = half way down high speed = fully down (Source - Owner's Manual)

F R A N C E

Manufacturer	Make/Model	Year	Remarks
Peugeot Citroen	Peugeot 504, 604	1977-1979	1 left, 1 right stalk left stalk (words & symbols) (1) pull towards driver (parking lights on) (2) from position 1, push down (low beam on) (3) from position 2, push away (hi-beam on) (4) from first position, push down (optical warning) washer - push end button in wiper - low speed - rotate away 1/4 turn high speed - rotate away 1/2 turn (Source Owner's Manual & Manufacturer's Sales Representative)
	104, 305		right stalk turn signal - up = L turn, down = R turn horn - pull towards (Source - Manufacturers Sales Representative)
	Citroen/ 2CV, Dyane, LN	1977-1979	1 left, 1 right stalk (Source - Manufacturer's Literature)

FRANCE

Manufacturer	Make/Model	Year	Remarks
Peugeot-Citroen	Citroen/AMI	1977-	2 left, 1 right stalk (symbols) near left stalk turn signal - up = R turn, down = L turn far left stalk wiper on = pull up washer on = pull towards driver right stalk turn the stalk (away from the driver?) off, down (parking lights, low beam beam switching - push the lever away (Source - Manufacturer's Literature)
Peugeot Citroen	Citroen/GS	1977-1979	2 left, 1 right stalk (all symbols) close left stalk - turn signal optical warning far left stalk - wiper/washer right stalk - headlights (Source - Manufacturer's Literature)

FRANCE

Manufacturer	Make/Model	Year	Remarks
Peugeot-Citroen	Citroen/CX	1979	2 fingertip reach pods left pod turn signal - rocker switch push down right side = right turn, left side = left turn horn - push on left side of pod wiper/washer wiper - off - low - high, slide switch below pod to right washer - pull slide switch tab towards driver hazard warning - push button below tab up right pod slide switch on bottom (move left) - off, parking lights, driving lights push button on right side - optical horn push button on top - high beam switch push button on bottmo for lights (Source - Owner's manual)
Peugeot-Citroen	Citroen Visa	1979	1 left pod (symbols) wiper - off, low, high - twist top clockwise washer - push button on top headlight - off, park, low beam - twist bottom counterclockwise beam switching - push/push switch tab on bottom turn signal - side rocker switch push top = right turn, push button = left turn horn - push button in back of cylinder (Source - Owner's Manual)

FRANCE

Manufacturer	Make/Model	Year	Remarks
Peugeot-Citroen	Citroen/GSA	1979	1 left, 1 right pod (symbols) left pod same as Visa right pod - 8 pushbuttons (2 columns of 4) front row, top to bottom rear fog lights unused front fog lights defroster back row, top to bottom hazard warning unused rear washer rear wiper (Source - Owner's Manual)

GERMANY

Manufacturer	Make/Model	Year	Remarks
Daimler-Benz	Mercedes 450, 230, 280, 609, 240D, 300D	1977-1978?	Single left stalk turn signal - up = right turn, down = left turn beam switching, towards dash = high beam, middle = low beam pull towards (spring-loaded) = flash wiper - on/off push/push hand switch wiper speed - rocker switch on face of hand switch optional warning - pull towards (spring loaded) (beam switch foot operated on 600,) washer - push away cruise control option - short left stalk up = accelerate and set down = decelerate and set towards = resume away = off (Source - undated Owner's manual)
	Mercedes	1979	Same except for wiper operation handle is rotary twist away from driver = off, intermittent, slow, fast (Source - owner's manual)

G E R M A N Y

Manufacturer	Make/Model	Year	Remarks
BMW	BMW 320; 528 633CS; 733	1979	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn beam switch - push away = high beam, pull towards = low beam, pull past low position for optical warning (spring loaded) right stalk washer - pull lever towards driver wiper - push lever up - off, intermittent, low, high

GERMANY

Manufacturer	Make/Model	Year	Remarks
Volkswagen-Audi-Nsu	VW/all except 1979 Audi 100 (Germany) (see remarks)	1977-1979	1 left, 1 right stalk left stalk (labeled with symbols) turn signal - down = left turn, up = right turn headlight dim - pull towards driver (on Polo/Darby (Germany) can also push lever to dash) right stalk (labeled with words and symbols) washer - pull lever toward steering wheel (except for Polo/Darby (Germany) and Type I and Varient (Brazil)) horn - pull lever toward steering wheel (1977 Polo/Derby only) wiper - (see the following page) (Source - Manufacturer's representative)
	VW/Audi 100 (Germany)		2 left, 1 right stalk near left stalk (labeled with symbols) turn signal - up = right turn, down = left turn headlight dimmer - pull towards or pull away from driver cruise control (option - labeled with words) set = push end button in resume = move slide switch to column off = move slide switch to door far left stalk (headlamp) - moves parallel to steering wheel plane, labeled with symbols bottom position = off mid position = park top position = low beam right stalk (labeled with words and symbols) washer - pull lever toward driver wiper - (see the following page) (Source - Manufacturer's representative)

WIPE POSITIONS (Right Stalk)

Vehicle	1st Up	2nd Up	3rd Up	1st Down	Rear Window Wash/Wipe
Audi 100 (Germany)	Intermittent	Lo	Hi	--	--
Type I (Brazil)	Lo	Hi	--	--	--
Varient II (Brazil)	Lo	Hi	--	--	--
Polo/Derby (Germany)	Lo	Hi	--	--	Optional
Golf/Scirocco Standard	Lo	Hi	--	--	--
(1977-1978)	Optional Intermittent	Lo	Hi	--	--
Passat 77-78-Standard	Lo	Hi	--	--	--
(German-Australia)	Optional Intermittent	Lo	Hi	--	--
Scirocco (England)	Lo	Hi	--	Optional Intermittent	Optional
Golf (England)	Lo	Hi	--	Optional Intermittent	--
Beetle 1200L (England)	Lo	Hi	--	Optional Intermittent	--
Audi 80 (Germany)	Lo	Hi	--	Optional Intermittent	--
Passat (1979 England)	Lo	Hi	--	Optional Intermittent	Optional
Type II (Germany)	Lo	Hi	--	Optional Intermittent	--
Type I (Germany)	Lo	Hi	--	Intermittent	--
Scirocco (1979 Germany)	Lo	Hi	--	Intermittent	Optional
Bettle, Dasher (USA)	Lo	Hi	--	--	Optional
Audi (USA)	Intermittent	Lo	Hi	--	Optional
Rabbit, Scirocco, Porsche (USA)	Lo	Hi	--	Intermittent	Optional
Brasilia, Model 113 Sedan, Caribe, Safari, Model 211 Panel, Combi (Mexico)	Lo	Hi			

OPTIONAL REAR WINDOW WASH/WIPE

Wipe - Push lever toward dash and release (3 wipes)
Wipe and Wash - Push lever toward dash and hold
(Source - Manufacturer's representative)

ITALY

Manufacturer	Make/Model	Year	Remarks
Fiat- Autobianch- Lancia- OM	Ferrari	1977- 1979?	2 left, 1 right stalks near short left stalk - turn signal up = right turn, down = left turn far left stalk - headlamps twist away from driver - extend retractable headlights and turn on upper position - parking lights mid position - low beam lower position - high beam pull towards driver = flash headlights right stalk - wiper/washer vehicle 365GT4/2 +2 — wiper - pull towards driver = off, low, high washer - ? 365GTB/4 — wiper - push down = off, low, high washer - pull towards driver Dino 240GT — wiper - push up = off, on washer - pull towards driver Dino 246GT? (Source - undated owner's manual)

I T A L Y

Manufacturer	Make/Model	Year	Remarks
Fiat-Autobianchi-Lancia-OM	Fiat/all (including USA, Brazil, Argentina, Uraguay & others)	1977-1979	2 left, 1 right stalks (symbols serve as labels) near short left lever turn signal - down = left turn, up = right turn far left stalk - headlamps up = low beam, down = high beam optical warning - pull towards driver right stalk washer - pull towards driver wiper - top position = off, mid position = low speed, bottom position = high speed (Source - Manufacturer's representative)
Maserati	Maserati/ (Merek, Khamsin, Bora)	1977-1979	1 left, 1 right stalk (labeled with pictures) left stalk turn signal - up - right turn, down = left turn headlamps - high beams = push away, low beam = middle position, pull towards driver = flash horn - push end handswitch in right stalk washer - push away wiper - top position = off, mid position = low speed, bottom position = high speed (Source - Manufacturer's representative)

I T A L Y

Manufacturer	Make/Model	Year	Remarks
Alfa-Romeo	all	1977-1979	2 left stalks (labeled with symbols?) near short stalk turn signal - up = right turn, down = left turn up = low beam down = high beam press button on stalk end - flash (Source - Manufacturer's representative)
Fiat-Autobianchi-Lancia-OM	Lancia	1977-1979?	2 left, 1 right stalk (labeled with symbols) near short left stalk - headlights far left stalk - turn signal up = right turn, down = left turn right stalk - wiper/washer (Source - undated manufacturer's literature)

JAPAN

Manufacturer	Make/Model	Year	Remarks
Toyota- Daihatsu-Hino	Toyota, Corolla, Celica, Cressida	1979	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn beam switching - push away = high beam, pull towards = low beam, low beam (spring-loaded) - flash headlamp - twist away from driver off, parking light, headlights right stalk washer - push end button wiper - push lever down - off, low, high option on all but Corolla - steering wheel tilt - push lever up to release (behind left stalk) (Source - Owner's Manual)
	Toyota Corona	1979	1 left, 1 right stalk left stalk - same as Corolla right stalk front windshield wiper - push lever down - off, intermittent, slow, fast rear wiper/washer: wiper on - twist end clockwise 1 click, washer on - twist beyond first click (Source - Owner's Manual)

JAPAN

Manufacturer	Make/Model	Year	Remarks
Nissan	Datsun/ B210	1977	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn headlights - pull towards = high beam, push away = low beam right stalk washer - end push button wiper - turn away from driver - off, intermittent, low, high (Source - Manufacturer's Representative)
	F10 610	1977	1 left, 1 right stalk left stalk = turn signal right stalk 2 position light switch? optical warning - pull to flash? (Source - Manufacturer's Representative)
	810 510	1977- 1978	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn twist (which way?) - lights on beam switching - pull = high, push = slow right stalk washer - push button on end wiper - twist (which way?) (Source - Manufacturer's Representative)

JAPAN

Manufacturer	Make/Model	Year	Remarks
Nissan	Datsun/710 200 SX	1977 1977- 1978	1 left stalk turn signal - up = right turn, down = left turn beam switching - pull = high, push = low (washer & other controls on dash) (Source - Manufacturer's Representative)
	210 310	1979	
Toyo - Kogyo	Mazda/626 RX7	1977- 1979	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn beam switching - pull/pull switch (if off - optical warning) washer - push end button wiper - rotary away - intermittent, off, low, high right stalk push up - off, park, headlights optional cruise control (Dana Corp. switch) on RX7 - additional stalk low on left (stationary) on GLC - attaches to left stalk
	Mazda/GLC	1977- 1979	2 left stalks near stalk - same as left stalk on 626, RX7 but intermittent wiper is option far stalk - same as right stalk on 626, RX7 optional cruise control - additional stationary stalk low on left (Source - Manufacturer's Representative)

