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# EFFECTS OF HIGH-MOUNTED BRAKE LIGHTS ON THE BEHAVIOR OF FOLLOWING DRIVERS


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16. Abstract

This interim report documents three experiments investigating in-traffic responses of unsuspecting drivers to brake signals presented by brake-light systems with or without supplemental, high-mounted brake lights. The signals were presented on a compact car. The frequency with which following drivers responded to the signals and the time between the signal onset and either a brake-light response or a speed change by following drivers was measured. The numbers of brake responses and of speed changes did not differ statistically among the systems tested on either of the two routes that were utilized. On a suburban route (speed: 56-72 km/h; intercar spacing: 3-5 car lengths), the reaction times did not differ among the systems tested. On a downtown route (speed: 32-40 km/h; intercar spacing: 1-2 car lengths), a brake-light system with a centered, supplemental, high-mounted brake light yielded statistically shorter reaction times than a system without high-mounted brake lights. Similar experiments using a full-sized car are now being carried out. A comprehensive documentation of both sets of experiments will be presented in the final report to appear in July 1981.

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# INTRODUCTION

Recent research evidence (e.g., Malone et al., 1978; Sivak et al., 1979; Reilly et al., 1980) suggests that under particular circumstances there might be some benefit in supplementing the conventional rear lighting systems with high-mounted brake lamp(s). The aim of the present investigation is to gather additional information about drivers' responses to brake signals presented by high-mounted brake lights and about combinations of circumstances under which any differences in the behavior of following drivers are observed.

The present interim report documents three experiments investigating in-traffic responses of unsuspecting drivers to brake-signals presented by various brake-light systems on a compact car. Similar experiments using a full-sized car are now being carried out. A comprehensive documentation of both sets of experiments will be presented in the final report.

## EXPERIMENT 1

### Brake Light Configurations

A brown 1980 AMC Spirit was used to display a control and two experimental brake-light systems (see Figure 1):

CONTROL SYSTEM - A conventional (low-mounted) configuration with one lamp on each side; each lamp serving all three functions--presence, stop, and turn. (The original equipment on the car had one additional redundant lamp on each side, but only the outboard lamp on each side was kept operational for this experiment. Consequently, the rear-light assembly was modified by the manufacturer so that each remaining [outboard] lamp alone exceeded the FMVSS 108 standard.)

SINGLE-HIGH-MOUNTED SYSTEM - The control system, plus an additional lamp mounted just under the rear window at the center of the lowermost portion of the hatchback lid. This supplemental lamp provided a stop signal only.

DUAL-HIGH-MOUNTED SYSTEM - The control system, plus two additional lamps mounted outboard just under the rear window on the lowermost portion of the hatchback lid. These supplemental lamps provided a stop signal only.

The supplemental lamps were Stimsonite HiLights (Model # 30505) manufactured by Amerace Corporation. (These lamps we used by Sivak et al., 1979, and they are identical to the Model # 3050 used by Malone et al. 1978 and Reilly et al., 1980). The dimensions of the trapezoidally-shaped lens of these lamps are 16 cm x 13 cm x 2 cm (maximum width x minimum width x height.)

The photometric measurements were made at the approximate eyepoint of a driver following at 15 m. These measurements indicated that each of the supplemental high-mounted lamps produced approximately 42 cd.

The supplemental lamps were originally equipped with # 1004 bulbs. However, because of the high failure rate of this bulb in the Malone et al. study, # 1142 bulbs were used throughout the present experiment.


Figure 1. The lead car with (from top to bottom): control, single-high-mounted, and dual-high-mounted brake-light system.

(Malone et al. [1978] also switched to these bulbs in the course of their study and Reilly et al. [1980] and Sivak et al. [1979] used these bulbs exclusively.)

Experimental Setup, Vehicles, and Equipment

The responses to the brake lamp systems were obtained from unsuspecting "subject" drivers who at the time of the trial were following behind the lead car (the above-mentioned 1980 Spirit) and in front of the monitoring car (a 1980 light-brown Ford station wagon). A schematic representation of the experimental setup is shown in Figure 2.

Three staff members were involved in running the experiment. The first drove the lead car and presented the signals. The second drove the monitoring car. The third staff member, seated in the back seat of the monitoring car, operated the event recorder and noted information about the subject and the subject's vehicle.

A Doppler radar antenna was mounted at the center of the front bumper on the monitoring car (Figure 3). The radar system monitored changes in the speed of the subject vehicle, relative to that of the monitoring car. The event recorder received an input from the radar system and a telemetered input from the lead car. The radar input generated a trace on one track of the event-recorder tape, indicating changes in the speed of the subject vehicle. The telemetered input from the lead car produced a pulse on a second track of the tape, marking the start and end of the lead car's brake signal. A data sample, showing the two traces, is presented in Figure 4.

