

POWER WINDOW CONTROL LOCATION STEREOTYPES

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A paper-and-pencil survey instrument and an operational test were used to assess stereotype strength for automobile power window controls. Control panel layout (square vs. linear) and mounting plane were examined along with stereotype differences between subjects with technical backgrounds and those with non-technical backgrounds.

A total of 273 participants ranging in age from 16 to 50 completed the survey instrument which requested responses to questions about which control was expected to activate a specified window. Subject preference for a particular control configuration was also solicited. A square control layout mounted on the instrument panel exhibited the strongest stereotype (94% of consistent responses for a single pattern) although it was the least preferred (22%). A square configuration mounted on the door panel possessed the second strongest stereotype (67% and 28% of consistent responses for the top two response patterns) and the highest preference (47%). A linear configuration mounted on the door panel exhibited a weaker stereotype (57% and 36% of consistent responses for the top two response patterns) and was preferred by 31% of the subjects. Preference tended to follow familiarity with controls in existing vehicles rather than ease of use or isomorphic arrangement.

Twenty-four of the survey participants were also tested using actual power window controls mounted in a vehicle mockup. The subject's task involved moving the left hand as quickly as possible from the steering wheel to the subject's selected control upon presentation of a pictorial or verbal cue to raise or lower a specific window. Cue presentation and measurement of reaction time and movement time were provided by a PC. The square control layout mounted on the instrument panel was superior in terms of response time, stereotype strength and response consistency.

INTRODUCTION

Fitts (1951) defined stereotype as "the relationship between a control movement and its effect which is expected by most of the population". Research has been conducted to examine various aspects of stereotypes (e.g., range burner controls, cultural differences, geometric symbols, automobile controls). Researchers have often used paper-and-pencil surveys to examine stereotypes (Kaminaka and Egli, 1984). Some researchers have found that the results from surveys were consistent with results obtained using an actual performance test (Lewis, 1986). In a power switch experiment, Lewis (1986) identified a difference in stereotype responses between subjects with technical backgrounds and those with non-technical backgrounds. However, in a study involving mining machines, Simpson and Chan (1988) found no significant difference based on the technical background of the subjects.

Noy (1987) has stated that a well-developed control-display relationship in the automobile can speed learning, reduce time and errors in operating controls, and help to reduce the likelihood of an accident. In the current study, a paper-and-pencil survey instrument and an operational test were used to assess stereotype strength for automobile power window controls. Control panel layout (square vs. linear) and mounting plane were examined along with stereotype differences between subjects with technical backgrounds and those with non-technical backgrounds.

A preliminary survey was conducted to identify control-window relationships currently in use. This survey was not exhaustive, but may be considered representative of current configurations. Six types of layouts from vehicles being driven in 1990 are presented in Figure 1. Many deviations from established human factors principles (Chapanis and Lindenbaum, 1959; Shinar and Action, 1978) are evident in the spatial arrangement of controls for the power window system.

QUESTIONNAIRE SURVEY

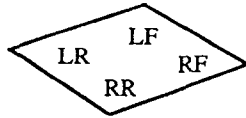
Method

Based on the preliminary survey, a questionnaire was developed to test stereotype strength for the control-window relationship using (1) a square control layout mounted on the instrument panel (SQR-IP), (2) a square control layout mounted on the door (SQR-DR), and (3) a linear control arrangement mounted on the door (LIN-DR). It was expected that controls mounted on the instrument panel (IP) in front of the driver would result in different stereotypes than controls on the door. A total of 273 participants ranging in age from 16 to 50 years completed the survey instrument which requested responses to questions about which control was expected to activate a specified window. Subject preference for a particular control configuration was also solicited. All questions and procedures were the same for all subjects. Of the 273 subjects, 174 possessed a technical background. Approximately 50% of the subjects were women.

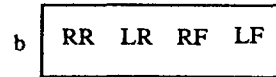
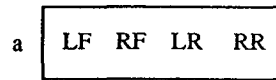
Results

Data from the survey consisted of the specific control response for each question and the preference for a particular control set. Patterns of responses were identified and tabulated for each control configuration along with an evaluation of response consistency. The results of the survey are presented in Table 1 which, in conjunction with Figure 2, identifies the three strongest stereotype patterns for each control configuration. A number of subjects provided inconsistent responses to the questions on the survey. For example, the same control was selected for two different windows in the same configuration, or two different controls were selected for the same window represented in two different questions. In addition to raw counts of the number of subjects using a particular control mapping, the stereotype strength is presented as a percentage of the total number of subjects and as a percentage of the total number of consistent subjects.