J A P A N

Manufacturer	Make/Model	Year	Remarks
Nissan	Datsun/210, 510, 210 SX, 310, 810	1979	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn beam switching - push away - high, pull towards = low, optical warning - pull towards driver past low (spring-loaded) lights - twist away = off, park, headlights right stalk wiper - push down = off, low, high (210), push down = off, intermittent, low, high (510, 210 SX, 310), twist away to adjust intermittent (310 only) washer - pull towards driver (Source - Manufacturer's Sales Representative and visit to Dealer)
	280Z	1979	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn beam switching - push away = high, pull towards = low, optical warning - pull towards driver past low (spring-loaded) cruise (option) set push button on end of stalk right stalk wiper - twist away = off intermittent, low, high washer - push end button in to column (Source - Manufacturer's Sales Representative and visit to Dealer)

J A P A N

Manufacturer	Make/Model	Year	Remarks
Fuji Heavy Industries	Suburu 1600	1977-1979	Single left stalk (labeled with picture and words) turn signal - up = right turn, down = left turn. beam switching - 1977 - push away for high beam, pull towards for low beam, 1978-79 positions reversed except for 1977 1600, pull/pull switch wiper (knob on end) turn counterclockwise - off, low, high washer - push button on end (on 1979 1600 GL5, 1800 GLF wiper/washer is panel-mounted) (Source - Manufacturers Representative & 1600 Owner's Manual)
Honda	Honda Accord, Civic, Prelude	1979	1 left, 1 right stalk (words) left stalk turn signal - up = right turn, down = left turn beam switching - pull/pull switch (towards driver) - European versions - button on end headlights - rotary switch on end turn away from driver - off, park, lights right stalk washer - pull towards wiper - push lever down off, intermittent, slow, fast ((1) Civic does not have intermittent, (2) on some 1979 models the off and intermittent positions were reversed) (Source - Manufacturer's Representative)

S W E D E N

Manufacturer	Make/Model	Year	Remarks
Saab-Scania	Saab	1977- 1979	1 left, 1 right stalk (labeled with symbols) left stalk turn signal - down = left turn, up = right turn headlights - low beam = push away, high beam = pull towards optional cruise control, set button on end, on/off switch on face right stalk washer - pull towards wiper - push down = off, intermittent (some models intermittent is spring-loaded with return to off, low speed, high speed (Source - Manufacturer's Representative)
Volvo	Volvo 242, 244, 245, 262c, 264, 265 (USA, Canada)	1977?- 1979	1 left, 1 right stalk (symbol & word labels) left stalk turn signal - down = left turn, up = right turn headlights beam switch - pull/pull (towards driver) switch cruise control (option on 262C) set button on end slide switch on face - move towards column = resume, on, off right stalk washer - pull towards driver (wiper also operates) wiper - top position = intermittent (1 stroke/7 seconds), off, single stroke (automatically returns to off), low speed, high speed option (242, 244, 245, 264, 265) - tailgate wiper & washer washer - push end button (wiper also completes 2-3 strokes) wiper - push slide switch on face to column, positions are interval (1 stroke/5 seconds), off, regular speed (Source - Owner's Manual)

UNITED KINGDOM

Manufacturer	Make/Model	Year	Remarks
Rolls Royce	Rolls Royce & Bentley	1977-1979	1 left stalk, 1 right stalk (all words) left stalk turn signal - up = right turn, down = left turn optical warning - pull towards (spring loaded) (European cars only) washer - push button on end (also results in 7 sweeps of wiper) right stalk gear selector (up/down) cruise control set switch - button on end switch on lever - off/on/ resume (Source - Manufacturer's Representative)
Lotus	Lotus Europa	1977-1979 ?	1 left, 1 right stalk (words) left stalk turn signal - up = right turn, down = left turn beam switching - high - push away, low - pull towards, optical warning - pull towards post low (spring loaded to return to low) right stalk washer - push hand switch in wiper - push up -single sweep, push down (post off) - low, high (Source - undated Owner's Manual)

UNITED KINGDOM

Manufacturer	Make/Model	Year	Remarks
British Leyland (BL Ltd.)	Jaguar, Triumph, MG, Midget MGB	1977-1979	1 left, 1 right stalk left stalk turn signal - up = right turn, down = left turn beam switching - pull/pull switch (except for 1977 MGM push = high, pull = low, pull past low (spring loaded) to flash horn - end push button (MG, Triumph only) right stalk washer Jaguar, MGB - end push button Triumph - push end head switch in All others - pull lever towards drivers horn - end push button (except for Jaguar (tab mount) and MG, Triumph) wiper - push up - off, low, high, momentary (single sweep) (except for Jaguar where single sweep is pull towards drivers, and Triumph where single sweep is push down) and MG Midget, MGB (push up for single sweep on MGB only, push down past off for low, then high) (Source - Owner's Manual and Manufacturer's Representative)

U. S. A.

Manufacturer	Make/Model	Year	Remarks
Checker	Checker	1977- 1979	except for the turn signal, Checker does not use stalk mounted controls (Source - Manufacturer's representative)
American Motors	Pacer Gremlin Hornet Matador Concord Spirit	1977-1979 1977-1979 1977 1977-1978 1978-1979 1979	single left stalk (labeled with words) turn signal- down = left turn, up = right turn cruise control (option) set button on end of lever slide switch on face - move to column = resume, on, off optional for lever - steering wheel tilt - pull towards driver to release (Source - Manufacturer's representative and owner's manual)
Chrysler	Chrysler and Dodge products except Colt, Omni, and Horizon	1977, 1978, 1979?	single left stalk (labeled with words) turn signal - down = left turn, up = right turn optional cruise control set button on end slide switch on face (to column - off, on, resume) (Source - Manufacturer's representative and owner's manual
	Chrysler/ Dodge "R" body (St. Regis, Chrysler New Yorker, Newport)	1979	single left stalk (labeled with words and symbols) turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) washer - end push button wiper - rotate away from driver (off, low, high) optional cruise control? optional steering wheel tilt? (Source - Manufacturer's representative and owner's manual)

U. S. A.

Manufacturer	Make/Model	Year	Remarks
Ford	Mercury/ Cougar, Ford/ Thunderbird, Ford/Ltd. II Mercury, Lincoln/ Continental Ford/Maverick	1977-1979? 1977-1979 1977-1979 1978 1977-1979 1977	single left stalk turn signal - down = left turn, up = right turn optional cruise control and tilt lever (Source - owner's manual and vehicle inspection)
Ford	Lincoln/ Versailles, Ford/Mustang II Mercury/ Monarch, Ford/Granada	1978-1979 1977-1978 1979 1977-1979	single left stalk (labeled with words) turn signal - down = left turn, up = right turn washer - end push button wiper - slide switch on face, move towards column = off, interval, low speed, high speed; interval (dwell) control is knob on end of lever, rotate clockwise to increase pause between sweep cruise control (option) - 4 buttons on steering wheel spokes off (left, closest to wheel rim), on (left, farthest from rim) decrease set speed (right, closest to wheel rim), increase set speed (right, farthest from rim) (Source - owner's manual and vehicle inspection)

U. S. A.

Manufacturer	Make/Model	Year	Remarks
Ford	Ford/Fair- mont, Ford Mustang, Mercury/Capri, Mercury Zephyr, Ford/Ltd., Ford/Futura	1977- 1979 1979 1979 1978- 1979 1979 1979?	2 left stalks (labeled with words) near left stalk turn signal - down - left turn, up - right turn horn - push end button on lever dimmer - pull/pull switch (towards driver) far left stalk washer - pull towards driver wiper - push lever up - button position = off, second position (optional) = interval wiper, third position = low speed, top position = high speed, interval adjust - turn and knob towards driver to increase interval (Source - owner's manual and vehicle inspection)
General Motors	Cadillac/all	1977- 1979	single left stalk (labeled with words) turn signal - down = left turn, up = right turn optional cruise control = set button on end of lever (Source - owner's manual)
	Buick/Skylark, Chevrolet/ Monza, Camaro,	1977- 1979	turn signal and steering wheel tilt levers only (left side) (Source - owner's manual)
	Buick/Century, Estate Wagon, Electra, Riviera	1977	single left stalk (labeled with words) turn signal - down - left turn, up = right turn beam switching - pull/pull switch (towards driver) - some models
	Pontiac/ Firebird	1977- 1979	(Source - owner's manuals - do not specify which models have foot operated beam switch)

U. S. A.

Manufacturer	Make/Model	Year	Remarks
General Motors	Chevrolet/ Corvette, Chevette	1977-1979	single left stalk (labeled with words) turn signal - down = left turn, up = right turn washer - push end button to column beam switching - pull/pull switch (towards driver) wiper - rotate switch away position = off, low, high (Source - owner's manual)
	Buick/ LeSabre, Estate Wagon, Electra, Riviera, Century, Skylark	1977-1979	single left stalk (labeled with words) turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) optional cruise control - set button on end of lever option: second far left stalk - steering wheel tilt - pull towards driver to release (Source - owner's manuals)
	Chevrolet/ Monte Carlo, Malibu, Caprice, Impala, El Camino	1977-1979	single left stalk (labeled with words) turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) optional cruise control - set button on end of lever option: second far left stalk - steering wheel tilt - pull towards driver to release (Source - owner's manuals)

U. S. A.

Manufacturer	Make/Model	Year	Remarks
General Motors	Oldsmobile/ Omega, Cutlass, Toronado, 88, 98, Custom Cruiser, Starfire	1977-1979	single left stalk (labeled with words) turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) optional cruise control - set button on end of lever option: second far left stalk - steering wheel tilt - pull towards driver to release (Source - owner's manual)
	Pontiac/ Grand Prix, Catalina, Bonneville, LeMans, Gran Am, Sunbird, Phoenix, Astre	1977-1979	single left stalk (labeled with words) turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) optional cruise control - set button on end of lever option: second far left stalk - steering wheel tilt - pull towards driver to release (Source - owner's manual)
	Buick/ Opel	1977-1978	1 left, 1 right stalk (labeled with words) left stalk turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) right stalk washer - push end button to column wiper - rotate towards driver, positions = off, low, high (Source - owner's manual)

U. S. A.

Manufacturer	Make/Model	Year	Remarks
Chrysler	Plymouth/ Arrow, Dodge/Colt	1977	single left stalk (labeled with words) turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) washer - push end button in wiper - twist away from driver (off, low, high) (Source - Manufacturer's representative and owner's manual)
Chrysler	Dodge/Omni, Plymouth/ Horizon ("L" body)	1978-1979	single left stalk, (labeled with words and symbols) turn signal - down = left turn, up = right turn beam switching - pull/pull switch (towards driver) washer - push handle completely in towards column wiper - pulse (single sweep) - push handle partly in towards column wiper speed - twist away from driver (counter-clockwise) = off, low, high speed (Source - Manufacturer's representative and owner's manual)
Ford	Ford/Pinto, Mercury/ Bobcat	1977-1979	no stalk controls other than turn signal (Source - owner's manual)
	Ford/ Fiesta	1977-1979	2 right, 1 left stalks (labeled with words) left stalk turn signal, down = left turn, up = right turn beam switching - push lever away from driver, pull towards flasher high beam horn - push button to column near right stalk washer - push handle towards column wiper - top position = fast, second position = normal, third position = off, bottom position = single wipe or intermittent far right stalk - headlights bottom position = off, middle position = parking lights, top position = headlights (Source - owner's manual)

APPENDIX E

ORGANIZATIONS INTERESTED IN MOTOR VEHICLES SAFETY STANDARDS

ISO. The purpose of this section is to provide background information on the organizations interested in standardization for those unfamiliar with the subject. The International Standards Organization (ISO) is the largest of such bodies. It was created in 1947 and today has 86 member countries. At last count there were 175 active Technical Committees responsible for 3,750 published standards (International Standards Organization, 1979).