Route Selection

The data were collected on a multi-lane roadway with two lanes per direction and a center turn lane throughout most of the utilized portion. The roadway has a speed limit of 72 km/h with sections of 56 km/h; the actual traffic speed was 48-80 km/h. All trials were presented at speeds of 56-72 km/h. The experiment was performed between 9:00 and 11:30 a.m. and between 1:30 and 4:00 p.m.

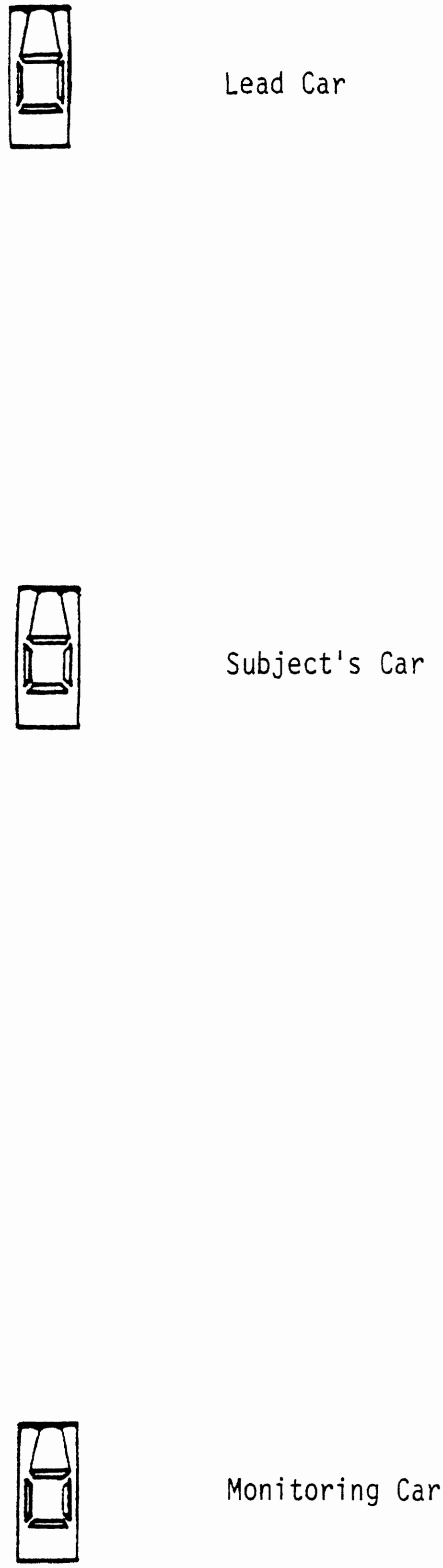


Figure 2. Diagram of a typical situation during a signal presentation.


Figure 3. Monitoring car with the radar antenna on the front bumper.

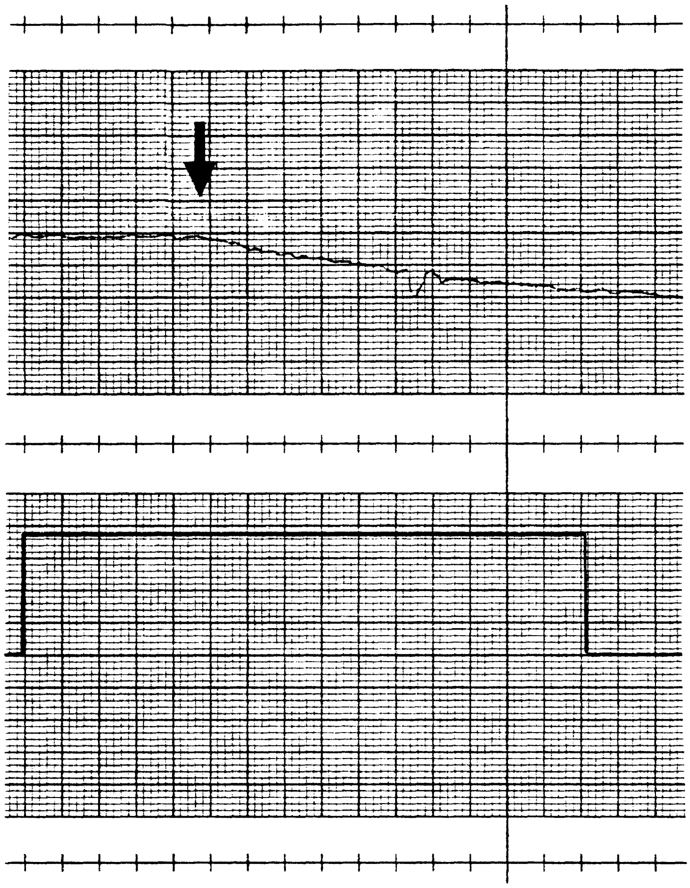

Figure 4. A data sample showing a reaction time of 0.96 s. The top trace indicates the relative speed of the subject's vehicle in relation to the monitoring vehicle. (The smallest vertical division is equal to approximately 0.2 miles/hour. Time increases from left to right; the smallest horizontal division is equal to 0.04 s.) The bottom trace indicates the onset and offset of the brake signal on the lead car. In this example, a change in the speed (see the arrow) occurred 0.96 s after the onset of the signal.