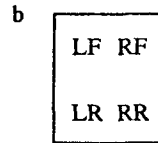
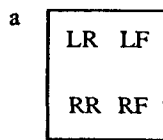
1. Door arm rest
(Nissan Maxima, Volvo)



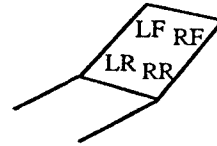
4. Linear arrangement on door panel
(a: GMC Suburban, b: Isuzu Trooper)



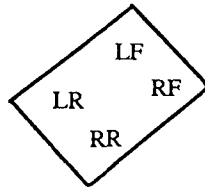
2. Vertical mounting on door panel
(a: GM Pontiac 6000, b: AMC Cherokee Jeep)



5. Upward extension of arm rest
(Jaguar)



3. Angle mounting on door panel
(Mercury Sable)



6. Center console
(Mercedes Benz, BMW)

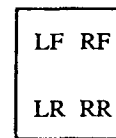


Figure 1. Power Window Control Layout in Market Survey.

Table 1. Stereotype Survey Results.

CONFIGURATION (PREFERENCE %)	PATTERN	NUMBER OF SUBJECTS	% OF TOTAL	% OF CONSISTENT
SQR-IP (22%)	A	199	72.9	94.3
	B	7	2.6	3.3
	C	5	1.8	2.4
	INCONSISTENT	52	19.0	---
SQR-DR (47%)	A	121	44.3	66.9
	B	50	18.3	27.6
	C	10	3.7	5.5
	INCONSISTENT	82	30.0	---
LIN-DR (31%)	A	96	35.2	57.1
	B	61	22.3	36.3
	C	11	4.0	6.5
	INCONSISTENT	83	30.4	---

The square control layout mounted on the instrument panel exhibited the strongest stereotype (94% of consistent responses for a single pattern) although it was the least preferred (22%). The square configuration mounted on the door panel possessed the second strongest stereotype (67% and 28% of consistent responses for the top two mappings) and the highest preference (47%). The linear configuration mounted on the door panel exhibited a weaker stereotype (57% and 36% of consistent responses for the top two response patterns) and was preferred by 31% of the subjects. Preference tended to follow familiarity with controls in existing vehicles rather than ease of use or isomorphic arrangement. A Chi-square test failed to demonstrate any significant difference between male and female subjects (min. $p = 0.210$), or between technical background and non-technical background subjects (min. $p = 0.304$).

PERFORMANCE EXPERIMENTS

Method

Twenty-four of the survey participants were also tested using actual power window controls mounted in a vehicle mockup (Figure 3). Twelve of the subjects had a technical background and approximately half of the subjects were women. The subject's task involved moving the left hand as quickly as possible from the steering wheel to the subject's selected control upon presentation of a pictorial or verbal cue to raise or lower a specific window. Cue presentation and measurement of reaction time and movement time to the nearest millisecond were provided by a Zenith 386 Personal Computer. At least a one-month interval existed between survey completion and operational testing to reduce possible carryover effects and increase the validity of comparing the two approaches.

Seven control configurations were tested using the pictorial stimulus cues which consisted of the outline of an automobile with the word *RAISE* or *LOWER* presented next to one of the window locations. In addition to testing the three configurations examined with the survey, tests were conducted with a square layout mounted on the door at either a 45° (SQR-45), 53° (SQR-53), 61° (SQR-61), or 69° (SQR-69) angle with respect to the plane of the door. These four angles were selected based on a pilot study to determine at what angle subjects tended to shift their plane of reference from the IP to the door. In essence, the square panel was evaluated at six reference angles including 0° (door panel) and 90° (IP). The square instrument panel layout (SQR-IP) was also tested with twelve subjects using verbal cues such as "LOWER THE FRONT PASSENGER WINDOW".

The distance from the left hand position on the steering wheel to any of the control sets was held constant at 30.5 cm. The order of testing for the SQR-DR, LIN-DR and the collection of SQR-xx control sets was essentially counterbalanced across subjects. Within this balance, the order of testing for the SQR-xx conditions was also counterbalanced.

For analysis, the independent variables in the study included control set configuration (seven levels including six mounting angles), window (four windows), direction (raise vs. lower), gender, technical background, and type of cueing (pictorial vs. verbal for the SQR-IP configuration only). In addition, a comparison was made of the survey responses and the performance data. The dependent measures for the operational testing consisted of reaction time, movement time, the specific control activated within the set, and the resulting

response pattern for each control configuration. The time interval from the onset of the cue until the left hand moved from the steering wheel was recorded as the reaction time (RT). The time interval from the hand leaving the steering wheel until activating the control was recorded as the movement time (MT). This movement time include the time to activate the control. RT+MT was recorded as the total response time (TT).