To achieve international harmonization in the design of controls and displays, International Standards Organization Technical Committee 22, Subcommittee 13 (ISO TC22/SC13) "Ergonomics of Road Vehicles," was formed in the late 1960's. That committee has met annually since 1969. Represented on Technical Committee 22 are 14 member nations: Australia, Belgium, Brazil, Bulgaria, Czechoslovakia, France, Germany, Hungary, Iran, Italy, Japan, North and South Korea, Mexico, New Zealand, Poland, Rumania, South Africa, Spain, U.S.A., U.K., U.S.S.R., and Yugoslavia. Most active have been France, Italy, Sweden, Germany, U.S.A., and the U.K.

Reporting to Subcommittee 13 are six Working Groups. Working Group 3 (WG3) is concerned with controls and displays location. Subcommittee 13 and its Working Groups have been quite active. (For some of the details of the organization and history of TC 22, see Atkin (1973). For an overview of current TC 22/SC 13 efforts see Simmonds (1979).

Because TC 22/SC13/WG3 ongoing activities are not considered matters for general public review, neither a document-by-document review nor a list of documents will be presented. It should suffice to say that WG3 efforts have been extensive. (Several TC 22 Committee members have expressed the view that many documents were produced for internal discussion only and that presenting them here would only be misleading.)

ECE. Parallel to ISO efforts are those of the Economic Commission for Europe (ECE). This organization is a branch of the United Nations.

The Commission headquarters are in Geneva. Activities concerning automobiles are handled by the Group of Experts on Vehicle Construction - Working Party 29 (WP29). They report to ECE headquarters through the Inland Transport Committee. Belonging to Working Party 29 are regulatory officials from all European nations and the U.S. Department of Transportation. This group is charged with the duty of producing model regulations which are adopted by the national governments following their sign-off in New York. Proposed documents are supposed to be sponsored by two contracting governments who theoretically are the first to adopt them. Activities within WP29 take place within a series of groups known as Groupes Des Rapporteurs (GR's). With regard to control standardization, the group of interest is GRSG, whose mandate is safety.

While active in the past, WP 29 has tended to rely on TC 22 for standards development.

EEC. The EEC, or European Economic Community, also known as the Common Market, has also been active in establishing vehicle regulations. The author has not been able to obtain any information regarding the structure of standards-generating groups associated with the Brussels-based organization.

ANSI. The American National Standards Institute (ANSI) is the lead organization for voluntary standards development in the United States with headquarters in New York. It is through ANSI that delegates are appointed to represent the United States on ISO Committees. Other nations have organizations equivalent to ANSI (e.g., BSI (British Standards Institution), AFNOR (Association Francoise de Normalisation), and DIN (Deutsches Insitut fur Normung).

SAE. The Society of Automotive Engineers (SAE) is the largest organization of professionals concerned with the development and manufacture of transportation equipment. That organization sponsors technical publications, professional meetings, and in general, fosters communication among automotive engineers. In addition, SAE has an active group of committees responsible for the development and dissemination of design practices, standards, and other technical information.

Responsibility for multifunction controls within the Society of Automotive Engineers (SAE) rests with the Multifunction Control Task Force. That group reports to the Controls and Displays Subcommittee that in turn reports to the Human Factors Engineering Committee.

MVMA. The Motor Vehicle Manufacturers Association (MVMA) of the United States is the motor vehicle manufacturer's trade group in the U.S. It has 12 member companies (American Motors, Checker, Chrysler, Ford, Freightliner, General Motors, International Harvester, The Nolan Company, PACCAR, Walter Motor Truck, Volkswagon, and White Motor). MVMA supports research (for example this report), monitors government regulatory activities affecting the industry and disseminates comprehensive statistical data describing vehicle production and use (MVMA, 1979). It does not develop standards though it does comment on them.

Activities in regard to controls are handled by the Human Factors Engineering Subcommittee. As a few members of that committee also belong to the SAE Controls and Displays Subcommittee and the U.S. Technical Advisory Group to ISO TC22/SC13, communication between those groups is facilitated.

AIA. The Automobile Importers Association (AIA) represents vehicle producers who sell but do not manufacture vehicles in the U.S. (Alfa Romeo, BMW, British Leyland, Citroen, Fiat, Honda, Isuzu, Lotus, Mazda, Mitsubishi, Nissan, Pdugeot, Renault, Rolls-Royce, Saab-Scania, Subaru, Toyota, and Volvo). It is much smaller and less active than MVMA. It does not generate standards and supports a minimum of research. The people belonging to the AIA Safety Committee are, for the most part, different from those on the SAE, US ISO TAG, and MVMA Committees.

APPENDIX F

ISO STANDARD 4040

INTERNATIONAL STANDARD ISO 4040

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Road vehicles — Passenger cars — Location of hand controls, indicators and tell-tales

Véhicules routiers — Voitures particulières — Localisation des commandes manuelles, des indicateurs et des témoins

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Descriptors : road vehicles, passenger cars, manual controls, signal devices, tell-tales, trafficators, sound signalling devices, position (location), human factors engineering.

FOREWORD

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4040 was developed by Technical Committee ISO/TC 22, *Road vehicles*, and was circulated to the member bodies in January 1976.

It has been approved by the member bodies of the following countries :

Austria	Italy	Romania
Belgium	Japan	South Africa, Rep. of
Brazil	Korea, Dem. P. Rep. of	Spain
Bulgaria	Korea, Rep. of	Sweden
France	Mexico	U.S.A.
Hungary	New Zealand	U.S.S.R.
Iran	Poland	Yugoslavia

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Czechoslovakia
Germany
United Kingdom

Printed in Switzerland

Road vehicles — Passenger cars — Location of hand controls, indicators and tell-tales

0 INTRODUCTION

There is a recognized potential for errors in the selection of controls essential to the safe operation of a vehicle, if these controls are not similarly located in all vehicles. Therefore, the standardization of these control locations must be considered a logical and beneficial design objective since drivers have an ever increasing opportunity to change from one vehicle to another.

1 SCOPE

This International Standard lays down the location of the controls in road vehicles, by sub-dividing the space within reach of drivers into specific zones to which certain controls essential to the safe operation of vehicles are assigned.

2 FIELD OF APPLICATION

This International Standard applies to hand-operated controls, to indicators and to tell-tales, for left- and right-hand drive passenger cars as defined in ISO 3833, sub-clause 3.1.

3 REFERENCES

ISO 3833, *Road vehicles — Types — Terms and definitions.*

ISO 3958, *Road vehicles — Passenger cars — Driver hand control reach.*

ISO ..., *Road vehicles — Determination of the H point and definition of the R point.*[1]

4 DEFINITIONS

4.1 reference plane : A vertical plane parallel to the longitudinal axis of the car, within a zone 50 mm to either side of the centre of the designated seating position for the driver at the R point.

4.2 operational area of a control : The area swept by those parts of a control which are activated by the hand while the possible modes or positions are selected in the manner intended by the designer (see figure 1).

4.3 display area of an indicator or tell-tale : The area which includes the identification of the quantity displayed and those portions required to determine its level at any point within the usable capacity of the instrumentation. It need not include, for example, bezels or the manufacturer's type number (see figure 2).

4.4 steering wheel plane : The plane passing through the upper surface of the steering wheel rim (see figure 3).

4.5 steering wheel axis : The line at right angles to the steering wheel plane, passing through the centre of rotation of the steering wheel rim.

5 REQUIREMENTS FOR LOCATION OF CONTROLS

5.1 The operational area of the following controls, when fitted to a car, shall be located to the left of the reference plane :

- driving lights control;
- side and rear lights control;
- driving light/passing light dip control;
- optical warning control;
- direction indicator control;
- emergency braking control (right-hand drive only).

5.2 The operational area of a control for the audible warning (horn) shall be located (see figure 3) :

a) between two planes parallel to the steering wheel plane, one 10 mm above and the other 130 mm below the steering wheel plane; and

b) within a cylinder which extends 50 mm beyond the periphery of the steering wheel rim and whose axis is on the steering wheel axis.

1) In preparation.

In addition, not less than half of this control operational area shall

– either lie to the left of two planes which intersect along the steering wheel axis, and whose intersections with the steering wheel plane are at 50° and 130° to the left from the reference plane; and shall lie outside a cylinder which passes 130 mm inside the periphery of the steering wheel rim and whose axis is on the steering wheel axis;

– or lie within a cylinder of 50 mm radius whose axis is on the steering wheel axis.

Additional audible warning controls may be located elsewhere, or operational areas of controls may extend beyond the zones described above.

These assessments are to be made with the vehicle front wheels in the straight-ahead position, and the gear selector control in top gear, or drive position.

5.3 The operational area of the following control, when fitted to a car, shall be located to the right of the reference plane :

– emergency braking control (left-hand drive only).