## Procedure

On each trial, the lead car adjusted its speed and/or lane position to achieve a headway of 3-5 car lengths in front of an unsuspecting driver. Care was taken not to draw the attention of the unsuspecting motorist to the test vehicle. This included not intruding more quickly into the lane ahead of a motorist than was common behavior for other drivers. Normally, this meant that the lead-vehicle driver positioned himself in the lane ahead of an approaching vehicle by making a smooth lane change when the subject got within 5-10 car lengths of the lead car. In so doing, the experimenter was generally able to match his speed to that of the car approaching from the rear when about 3-5 car lengths separated the vehicles. He continued to gradually modulate his speed without braking to obtain a headway of about 3 car lengths. This gradual lane intrusion and speed modulation allowed the lead vehicle to obtain the proper position without alarming the unsuspecting driver or presenting him with a brake signal before the actual trial. Simultaneously, the monitoring car proceeded to get into a position that placed the subject vehicle within the radar beam. This was done by approaching the subject's vehicle from the rear until a headway of approximately three to six car lengths was obtained. Ensuring that the speed of the monitoring car was between 56 and 72 km/h, the cruise control mechanism on the monitoring car was set. This precaution was taken to assure that the changes in speed recorded by the radar system were those of the subject's vehicle and not of the monitoring car.

The event recorder was then turned on and when the trace on the radar-system track was sufficiently noise free (roadway bumps occasionally interfered with the smooth radar pickup of the subject vehicle, generating noise in the signal), the experimenter checked to ensure that the spacing between the lead and subject car appeared to be within five car lengths and informed the experimenter in the lead car (via a hand-held radio) that the conditions were right for a trial. The experimenter in the lead car, after double-checking the situation in his rear view mirror, initiated a trial via a switch which both turned on the brake light configuration being tested (without actually braking or decelerating) and generated a pulse on one track of the event recorder tape for the duration of the brake signal presentation. The brake signal was presented for 3 seconds, the duration controlled by an electronic timer.

An additional task of the experimenter in the back seat of the monitoring car was to record whether during the 3-second brake-signal presentation the subject's brake lights became illuminated, and whether the subject changed lanes in response to the brake signal. He also recorded the subject's age (young, middle-aged, old), sex, height (short, medium, tall), and the size of the subject's vehicle (small, medium, large, pickup truck/van). If subject's age, sex, or height could not be clearly ascertained, the experimenter in the lead car was asked for assistance via radio.

Only one trial was given to each subject. Two measures were taken to ensure that the subject was shown the illuminated supplemental lamps for the first time when a trial was presented. First, during actual braking by the lead car in traffic, only the conventional lamps were illuminated. Second, when running the high-mounted conditions, drivers who stopped immediately behind the lead car in traffic (due to traffic signal, etc.) and so potentially observed the unlit supplemental lamps, were not used as subjects.

A major concern was to operate the lead and monitoring cars legally and safely, and not to create a stressful situation for the subject driver or other motorists.

<u>Data Analysis</u>

Two aspects of the response of the subject to the onset of the lead car's brake signal were of interest: (1) whether the subject either applied his brakes or simply decelerated, and (2) if so, the reaction time between signal onset and the braking or speed-change response. Only trials meeting the following criteria were included in the analysis:

1. The subject vehicle did not appear to have braked or decelerated in response to vehicles ahead of or adjacent to the lead car, changes in roadway configuration or a traffic control device, or in preparation for turning off the roadway. Responses to vehicles ahead of or adjacent to the lead vehicle were assumed to have occurred when a braking or deceleration response occurred after initiation of vehicle control maneuvers (e.g., braking or lane changing) by nearby vehicles. Responses to changes in roadway configuration were assumed to have occurred when a braking or deceleration response continued until negotiation of a curve was executed. Responses to a traffic control device were assumed to have occurred when the subject vehicle braked or decelerated while approaching a red light or other traffic control device. Responses related to preparation of the subject vehicle to turn off the roadway were assumed to have occurred when a braking or deceleration response continued until the beginning of a turning maneuver (as indicated by turn signals or actual turning).