Results

The operational test data are summarized in Table 2 using the same mapping identification provided in Figure 2. With respect to response patterns, the square control layout exhibited a strong stereotype pattern (mapping 'A') for all angles from 45° to 90°. The stereotype for the SQR-DR panel was not as strong but mapping 'A' was clearly dominant (75% of all subjects; 82% of all consistent subjects). The linear control layout did not exhibit any clearly dominant pattern. In fact, eight different consistent patterns were observed. The most predominant pattern was mapping 'B', but only 33% of the subjects followed this pattern. A Chi-square test failed to demonstrate any significant difference between male and female subjects (min. $p = 0.088$), or between technical background and non-technical background subjects (min. $p = 0.112$).

Reaction times and movement times for the seven control configurations are presented in Figure 4. The linear configuration took significantly longer than any of the square configurations except for SQR-DR. A comparison of reaction times for the four windows revealed that only the right front (RF) window took significantly longer than the left front (LF, driver's) window. In terms of movement time and total time, the RF, LR, and RR windows all took significantly longer than the driver's window (LF) while the RF, LR, and RR windows did not differ significantly among themselves.

No interaction was found between configuration and window with respect to reaction time. However, a significant configuration-by-window interaction existed with regard to movement time ($p < 0.05$) and total response time ($p < 0.01$). Differences in performance for the LIN-DR configuration, where subjects quickly responded to both the LF and RR windows, accounted for most of the interaction.

In terms of reaction time, there was no difference between the raise vs. lower instructions. In terms of movement time and total response time, Raising took significantly longer than Lowering. The reason for this difference was not evident.

For the twenty-four subjects who participated in both the survey and operational testing, consistency of response was examined for the SQR-IP, SQR-DR, and LIN-DR layouts. Only nine of twenty-four subjects for LIN-DR, fifteen of twenty-four subjects for SQR-DR, and seventeen of twenty-four subjects for SQR-IP showed a consistent response pattern between the survey and the performance data. Only seven of the twenty-four subjects responded consistently for all three layouts. In general, this result shows that a written questionnaire may not be a good substitute for a performance experiment to examine stereotypes when spatial arrangement is involved. Even though a written questionnaire requires less time and fewer facilities than a performance experiment, it can not be recommended for investigating stereotypes based on the results of this study.

Table 2. Stereotype Performance Results

CONFIGURATION	PATTERN	NUMBER OF SUBJECTS	% OF TOTAL	% OF CONSISTENT
SQUARE-IP	A	24	100	100
	A	18	75.0	81.8
SQUARE-DOOR	B	3	12.5	13.6
	C	1	4.0	4.5
	INCONSISTENT	2	8.0	/
LINEAR-DOOR	B	8	33.3	34.8
	A	5	20.1	21.7
	C	5	20.1	21.7
SQUARE-45	INCONSISTENT	1	4.0	/
	A	23	96.0	96.0
	B	1	4.0	4.0
SQUARE-53	A	21	88.0	95.5
	B	1	4.0	4.5
	INCONSISTENT	2	8.0	/
SQUARE-61	A	23	96.0	96.0
	B	1	4.0	4.0
SQUARE-69	A	23	96.0	96.0
	B	1	4.0	4.0