5.4 The controls listed in 5.1, 5.2 and 5.3 shall be within the operational reach of drivers as defined by ISO 3958.

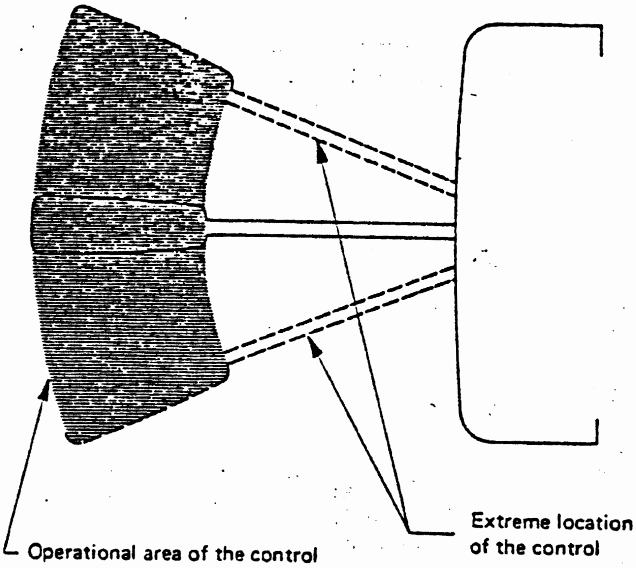


FIGURE 1 – Operational area of a control

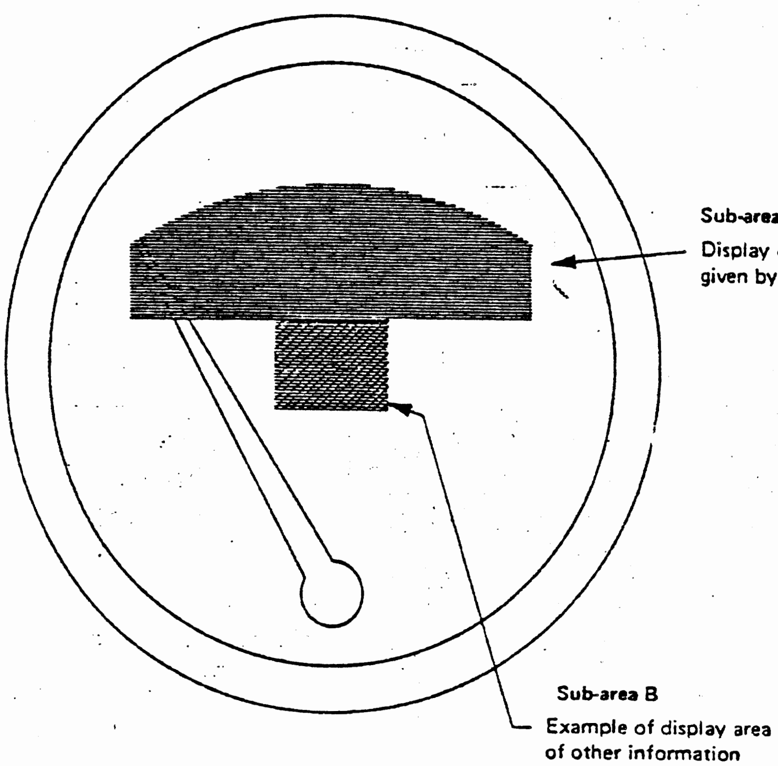


FIGURE 2 – Example of display area of indicators

Dimensions in millimetres

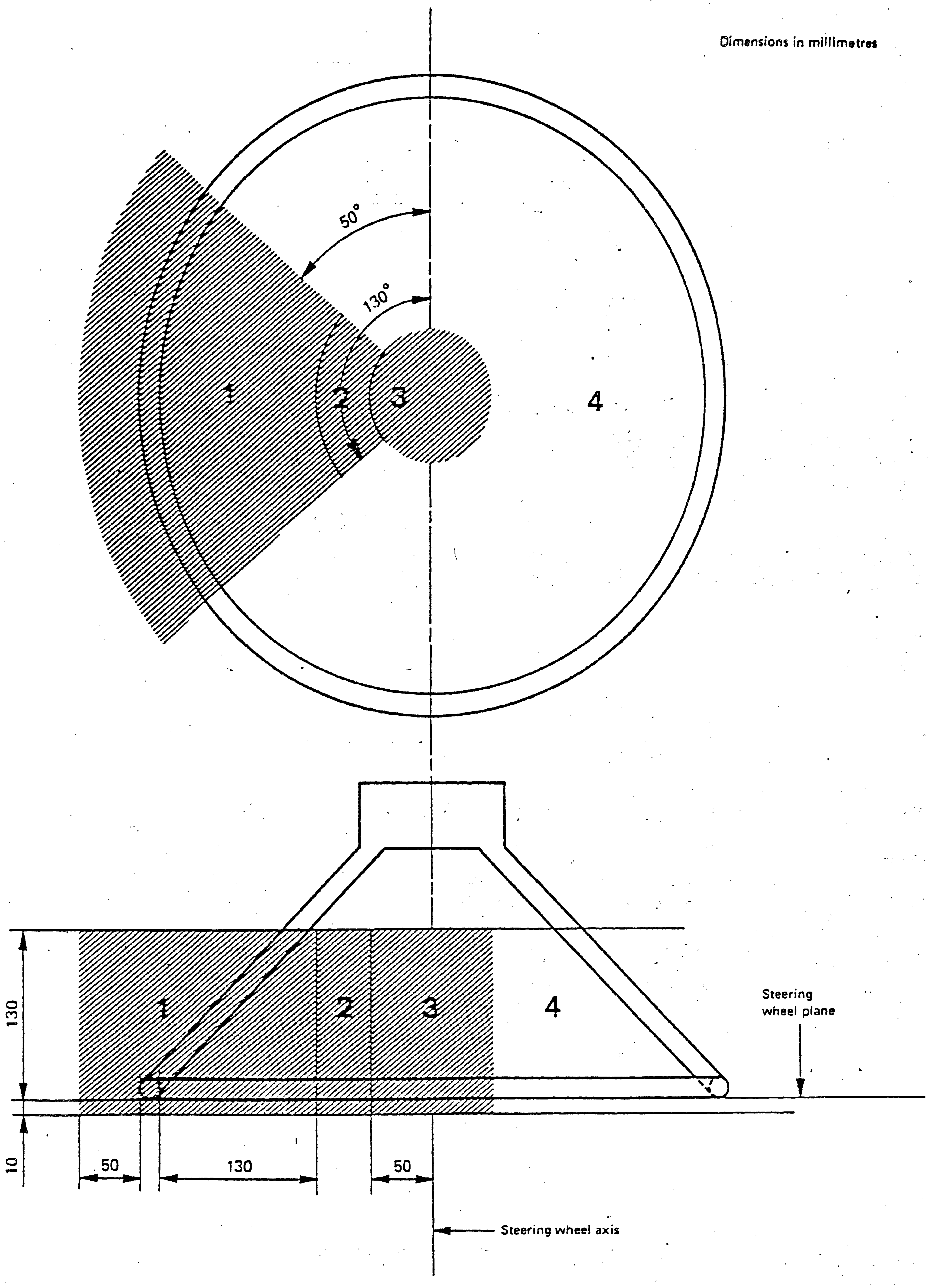


FIGURE 3 – Location of horn control

APPENDIX G

SAE J1138

DESIGN CRITERIA—DRIVER HAND CONTROLS LOCATION FOR PASSENGER CARS, MULTI-PURPOSE PASSENGER VEHICLES, AND TRUCKS (10 000 GVW AND UNDER)—SAE J1138

SAE Recommended Practice

Report of Human Factors Engineering Committee approved September 1977.

1. Scope—The purpose of this SAE Recommended Practice is to describe design criteria pertaining to the location and labeling of hand controls necessary to or frequently used during the operation of passenger cars, MPV, and trucks 10 000 GVW and under. The results of SAE human factors research have strongly influenced these recommendations, specifically in the areas of driver reach, control-locating performance, and control location expectancies. Deviations from this recommended practice should be made only after careful study of the various SAE publications on these subjects, as referenced here and in SAE J1139 (September, 1977), Supplemental Information—Driver Hand Controls Location for Passenger Cars, MPV's and Trucks (10 000 GVW and Under).

2. Introduction—The location of essential controls should be based, insofar as possible, on performance rather than design considerations and must be governed by human engineering practice as it pertains to hand reach, visibility, identification, and operating mode. These considerations may be mutually exclusive, in certain vehicles, because of conflicting design requirements. In these cases, the recommended practice should be followed starting with the highest priority considerations until all available control location space has been used.

Any restriction in the location of controls and displays must respect the need to accommodate not only safety requirements and serviceability, but also the spatial requirements necessary to package the components behind the control and display surface. These restrictions in control locations are not intended to preclude the adoption of new control innovations or inventions that may be superior to known technology and which could result in safer, more efficient operation of the vehicle. It should be recognized that different classes of vehicles such as trucks may require different control locations because of their distinct environment.

3. Term Definitions

3.1 Driver Hand Control Reference Plane—A vertical longitudinal plane through the steering wheel center Y coordinate.

3.2 Driver Hand Control Operational Area—The area or region swept by those parts of a control which are activated or contacted by the hand while the control is in all the possible modes or positions. (See Fig. 1.)

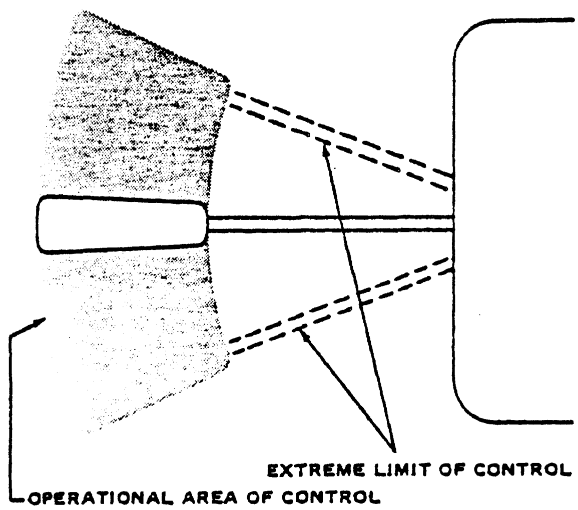


FIG. 1—OPERATIONAL AREA OF CONTROL

3.3 **Driver Hand Control Display Area**—The area which includes the identification of the control and those portions required to determine its position at any point within its range. It need not include, for example, bezels or manufacturers' type numbers. (See Fig. 2 and SAE J1050a (January, 1977).)

3.4 **Primary Driver Hand Controls**—Those controls essential to the operation of a vehicle.

3.5 **Secondary Driver Hand Controls**—Those hand operated controls other than primary controls, intended for use by the driver when the vehicle is

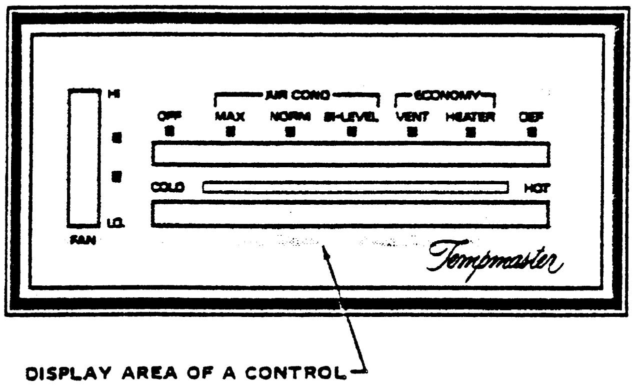


FIG. 2—DISPLAY AREA OF A CONTROL

in motion for comfort and convenience, and those other controls not required for the principal operation of the vehicle.

4. Design Criteria in Order of Priority

4.1 The operational area of the following primary hand controls should be within the reach of a driver wearing a lap and shoulder restraint and the following secondary hand controls should be within reach of a driver wearing a lap belt only. (Reference SAE J287 (July, 1976), Driver Hand Control Reach.) *SAE J287 (July, 1976) defines reach capability under specific conditions of finger grasp control operation for two restraint conditions; a diagonal non-extending shoulder strap with lap belt and lap belt only. Fingertip operated controls may permit greater reach, while full hand grasp operated controls may result in lesser reach. In addition, a diagonal extending shoulder strap may permit greater reach than a non-extending shoulder strap.*

Primary Driver Hand Controls	Secondary Driver Hand Controls
Steering Control Gearshift Control Turn Signal Control Ignition Control Audible Horn Control Headlamp Dimmer Control Washer/Wiper Control(s) Headlamp Control Defroster Control Hazard Flasher Control Hand Brake	Headlamp Optical Warning Control Climate Control Radio Controls Vent Remote Control Cigarette Lighter Ashtray Accessory Controls

4.2 The audible horn control should be located on the steering control.

4.3 The display area of the following driver hand controls should be within view of the restrained driver with head movement so as to permit identification. Areas obscured by the steering control are defined in SAE J1050a (January, 1977), Describing and Measuring the Driver's Field of View.

Primary Driver Hand Controls	Secondary Driver Hand Controls
Washer/Wiper Control(s) Headlamp Control Defroster Control	Climate Control Radio Control Vent Remote Control Cigarette Lighter (except in the ashtray) Ashtray Accessory Controls

4.4 The following driver hand controls should be labeled with words or words and symbols.

Primary Driver Hand Controls	Secondary Driver Hand Controls
Washer/Wiper Control(s) Headlamp Control Defroster Control Hazard Flasher Control	Climate Control Functions Vent Remote Control Cigarette Lighter Ashtray Accessory Controls

4.5 The following driver hand controls should be located to the left of the reference plane. A differentiation between the operating modes of the headlamp control and the washer/wiper control(s) should exist.

Primary Driver Hand Controls	Secondary Driver Hand Controls
Turn Signal Control Headlamp Dimmer Control Washer/Wiper Control(s) Headlamp Control	Headlamp Optical Warning Control

4.6 The following driver hand controls should be located to the right of the reference plane.

Primary Driver Hand Controls	Secondary Driver Hand Controls
Gearshift Control Ignition Control Defroster Control Hazard Flasher Control	Climate Control Radio Controls Cigarette Lighter Ashtray

4.7 Controls not specifically mentioned in this recommended practice should be located insofar as possible in accordance with SAE publications concerning driver reach, control-locating performance, and expectancies.

5. References

5.1 SAE J287 (July, 1976), Driver Control Reach.

5.2 SAE J1048 (September, 1974), Symbols for Motor Vehicle Controls, Indicators, and Tell-Tales.

5.3 SAE J1050a (January, 1977), Describing and Measuring Driver's Field of View.

5.4 J. J. McGrath, "Driver Expectancy and Performance in Locating Automotive Controls," SAE SP 407, presented at SAE Automotive Engineering Congress and Exposition, February 23-27, 1976.

5.5 SAE J1139 (September, 1977), Supplemental Information Driver Hand Controls Location for Passenger Cars, Multi-Purpose Passenger Vehicles, and Trucks (10 000 GVW and Under).

5.6 SAE J1100a (September, 1975), Motor Vehicle Dimensions.

APPENDIX H

SAE J1139

SUPPLEMENTAL INFORMATION—DRIVER HAND CONTROLS LOCATION FOR PASSENGER CARS, MULTI-PURPOSE PASSENGER VEHICLES, AND TRUCKS (10 000 GVW AND UNDER)—SAE J1139

SAE Information Report

Report of Human Factors Engineering Committee approved September 1977.

This information report should be used as a supplement to SAE J1138 (September, 1977), Design Criteria—Driver Hand Controls Location for Passenger Cars, Multi-Purpose Passenger Vehicles, and Trucks (10 000 GVW and Under). It is intended to provide additional information which is important to the automotive designer and engineer in the process of designing, developing, and engineering the instrument panel.

1. General—The question of driver hand controls location is a complex one. While there is a general feeling that decrements in performance in locating and operating controls may affect the safety with which a vehicle is operated, there is no solid evidence linking accidents with the inadvertent operation of automotive controls or to the inability to locate an essential control in a timely manner.

The Anacapa studies and final SAE report SP407 indicate that errors and response times increase when hand controls are not located in their expected location and that this offers the potential for a decrement in operator performance. The measure or consequence of the decrement has not yet been determined and may never be determined in a totally objective manner.

However, if there is a potential improvement in operator performance, which could be achieved by the location of certain hand controls, then that is the goal.

Numerous studies, including Anacapa,[1] indicate that drivers quickly adapt to a new control within a new environment after the first trial, with both response time and error rates reaching *own car* levels. Other studies, again including Anacapa, show a number of drivers reporting *own car* control location difficulties.

The Anacapa "Analysis of Expectancies of European Drivers and the Commonality of Automotive Controls Location on European Cars" study (Ref. 6), has demonstrated that driver populations have distinct control location expectancies and that these expectancies vary by country and by car type. Although the Anacapa studies show that there are decrements in response time and error performance when a control is located in an area other than the expected one, the European driver study (247.1) shows that the drivers make an attempt to adapt to the unfamiliar vehicle environment.

The Anacapa study (Ref. 4), demonstrates that expectancy is based on the driver's total experiences not just his most recent experience. This may account for those drivers still reporting the control location difficulties with their own cars after extended use as shown in the "Problem Incidence Survey—Own Car Drivers". These results suggest that some degree of location standardization ought to improve driver performance for both the first use and the extended use situation.

One of the most important factors in the Anacapa research affecting the driver's ability to locate controls was the presence or absence of labeling. Labeling was found to be essential to locating controls and significantly improved driver's performance. However, the results indicate that for comparably labeled controls, the actual location versus the expected location was the primary factor.

One additional finding which should not be ignored concerning instrument panel controls locations, but may be of even more importance in multi-function controls, is the *clutter effect*. There is a clutter effect if too many or varied controls are located in a given area. As the number of controls increase, so do the errors and response times.

It is assumed from the comparison of the findings in the Anacapa European and Japanese driver study versus the American driver study and from the fact that the current American production cars already possess a greater degree of commonality in controls location than do the European and Japanese cars, that the American drivers have a higher degree of expectancy and therefore better performance. It shows that there is less commonality of controls locations on European and Japanese cars and that as a consequence the Probability of Confirmed Expectancy by those drivers in their cars is less than American drivers in American cars.

Based upon the available research information it is concluded that certain practices should be adhered to in the design, development, and engineering of the instrument panel.

Incorporated in this report are positive proposals as well as design practices which should be avoided.

[1] Anacapa "Problem Incidence Survey Own Car Drivers."

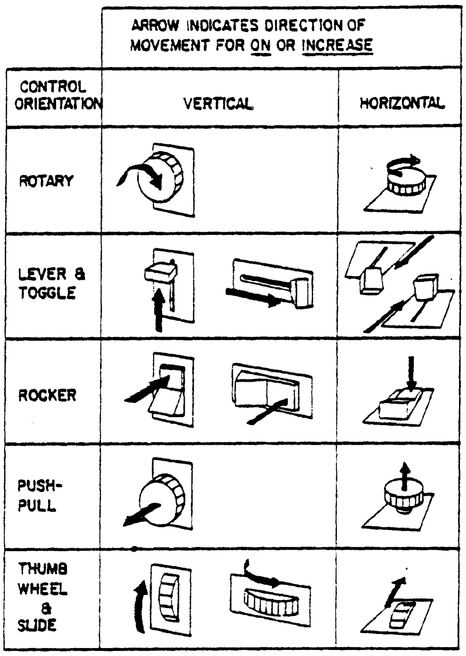


FIG. 1—ASSUMED DIRECTION OF CONTROL MOVEMENT FOR ON OR INCREASE

2. Specific

2.1 Cigarette Lighter—It is expected to be near or in the ashtray.

2.2 Vent Remote Control—A relocation in an area other than its expected location to the right of the reference place causes performance decrements and should be avoided. It is expected to be incorporated in or located near the climate control.

2.3 Hood Release—A location in an area other than its expected location to the left of the reference plane would be inconvenient.

3. Operation—The conclusions of this information report were made in consideration of the basic human factors guidelines on *direction of motion convention*. (See Fig. 1.)

4. Practices to be Avoided—Examples of the type of conditions which should be avoided:

4.1 Parking brake and hood release which are located side by side, and look alike.

4.2 Climate control which is designed in such a way as to have the appearance of a radio.

4.3 Ashtray which is difficult to locate.

5. Hazard Avoidance—Because of the high expectancy of the United States drivers to find certain essential operating controls on the same side of the reference plane or in the same area, care should be exercised in the design of controls to provide differences in: appearance, tactile recognition, and the modes of operation.

6. References

6.1 SAE J287 (July, 1976), Driver Control Reach.

6.2 SAE J1048 (September, 1974), Symbols for Motor Vehicle Controls, Indicators, and Tell-Tales.

6.3 SAE J1050a (January, 1977), Describing and Measuring Driver's Field of View.

6.4 J. J. McGrath, "Driver Expectancy and Performance in Locating Automotive Controls", SAE SP 407, presented at SAE Congress February 23-27, 1976.

6.5 SAE J1138 (September, 1977), Design Criteria—Driver Hand Controls Location for Passenger Cars, Muti-Purpose Passenger Vehicles, and Trucks (10 000 GVW and Under).

6.6 J. J. McGrath "Analysis of Expectancies of European Drivers and Commonality of Automotive Controls Location on European Cars", 247-1 September 26, 1974.

APPENDIX I

FMVSS 101

[4910-59]

CHAPTER V—NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION, DEPARTMENT OF TRANSPORTATION

[Docket No. 1-18; Notice 13]

PART 571—FEDERAL MOTOR VEHICLE SAFETY STANDARDS

Controls and Displays

AGENCY: National Highway Traffic Safety Administration, Department of Transportation.

ACTION: Final rule.

SUMMARY: This notice expands the application of the standard for the location, identification, and illumination of driver controls and displays (e.g., gauges and meters) by establishing requirements for additional controls and by introducing selected displays which, if furnished, must be located and illuminated under specified conditions and identified by a specified symbol and/or selected word. The purpose of the requirements is to encourage international standardization and harmonization of controls and displays in order to convey information more quickly to drivers and with less chance of human error. This will reduce the interval during which a driver's attention is diverted from the roadway to his controls and displays, thus decreasing the possibility of an accident.

EFFECTIVE DATE: September 1, 1980.

FOR FURTHER INFORMATION CONTACT:

Mr. Nelson Erickson, Office of Motor Vehicle Programs, 400 Seventh Street SW., Washington, D.C. 20590, 202-426-2155.

SUPPLEMENTARY INFORMATION: This notice establishes new requirements for the location, identification, and illumination of controls and displays in passenger cars, multipurpose passenger vehicles, trucks, and buses. The new rule is designated 49 CFR 571.101-80, *Controls and Displays*, and becomes effective September 1, 1980. The existing rule on this subject, 49 CFR 571.101, *Control Location, Identification, and Illumination*, is amended to permit, at the vehicle manufacturer's option, compliance with that standard or the new requirements of Standard No. 101-80 before September 1, 1981.

On October 21, 1976, the National Highway Traffic Safety Administration published (41 FR 46460) a notice proposing to update the existing controls and displays standard (Standard 101) by incorporating all pertinent amendments and interpretations published since the original issuance on January 31, 1967. It also proposed to consolidate the control and display requirements of other standards in one regulation. This notice takes final action on that proposal. All comments were considered and the major ones are discussed below.

The notice issued in October 1976 proposed that most controls and displays be required to be identified with specified symbols which are internationally standardized. Words would have been permitted in addition to the symbols, although the choice of words would have been limited to ensure uniformity. Specified words would have been required for those controls and displays for which no symbols had been established.

The rationale behind the proposed requirement of symbols was that they can convey information more quickly and with less chance of human error than words. This is particularly true with respect to the large foreign language speaking population of this country. By simplifying the identification of controls and displays, the standard should reduce the problems resulting from driver's attention being diverted from the roadway to his controls and displays. An additional benefit cited in the proposed notice is that manufacturers who sell vehicles both in and outside of the United States could realize significant cost savings by utilizing internationally standardized symbols.

The National Motor Vehicle Advisory Council and the Vehicle Equipment Safety Commission did not take positions on the proposal. The majority of commenters favored the use of symbols in the interest of international standardization and harmonization. The final rule, therefore, requires the use of symbols and allows the use of additional words if the manufacturer so chooses.

One of the major concerns of manufacturers commenting was that the proposed rule would inhibit the design and development of electronic "readout" panels which can effectively present to the driver specific information concerning vehicle and environmental conditions affecting safety. These displays are currently capable of exhibiting information and warnings with word messages and not with symbols. The optional use of symbols or words will permit the continued development of informational readout displays. The NHTSA supports the development of more efficient and effective control and display information systems and has, consequently, permitted informational readout displays to be identified by words only so as to not impede the development of electronic displays.

The symbols that are permitted by this rule to identify controls and displays are those developed by the International Standards Organization (ISO). By specifying symbols adopted by the ISO, this agency is facilitating the achievement of an international uniform identification system. New symbols for five controls and eight displays are added to those presently designated in the existing standard. Additional symbols will be added when the NHTSA determines which ones will be readily recognizable, thus reducing driver diversion.

Some commenters noted that a few of the symbols, such as the clearance lamp symbol, deviate slightly from those adopted by the ISO. The NHTSA, while basing its symbols on those developed by the ISO, is not specifying ISO symbols which it determines will not adequately convey the intended message. Thus, the symbols proposed in the October notice are adopted, even though some of them deviate from the ISO symbols. Some existing ISO symbols are not included in this final rule due to the fact that additional data are needed on their recognizability. When such data have been accumulated and analyzed, the NHTSA will determine whether the symbols should be added to Standard 101-80.

A few commenters suggested the deletion of the symbols for the turn signal and high beam tell-tales because these have long been identified by color and operate only after deliberate operation by the driver. It is the belief of the NHTSA that these symbols should be retained. They are necessary to educate new drivers, to act as reminders to those who drive infrequently, and to further the uniformity and harmonization of symbols. It should be noted that the turn signal was inadvertently omitted from Table I. It was, however, listed in S5.1 as one of the hand-operated controls and discussed in the preamble.