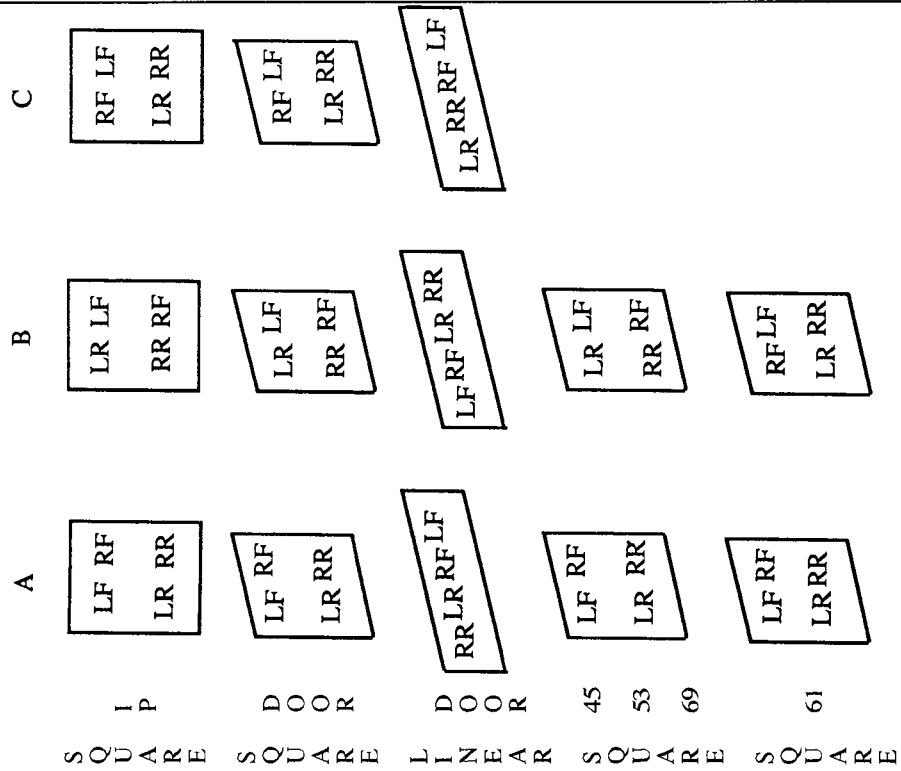


Figure 2. Strongest Stereotype Mappings.

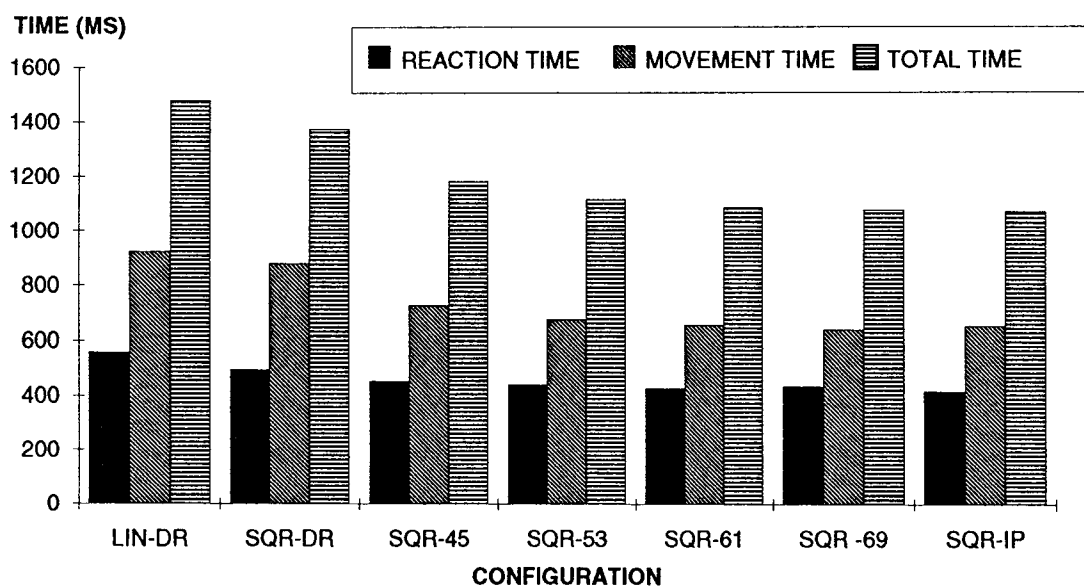


Figure 4. Response Time for Various Control/Configurations.

A comparison of pictorial vs. verbal cues was provided only for the SQR-IP condition with 12 of the 24 subjects. Because of the isomorphic similarity between the CRT display, the control panel, and the automobile windows, all twelve subjects responded with the expected mapping. With pictorial cueing, only one subject committed an 'error' (one or two responses of eight replications not following the subject's established pattern). With verbal cueing, nine of the twelve subjects made mistakes although they did not deviate from the expected mapping to any great extent. RT, MT, and TT all took approximately twice as long with verbal cueing compared to pictorial cueing. Overall, these results demonstrated the superiority of pictorial cueing in terms of accuracy and response time for a task involving spatial processing.

DISCUSSION

In summary, the SQR-IP configuration provided the greatest isomorphic similarity between the control layout and the window arrangement. It was superior in terms of response time, strength of stereotype, and consistency of response. Of the configurations tested, the SQR-IP receives the top recommendation even though no automobile currently uses this design. The SQR-DR layout is one of the most common control configurations on the market. If manufacturers use this control, a mapping with the upper edge of the control panel representing the front of the vehicle is preferred to a mapping where the front edge of the control represents the front of the vehicle.

The linear configuration is not recommended because of unclear stereotypes, longer response times, and lower consistency of responses. In general, there was a significant difference between the performance of technical background and non-technical background subjects when using the LIN-DR configuration (which was the most confusing control set).

Although the paper-and-pencil survey proved more efficient in terms of time and cost of data collection, results from the survey did not compare favorably with results from the operational test. Pictorial cueing was more effective than verbal cueing and resulted in faster and more consistent

responses. Pictorial instructions appear to represent lower mental workload and provide more accurate understanding. Preference was related more to familiarity than ease of use and was not necessarily related to the strength of the stereotype. As a result, designers must be careful to base control design on performance-based stereotype data rather than on survey and preference information.

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