Another question that was raised was whether the manufacturers could use symbols that deviate from those designated in the standard. As stated in previous notices on controls and displays, minor deviations are allowed, as long as the symbol used substantially resembles that specified in the standard.

Several commenters raised concerns about the color of various symbols. The hazard warning telltale was inadvertently designated as green in the proposed rule. That color should be red and the final rule has been corrected to reflect this. Several commenters mentioned that because of the technology of light emitting diodes, telltales are technologically feasible only in yellow, green, or red. One commenter noted that neon gas discharge displays emit a characteristic neon red-orange light, rather than red. These displays rate high in intensity, durability, and reliability and are low in cost. Because of these factors, the final rule has been amended so that a designation of the color red can be either red or red-orange and the color blue may be either blue or blue-green.

Many of those commenting objected to the prohibition of any words other than the words specified in the table. The NHTSA has decided, to permit the manufacturer to use additional words, but only for clarification. For example, the manufacturer may combine an instruction with the specified identification, such as "pull to defrost," or it may use another word for the purpose of clarity, such as "unleaded fuel only." The manufacturer will be permitted to describe the "automatic vehicle speed system" in words of his choosing because over the years customers have become used to the various descriptors, such as "cruise control" and "speed control," which manufacturers have used. The NHTSA does not believe that either descriptor is superior to the other. In addition, the manufacturer will be permitted to describe the "automatic gear position" by words of his choosing since these controls are conspicuous and automatic transmissions are not uniform, some not providing a park (P) position and others with additional gears. In response to one question, it should be noted that "automatic gear position" by virtue of its being automatic is not a hand-operated control as referred to in S5.3.1.

In accordance with the suggestions of commenters, the final rule adopts the use of "volts" or "charge" in addition to "amp" for the electrical charge telltale and gauge. Many other alternate words were suggested, but the NHTSA believes that the ones adopted in the final rule best convey the appropriate information. With the allowance of additional words, objection to those required should no longer remain.

Manufacturers of vehicles over 10,000 pounds gross vehicle weight rating (GVWR) objected to the application of this rule to their vehicles. They emphasized that with the increased number of gauges and expanded level of display information utilized by such vehicles, the application of this rule would result in panels that are a "hodgepodge of symbols." It was also asserted that this application would necessitate redesign of the instrument panels, possibly increasing driver diversion instead of decreasing it. Most heavy duty trucks comply with SAE recommendations for the location standardization of controls and displays in the operator's compartment. The operators of vehicles in the heavy duty category are professionals who are familiar with these standardized locations and do not need to read a legend or symbol. In addition, heavy duty trucks are not subject to yearly redesign or model changes. Because of these concerns, the agency has decided that vehicles over 10,000 pounds GVWR need not meet display requirements of this standard. They must, however, meet the control requirements.

A large number of commenters requested that the location of the controls and displays be uniform. An additional request was made to require common carriers to maintain illumination devices on all equipment. While these recommendations are noteworthy, they are not the subject of this rulemaking action, but will be considered for possible future rulemaking.

In the October proposal, it was specified that the control identification be placed on or adjacent to the particular control. The display identification, on the other hand, was to be placed on the display, unless the exposed portion of the lens was in the shape of the required identification. The proposal also stated that the identification of the high-beam indicator and of any gauge could be placed on or adjacent to the display that it identified. In response to the comments that identification could be met equally well by placing the symbol adjacent to the telltale, the NHTSA has decided to leave it up to the manufacturer to determine whether the identification should be placed directly on the control or display or whether an adjacent position would be satisfactory. The final rule does require that the identification be visible to the driver. In response to one commenter, the NHTSA does recognize that the spokes of the steering wheel may at times interfere with the visibility of the controls and displays. The visibility requirement will be satisfied even if the driver needs to make minimal movements toward the front, to the left, and to the right to see the identifications. The NHTSA has determined that these minor necessary movements will have virtually no effect on the safe operation of the vehicle.

The designation of "Km" for kilometres has been corrected in the final rule to read "km". Any odometer that records distance in kilometres must be labeled "KILOMETRES" or "km" so as to avoid confusion. The October 1976 proposal provided an option regarding English or metric units for labeling speedometers. Any proposal setting forth alternatives implicitly carries with it the possibility that one or more of the alternatives may become mandatory. In light of this and in light of the decision in Federal Motor Vehicle Safety Standard No. 127, 43 FR 10919, to require speedometers to record speed in both English and in metric, this rule requires that both speed scales be labeled so as to avoid confusion. Therefore, for dual readings of MPH and km/h on speedometers the manufacturer is required to clearly label the appropriative display.

The proposed effective date for this rule was September 1, 1979. Due to the numerous comments received, indicating that more lead time would be desirable in order to permit the conversion of controls and displays to coincide with routine redesign of various vehicle models, an effective date of September 1, 1980, has been adopted.

The primary authors of this notice are Mr. Nelson Erickson, Office of Motor Vehicle Programs, and Ms. Kathleen DeMeter, Office of the Chief Counsel.

In consideration of the foregoing, Part 571 of Title 49 of the Code of Federal Regulations is amended as follows:

1. S4 of § 571.101, *Control location, identification, and illumination*, is amended to read:

§ 571.101-80 Standard No. 101, control location, identification, and illumination.

* * * * *

S4. *Requirements*. Each passenger car, multipurpose passenger vehicle, truck, and bus manufactured before September 1, 1980, with any control listed in S4.1 or in column 1 of Table 1, shall meet either the requirements of this standard or § 571.101-80 of this part (Standard No. 101-80) for the location, identification, and illumination of such control.

2. A new § 571.101-80, *Controls and displays*, is added, to read as set forth below:

§ 571.101 Standard No. 101-80, controls and displays.

S1. *Scope*. This standard specifies requirements for the location, identification, and illumination of motor vehicle controls and displays.

S2. *Purpose*. The purpose of this standard is to ensure the accessibility and visibility of motor vehicle controls and displays and to facilitate their selection under daylight and nighttime conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task, and by mistakes in selecting controls.

S3. *Application*. This standard applies to passenger cars, multipurpose passenger vehicles, trucks, and buses.

S4. *Definitions*.

"Telltale" means a display that indicates, by means of a light-emitting signal, the actuation of a device, a correct or defective functioning or condition, or a failure to function.

"Gauge" means a display that is listed in S5.1 or in Table 2 and is not a telltale.

"Informational readout display" means a display using light-emitting diodes, liquid crystals, or other electro illuminating devices where one or more than one type of information or message may be displayed.

S5. *Requirements.* Each passenger car, multipurpose passenger vehicle, truck and bus manufactured with any control listed in S5.1 or in column 1 of Table 1, and each passenger car, multipurpose passenger vehicle and truck or bus less than 10,000 pounds GVWR with any display listed in S5.1 or in column 1 of Table 2, shall meet the requirements of this standard for the location, identification, and illumination of such control or display.

S5.1 *Location.* Under the conditions of S6, each of the following controls that is furnished shall be operable by the driver and each of the following displays that is furnished shall be visible to the driver. Under conditions of S6, telltales and informational readout displays are considered visible when activated.

HAND-OPERATED CONTROLS

(a) Steering wheel.
(b) Horn.
(c) Ignition.
(d) Headlamp.
(e) Taillamp.
(f) Turn signal.
(g) Illumination intensity.
(h) Windshield wiper.
(i) Windshield washer.
(j) Manual transmission shift lever, except transfer case.
(k) Windshield defrosting and defogging system.
(l) Rear window defrosting and defogging system.
(m) Manual choke.
(n) Driver's sun visor.
(o) Automatic vehicle speed system.
(p) Highbeam.
(q) Hazard warning signal.
(r) Clearance lamps.
(s) Hand throttle.
(t) Identification lamps.

FOOT-OPERATED CONTROLS

(a) Service brake.
(b) Accelerator.
(c) Clutch.
(d) Highbeam.
(e) Windshield washer.
(f) Windshield wiper.

DISPLAYS

(a) Speedometer.
(b) Turn signal.
(c) Gear position.
(d) Brake failure warning.
(e) Fuel.
(f) Engine coolant temperature.
(g) Oil.
(h) Highbeam.
(i) Electrical charge.

S5.2 *Identification.*

S5.2.1 Any hand-operated control listed in column 1 of Table 1 that has a symbol designated in column 3 shall be identified by that symbol. Such a control may, in addition, be identified by the word or abbreviation shown in column 2. Any such control for which no symbol is shown in Table 1 shall be identified by the word or abbreviation shown in column 2. Additional words or symbols may be used at the manufacturer's discretion for the purpose of clarity. The identification shall be placed on or adjacent to the control. The identification shall, under the conditions of S6, be visible to the driver and, except as provided in S5.2.1.1 and S5.2.1.2, appear to the driver perceptually upright.

S5.2.1.1 The identification of a headlamp and taillamp control that adjusts control and display illumination by means of rotation, or of any other rotating control that does not have an off position, need not appear to the driver perceptually upright.

S5.2.1.2 The identification of a rotating control other than one described by S5.2.1.1 shall appear to the driver perceptually upright when the control is in the off position.

S5.2.2 Identification shall be provided for each function of any automatic vehicle speed system control and any heating and air conditioning system control, and for the extreme positions of any such control that regulates a function over a quantitative range. If this identification is not specified in Tables 1 or 2, it shall be in word form unless color coding is used. If color coding is used to identify the extreme positions of a temperature control, the hot extreme shall be identified by the color red and the cold extreme by the color blue.

Example 1. A slide lever controls the temperature of the air in the vehicle heating system over a continuous range, from no heat to maximum heat. Since the control regulates a single function over a quantitative range, only the extreme positions require identification.

Example 2. A switch has three positions, for heat, defrost, and air conditioning. Since each position regulates a different function, each position must be identified.

§5.2.3 Except for informational readout displays, any display located within the passenger compartment and listed in column 1 of Table 2 that has a symbol designated in column 4, shall be identified by that symbol. Such display may, in addition be identified by the word or abbreviation shown in column 3. Any such display for which no symbol is provided in Table 2 shall be identified by the word or abbreviation shown in column 3. Informational readout displays may be identified by the symbol designated in column 4 of Table 2 or by the word or abbreviation shown in column 3. Additional words or symbols may be used at the manufacturer's discretion for the purpose of clarity. The identification required or permitted by this section shall be placed on or adjacent to the display that it identifies. The identification of any display shall, under the conditions of S6, be visible to the driver and appear to the driver perceptually upright.

S5.3 *Illumination.*

§5.3.1 Except for foot-operated controls or hand-operated controls mounted upon the floor, floor console, or steering column, or in the windshield header area, the identification required by §5.2.1 or §5.2.2 of any control listed in column 1 of Table 1 and accompanied by the word "yes" in the corresponding space in column 4 shall be capable of being illuminated whenever the headlights are activated. However, control identification for a heating and air-conditioning system need not be illuminated if the system does not direct air directly upon windshield. If a gauge is listed in column 1 of Table 2 and accompanied by the word "yes" in column 5, then the gauge and its identification required by §5.2.3 shall be illuminated whenever the ignition switch and/or the headlamps are activated. Controls, gauges, and their identifications need not be illuminated when the headlamps are being flashed. A telltale shall not emit light except when identifying the malfunction or vehicle condition for whose indication it is designed or during a bulb check upon vehicle starting.

S5.3.2 Except for informational readout displays, each discrete and distinct telltale shall be of the color shown in column 2 of Table 2. The identification of each telltale shall be in a color that contrasts with the lens, if a telltale with a lens is used. Any telltale used in conjunction with a gauge need not be identified. The color of informational readout displays will be at the option of the manufacturer.

S5.3.3 Light intensities for controls, gauges, and their identification shall be continuously variable from: (a) A position at which either there is no light emitted or the light is barely discernible to a driver who has adapted to dark ambient roadway conditions to (b) a position providing illumination sufficient for the driver to identify the control or display readily under conditions of reduced visibility. Light intensities for informational readout systems shall have at least two values, a higher one for day, and a lower one for nighttime conditions. The intensity of any illumination that is provided in the passenger compartment when and only when the headlights are activated shall also be variable in a manner that complies with this paragraph. The light intensity of each telltale shall not be variable and shall be such that, when activated, that telltale and its identification are visible to the driver under all daytime and nighttime conditions.

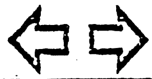
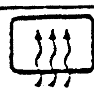
S6. *Conditions.* The driver is restrained by the crash protection equipment installed in accordance with the requirements of §571.208 of this part (Standard No. 208), adjusted in accordance with the manufacturer's instructions.

(Secs. 103, 119, Pub. L. 89-563, 80 Stat. 718 (15 U.S.C. 1392, 1407); delegation of authority at 49 CFR 1.50.)

Issued on June 21, 1978.

JOAN CLAYBROOK,
Administrator.

TABLE 1
Identification and Illumination of Controls

Column 1 Hand Operated Controls	Column 2 Identifying Words or Abbreviation	Col. 3 Identifying Symbol	Col. 4 Illumination
Headlamps and Tail Lamps	Lights	 [2,4]	—
Turn Signal	—		—
Hazard Warning Signal	Hazard		Yes
Clearance Lamps System	Clearance Lamps or Cl Lps	 [3,4]	Yes
Windshield Wiping System	Wiper or Wipe		Yes
Windshield Washing System	Washer or Wash		Yes
Windshield Washing and Wiping Combined	Wash-Wipe		Yes
Heating and/or Air Conditioning Fan	Fan		Yes
Windshield Defrosting and Defogging System	Defrost, Defog or Def		Yes
Rear Window Defrosting and Defogging System	Rear Defrost, Rear Defog or Rear Def		Yes
Engine Start	Engine Start[1]	—	—
Engine Stop	Engine Stop[1]	—	Yes
Manual Choke	Choke	—	—
Hand Throttle	Throttle	—	—
Automatic Vehicle Speed	(Mfg. Option)	—	Yes
Identification Lamps	Identification Lamps or Id Lps	—	Yes
Heating and Air Conditioning System	(Mfg. Option)	—	Yes

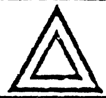
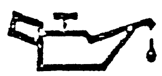
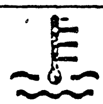
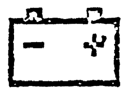
1. Use when engine control is separate from the key locking system.

2. Use also when clearance, identification, parking and/or side marker lamps are controlled with the headlamp switch

3. Use also when clearance lamps, identification lamps and/or side marker are controlled with one switch other than the headlamp switch.

4. Framed areas may be filled.

TABLE 2
Identification and Illumination of Internal Displays

Column 1 Display	Col. 2 Telltale Color	Column 3 Identifying Words or Abbreviation	Col. 4 Identifying Symbol	Col. 5 Illuminate
Turn Signal Tell-Tale	Green	Also see FMVSS 108	 [1] [5]	—
Hazard Warning Tell-Tale	Red [4]	Also see FMVSS 108	 [2] [5]	—
Seat Belt Tell-Tale	Red [4]	Also see FMVSS 208		—
Fuel Level Tell-Tale	Yellow	Fuel		—
Gauge	—	Fuel		Yes
Oil Pressure Tell-Tale	Red [4]	Oil		—
Gauge	—	Oil		Yes
Coolant Temperature Tell-Tale	Red [4]	Temp		—
Gauge	—	Temp		Yes
Electrical Charge Tell-Tale	Red [4]	Volts, Charge or Amp		—
Gauge	—	Volts, Charge or Amp		Yes
Speedometer	—	MPH and Km/h	—	Yes
Odometer	—	— [3]	—	—
Automatic Gear Position	—	Also see FMVSS 102	—	Yes
High Beam Tell-Tale	Blue [4]	Also see FMVSS 108	 [5]	—
Brake Air Pressure Position Tell-Tale	Red [4]	Brake Air Also see FMVSS 108	—	—
Malfunction in Anti-Lock or	Yellow	Anti-Lock Also see FMVSS 121	—	—
Brake System	Red [4]	Brake Also see FMVSS 121	—	—

1. The pair of arrows is a single symbol. When the indicators for left and right turn operate independently, however, the two arrows will be considered separate symbols and may be spaced accordingly.

2. Not required when arrows of turn signal tell-tales that otherwise operate independently flash simultaneously as hazard warning tell-tale.

3. If the odometer indicates kilometers, then "KILOMETERS" or "km" shall appear; otherwise, no identification is required.

4. Red can be red-orange. Blue can be blue-green.

5. Framed arrows may be filled.

[FR Doc. 78-17672 Filed 6-21-78; 4:55 pm]

49 CFR Part 571

[Docket No. 1-18; Notice 14]

Federal Motor Vehicle Safety Standards; Controls and Displays

AGENCY: National Highway Traffic Safety Administration (NHTSA), Department of Transportation.

ACTION: Response to petitions for reconsideration.

SUMMARY: This notice responds to petitions for reconsideration of Federal Motor Vehicle Safety Standard (FMVSS) 101–80, *Controls and Displays*, published June 26, 1978. Several aspects of the petitions are granted, most notably those relating to clarification of the references to other vehicle safety standards and additional symbols. The other aspects of the petitions are denied.

EFFECTIVE DATE: September 1, 1980, except that the amendments to Federal Motor Vehicle Safety Standard No. 208 (49 CFR 571.208), become effective on September 27, 1979.

FOR FURTHER INFORMATION CONTACT: Mr. Nelson Erickson, Office of Vehicle Safety Standards, 400 Seventh Street, S.W., Washington, D.C. 20590, 202-426-2720.

SUPPLEMENTARY INFORMATION: On June 26, 1978, the NHTSA published (42 FR 27541) a final rule establishing new requirements in FMVSS 101–80 for the location, identification, and illumination of controls and displays in passenger cars, multipurpose passenger vehicles, trucks, and buses.

Petitions for reconsideration of FMVSS No. 101–80 were received from the following organizations: Ford Motors Company; American Motor Corporation, British Leyland UK Ltd., Volkswagen of America, Blue Bird Body Company and Mack Trucks, Inc. A discussion of the issues raised by the petitions and their resolution follows. All petitions are denied except as otherwise noted.

Ford requested that vehicles over 10,000 pounds gross vehicle weight rating (GVWR) be excluded from the control requirements. Blue Bird made a similar request, asking that school buses over 10,000 pounds GVWR be excluded. The notice of proposed rulemaking issued on October 21, 1976 (41 FR 46460) would have required all passenger cars, multipurpose passenger vehicles, trucks, and buses to meet its control and display requirements. The agency, however, found merit in the comments of truck manufacturers who objected to the application of display requirements to heavy duty vehicles. As a result, the final rule provided that heavy duty vehicles need not comply with the display requirements, but must meet the control requirements. Ford and Blue Bird believe that the reasons for excluding these vehicles from the display requirements are equally applicable to the control requirements. They indicated that the operators of these vehicles are professionals who are familiar with the controls and their functions. They further stated that compliance would impose unwarranted redesign and expenditures.

Neither Ford nor Blue Bird addressed the issue of applicability to heavy duty vehicles in commenting on the proposed rule. No other manufacturers of these vehicles have petitioned for reconsideration of those requirements.

The agency draws a distinction between controls and displays in regard to the safety significance of drivers' being able to quickly and correctly locate and identify them. Controls are typically far more important than displays in driving safely and responding to emergency operating conditions. Further, while drivers do become familiar in time with control location, the identification of controls can be critical during the period of familiarization and continues to promote safety even after that period. The agency notes that it has plans for examining the desirability of further regulating controls and displays by standardizing their location and, in the case of some controls, their manner of operation. If rulemaking is undertaken on this matter, the requirements for controls would be put into effect first. The agency concludes that the task of complying with the existing control requirements is not so difficult as to justify foregoing the benefits of those requirements.

British Leyland petitioned for the ISO symbol for the Manual Choke to be added to Table 1 and the ISO symbol for the Brake System to be added to Table 2. No amendment of the standard is necessary to permit use of these two symbols since FMVSS 101–80 does not specify any requirements regarding symbols for those items. Amendment of the standard to require the use of those symbols would require a new proposal to be issued since such an amendment would be beyond the scope of the October 12, 1976, proposal which led to the June 26, 1978 final rule. Treating this part of British Leyland's petition as a petition for rulemaking instead of a petition for reconsideration, the agency grants it. It should be understood that granting the petition does not necessarily mean that an amendment will ultimately be adopted.

American Motors Corporation petitioned to have the requirement for the turn signal control symbol deleted from the final rule because it was not part of the 1976 proposal and they did not have an opportunity to comment. The commenter stated also that there was no safety need because the column mounted lever was in common usage and standardized through accepted industry practice. The commenter's suggestion that there was no notice for the turn signal control symbol lacks merit. Under the Administrative Procedures Act, notice may be given for a requirement by generally raising the issue in the preamble of a proposal or setting forth the text of the proposed requirement. While the turn signal control symbol was inadvertently omitted from Table I (concerning contro symbols) in the proposed rule, S5 of that rule required use of a turn signal control symbol. The symbol to be used could have been determined from the preamble which expressly provided that the proposal would require use of the ISO turn signal control symbol. Further, that symbol was shown in Table II (concerning display symbols) of the proposed rule.

The location and operation of the turn signal control has over the past several years, become standardized as a finger tip operated lever mounted on the left side of the steering column. There are no reported incidents of accident causation because of the driver's unfamiliarity with the position and use of this control. NHTSA is, therefore, granting AMC's petition to delete the requirement for symbol identification with regard to those vehicles that have a single standardized finger tip operated lever mounted on the left side of the steering column.

American Motors also objected to the use of the highbeam telltale, stressing that it was already uniquely identified by a blue color. It further stated that most vehicles have the highbeam located in the same area as the speedometer dial. This position is in the normal line of sight of the driver, thereby minimizing the time of diversion from the roadway. AMC indicated that an additional graphic representing the highbeam would require its relocation to an area further from the normal line of sight because of the limited area near the speedometer. Such a relocation, AMC argued, would offset any potential benefit. It, therefore, urged that the highbeam telltale symbol be optional.

The NHTSA believes that the highbeam telltale symbol is necessary to alert drivers to the fact that their highbeams are on. Its presence would educate new drivers and act as a reminder to all drivers, especially those who drive infrequently. As to the alleged uniqueness of the use of blue to indicate highbeams, there is no regulation prohibiting its use for telltales other than highbeams. In fact, the color blue is also being proposed by Working Group 5 of Subcommittee 13 of the ISO Technical Committee 22 to the ISO as the color that would be used to indicate spot lamp, long range lamp, cold air, an cold. Therefore, it is possible that further use of the color blue could lead -onfusion unless the highbeam bol also is required. The NHTSA a elieves that the space in the area ot the speedometer face is sufficient to allow the symbol for the highbeam to be located there. Therefore, AMC's petition is denied with regard to the highbeam telltale symbol.

In a related vein, Mack, British Leyland, and Mercedes Benz petitioned the agency to substitute the ISO master lighting switch symbol (an illuminated light bulb) for the headlamp and tail lamp symbol (an illuminated headlamp) specified in Table 1 of FMVSS 101-80 or to add the ISO symbol as an optional alternative to the currently specified symbol. The commenters indicatd that the European Economic Community's (EEC) Directive 78/316 requires use of the ISO symbol and that Canada allows either that symbol or the one specified by FMVSS 101-80. Mack argued that use of the ISO symbol should be permitted to enable the company to avoid expensive changes in vehicles that are shipped overseas.

If a vehicle contains a master lighting control in addition to a headlamp and tail lamp control, the ISO symbol may be used for the master lighting control. The agency recognizes, however, that m-t vehicles presently sold in this ry have one control that operates all lights, including the headlamps and tail lamps. On those vehicles, the single control must be identified by the headlamp and tail lamp symbol specified in FMVSS 101-80. The agency believes that this requirement should be retained because the headlamps and tail lamps are the more important lights controlled by a master light control. Further, the agency believes that the headlamp and tail lamp symbol is more easily recognizable as related to those lamps than is the ISO master lighting symbol. However, in the agency's forthcoming proposal on controls and displays, the agency will propose that the ISO symbol be required on master lighting controls in vehicles having both a master lighting control and a headlamp and tail lamp control. We will, however, request comments on allowing the ISO symbol as an optional alternative to the headlamp/tail lamp symbol and or requiring the ISO symbol instead of the headlamp/tail lamp symbol.

American Motors raised a final question about the phase-in of the requirements of the final rule. It noted that S4 of the existing Federal Motor Vehicle Safety Standard (FMVSS) 101 mended to allow any manufacturer to meet the requirements of that standard with regard to the location, identification and illumination of the listed controls or to meet the requirements of FMVSS 101-80 with respect to such controls. Although the amendment did not expressly provide for early compliance with the display requirements of FMVSS 101-80, early compliance is nevertheless permissible. Early compliance with a new FMVSS is always permissible unless the requirements of the new FMVSS conflict with those of an existing FMVSS. If early compliance is to be allowed in the case of a conflict, then the existing standard must be amended to permit compliance with the new FMVSS in lieu of compliance with the existing FMVSS. As to display requirements, there is no conflict since FMVSS 101 does not regulate displays.

Volkswagen of America petitioned to allow the use of yellow as an alternative color for the telltale indicator for the headlamp highbeam. It maintains that the designated blue color or alternative blue-green will prohibit the use of light emitting diodes (LEDs). VW submitted supporting documentation that blue LEDs are not currently in production and technically will not be feasible for a number of years. They also stated that several European countries are permitting the color yellow, as well as red, as alternatives for the highbeam indicator. VW stressed the reliability and longer service of LEDs as reasons for installing them in vehicles rather than the current incandescent lamps. VW also alleged that the color yellow is more desirable for the telltale than blue or blue-green.

The NHTSA does not believe that the available information justifies granting VW's request. Presently, the activation of the highbeam indicator is conveyed primarily by the colors blue or red. The ISO and EEC are currently undergoing an effort, like that of the NHTSA, to further standardize the color to blue, thereby improving driver performance. The introduction of a yellow indicator is likely to result in greater driver confusion. Further, VW's contention that reliablility is an important design criterion for the highbeam telltale is not of great significance. The highbeam is in use approximately 5 percent of the total driving time. Given this small usage rate, current incandescent lamps are capable of lasting many years. Replacements are also inexpensive and readily available. The NHTSA also disagrees with VW that yellow is more desirable than blue or blue-green. As the eye becomes more adapted to the dark it is more sensitive to blue, not yellow. For these reasons, Volkswagen's petition is denied.

Several minor technical changes have also been made in the rule. In Table I, the abbreviations "Mfg" are changed to "Mfr". In Column 3 of Table 2, the cross reference for Brake Air Pressure is changed from FMVSS 108 to FMVSS 121, the cross reference for Malfunction in Anti-Lock is changed from FMVSS 121 to FMVSS 105-75, and the cross reference for Malfunction Brake System is changed from FMVSS 121 to FMVSS 105-75. Footnote 5 to Table 2 is changed to read "Framed areas may be filled."

Federal Motor Vehicle Safety Standard 208 is also amended to permit the seat belt telltale symbol specified in FMVSS 101-80 to be displayed in place of the words "Fasten Seat Belts" or "Fasten Belts."

In consideration of the foregoing, Part 571 of Title 49 of the Code of Federal Regulations is amended as follows:

1. The first sentence of S4.5.3.3(b)(1) of § 571.208, *Occupant Crash Protection*, is amended to read:

§ 571.208 Standard No. 208, Occupant Crash Protection.

* * * * *

S4.5.3.3(b) (1) At the left front designated seating position (driver's position), be equipped with a warning system that activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position), a continuous or flashing warning light, visible to the driver, displaying the words "Fasten Seat Belt" or "Fasten Belt" or the identifying symbol for the seat belt telltale in Table 2 of Federal Motor Vehicle Safety Standard No. 101-80 when condition (A) exists simultaneously with condition (B).

2. The first sentence of S7.3 of § 571.208, *Occupant Crash Protection*, is amended to read:

§ 571.208 Standard No. 208, Occupant Crash Protection.

* * * * *

S7.3 Seat belt warning system. A seat belt assembly provided at the driver's seating position shall be equipped with a warning system that activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position), a continuous or flashing warning light, visible to the driver, displaying the words "Fasten Seat Belt" or "Fasten Belt" or the identifying symbol for the seat belt telltale in Table 2 of Federal Motor Vehicle Safety Standard No. 101-80 when condition (a) exists, and a continuous or intermittent audible signal when condition (a) exists simultaneously with condition (b).

3. The first sentence of S7.3.1 of § 571.208, *Occupant Crash Protection*, is amended to read:

§ 571.208 Standard No. 208, Occupant Crash Protection.

* * * * *

S7.3.1 Seat belt assemblies provided at the front outboard seating positions in accordance with S4.1.1 or S4.1.2 shall have a warning system that activates, for at least 1 minute, a continuous or intermittent audible signal and continuous or flashing warning light, visible to the driver, displaying the words "Fasten Seat Belt" or "Fasten Belt" or the identifying symbol for the seat belt telltale in Table 2 of Federal Motor Vehicle Safety Standard No. 101–80 when condition (a) exists, simultaneously with either of conditions (b) or (c).

4. The first sentence of S7.3a of § 571.208, *Occupant Crash Protection*, is amended to read:

§ 571.208 Standard No. 208, Occupant Crash Protection.

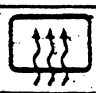
* * * * *

S7.3a A seat belt assembly provided at the driver's seating position shall be equipped with a warning system that activates, for a period of not less than 4 seconds and not more than 8 seconds (beginning when the vehicle ignition switch is moved to the "on" or the "start" position), a continuous or flashing warning light, visible to the driver, displaying the words "Fasten Seat Belts" or "Fasten Belt" or the identifying symbol for the seat belt telltale in Table 2 of Federal Motor Vehicle Safety Standard No. 101–80 when condition (a) exists, and a continuous or intermittent audible signal when condition (a) exists simultaneously with condition (b).

5. Table 1 of § 571.101–80, *Controls and Displays*, is amended to read:

BILLING CODE 4910–59–M

TABLE 1
Identification and Illumination of Controls

Column 1	Column 2	Col. 3	Col. 4
Hand Operated Controls	Identifying Words or Abbreviation	Identifying Symbol	Illumination
Headlamps and Tail Lamps	Lights	 [2,4]	—
Turn Signal	—		—
Hazard Warning Signal	Hazard	 [4]	Yes
Clearance Lamps System	Clearance Lamps or Cl Lps	 [3,4]	Yes
Windshield Wiping System	Wiper or Wipe		Yes
Windshield Washing System	Washer or Wash		Yes
Windshield Washing and Wiping Combined	Wash-Wipe		Yes
Heating and/or Air Conditioning Fan	Fan		Yes
Windshield Defrosting and Defogging System	Defrost, Defog or Def.		Yes
Rear Window Defrosting and Defogging System	Rear Defrost, Rear Defog or Rear Def		Yes
Engine Start	Engine Start[1]	—	—
Engine Stop	Engine Stop[1]	—	Yes
Manual Choke	Choke	—	—
Hand Throttle	Throttle	—	—
Automatic Vehicle Speed	(Mfr. Option)	—	Yes
Identification Lamps	Identification Lamps or Id Lps	—	Yes
Heating and Air Conditioning System	(Mfr. Option)	—	Yes

1. Use when engine control is separate from the key locking system.

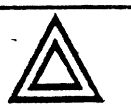
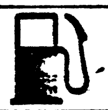
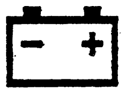
2. Use also when clearance, identification, parking and/or side marker lamps are controlled with the headlamp switch.

3. Use also when clearance lamps, identification lamps and/or side marker are controlled with one switch other than the headlamp switch.

4. Framed areas may be filled.

6. Table 2 of § 571.101-80, Controls and Displays, is amended to read:

TABLE 2
Identification and Illumination of Internal Displays

	Col. 2	Column 3	Col. 4	Col. 5
Display	Telltale Color	Identifying Words or Abbreviation	Identifying Symbol	Illuminate
Turn Signal Tell-Tale	Green	Also see FMVSS 108	 [1] [5]	—
Hazard Warning Tell-Tale	Red [4]	Also see FMVSS 108	 [2] [5]	—
Seat Belt Tell-Tale	Red [4]	Also see FMVSS 208		—
Fuel Level Tell-Tale	Yellow	Fuel		—
Gauge	—	Fuel		Yes
Oil Pressure Tell-Tale	Red [4]	Oil		—
Gauge	—	Oil		Yes
Coolant Temperature Tell-Tale	Red [4]	Temp		—
Gauge	—	Temp		Yes
Electrical Charge Tell-Tale	Red [4]	Volts, Charge or Amp		—
Gauge	—	Volts, Charge or Amp		Yes
Speedometer	—	MPH and Km/h	—	Yes
Odometer	—	— [3]	—	—
Automatic Gear Position	—	Also see FMVSS 102	—	Yes
High Beam Tell-Tale	Blue [4]	Also see FMVSS 108	 [5]	—
Brake Air Pressure Tell-Tale	Red [4]	Brake Air Also see FMVSS 121	—	—
Malfunction in Anti-Lock or	Yellow	Anti-Lock Also see FMVSS 105-75	—	—
Brake System	Red [4]	Brake Also see FMVSS 105-75	—	—

1. The pair of arrows is a single symbol. When the indicators for left and right turn operate independently, however, the two arrows will be considered separate symbols and may be spaced accordingly

2. Not required when arrows of turn signal tell-tales that otherwise operate independently flash simultaneously as hazard warning tell-tale.

3. If the odometer indicates kilometres, then "KILOMETRES" shall appear; otherwise, no identification is required.

4. Red can be red-orange. Blue can be blue-green.

5. Framed areas may be filled.

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7. The first sentence of S5.2.1 of § 571.101–80, *Controls and Displays*, is amended to read:

§ 571.101–80 Standard No. 101–80, Controls and Displays. (Effective Sept. 1, 1980.)

* * * * *

S5.2.1. Except for a turn signal control which is operated in a plane essentially parallel to the steering wheel by the only lever mounted on the left side of the steering column, any hand operated control listed in column 1 of Table 1 that has a symbol designated in column 3 shall be identified by that symbol.

(Secs. 103, 119, Pub. L. 89–563, 80 Stat. 718 (15 U.S.C. 1392, 1407); delegation of authority at 49 CFR 1.50)

Issued on September 19, 1979.

Joan Claybrook,
Administrator.

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