2. The monitoring car did not brake during the 3 second presentation of the lead car's brake signal. Occasionally in response to maneuvers of nearby vehicles on the roadway, it became necessary for the driver of the monitoring vehicle to brake, thereby disengaging the cruise control mechanism and adding noise to the radar record of the speed of the subject car, relative to the monitoring car.

3. The roadway was flat and generally straight. The utilized stretch of roadway contained two slight inclines which occasionally, in conjunction with the cruise control mechanism, caused the monitoring car to surge in speed. Therefore no data were collected on these portions of the roadway, as well as on two curved portions, where locating the subject's vehicle within the radar beam was difficult.

4. The subject vehicle was a passenger car, pickup truck, or van. No passenger vehicles with a trailer attached or commercial vehicles were used.

5. The trial was the first and only signal presentation for each subject driver.

## Results

Table 1 presents, for each system tested, the number of trials in which the subjects responded by speed change (both with and without braking) to the brake signal on the lead car, as well as the corresponding mean reaction times. (In all present experiments, only a speed change with a delay of 3 s or less was considered to be a response to a signal presentation.) The Pearson test of association (Hays, 1963) indicates that the probability of responding to a signal (whether by braking or otherwise) did not differ among the systems tested. Similarly, analyses of variance and _t_ tests for contrasts indicate that there were no statistically significant differences in the corresponding reaction times. (Throughout this report the statistically significant level was set at $p < 0.05$.) The distributions of the reaction times of all responses to the three brake-light systems are shown in Table 2.

Tables 3 and 4 present cross-tabulations according to the brake-light system, subject's age, sex, and car size, and whether subject changed lanes in response to the brake signal. The results of _t_ tests for contrast (see Tables 3 and 4) indicate that most of these variables did not produce statistically significant interactions with the reaction times to the three brake-light systems. Two exceptions are that old subjects responded fastest to the single-high-mounted system, and the subjects in pickups/vans responded slowest to the dual-high-mounted system. (These results should be interpreted with caution because of the small number of old subjects and subjects in pickups/vans.)

The mean reaction-time data (collapsed across all three brake-light systems) are presented in Table 5. While these data show several trends, analyses of variance and _t_ tests for contrasts revealed only one difference to be statistically significant: The old subjects had longer reaction times than a combined group of the young and middle-aged subjects.

Table 1

Types of responses, their frequencies, and the corresponding mean reaction times in seconds.

| Brake-Light System | Number of Trials | Trials Responded to by a Speed Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | With Braking | | Without Braking | | Total | |
| | | Number | Reaction Time | Number | Reaction Time | Number | Reaction Time |
| Control | 106 | 14 | 1.04 | 60 | 1.25 | 74 | 1.21 |
| Single-High-Mounted | 106 | 16* | 1.04 | 56 | 1.17 | 72* | 1.14 |
| Dual-High-Mounted | 106 | 14 | 1.14 | 65 | 1.29 | 79 | 1.26 |

* On two trials with the single-high-mounted system there was a brake response, but no discernible speed change.

Table 2

The distributions of the reaction times of all responses to the three brake-light systems.

| Interval Midpoint (s) | Frequency | | |
|---|---|---|---|
| | Control System | Single-High-Mounted System | Dual-High-Mounted System |
| 0.1 | 0 | 0 | 0 |
| 0.3 | 1 | 4 | 4 |
| 0.5 | 11 | 8 | 8 |
| 0.7 | 8 | 14 | 7 |
| 0.9 | 14 | 7 | 11 |
| 1.1 | 6 | 8 | 12 |
| 1.3 | 7 | 5 | 9 |
| 1.5 | 9 | 9 | 5 |
| 1.7 | 3 | 3 | 8 |
| 1.9 | 5 | 4 | 2 |
| 2.1 | 1 | 3 | 4 |
| 2.3 | 6 | 1 | 2 |
| 2.5 | 1 | 3 | 4 |
| 2.7 | 2 | 1 | 2 |
| 2.9 | 0 | 0 | 1 |

Table 3

A. Mean reaction times for each brake-light system according to the subject's age, sex, and height. The numbers in parentheses are the corresponding frequencies.

B. Results of _t_ tests for contrasts. Each of the first three contrasts involves a comparison of one system against another system. Each of the last three contrasts involves a comparison of two systems against a third system. An entry indicates the system(s) with significantly shorter reaction time. Lack of an entry indicates an absence of a statistically significant difference.

| | Brake-Light System | Subject's Age | | | Subject's Sex | | Subject's Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Young | Middle-Aged | Old | Male | Female | Short | Medium | Tall |
| A | Control (C) | 1.25 (30) | 1.12 (33) | 1.39 (11) | 1.20 (42) | 1.23 (32) | 1.31 (4) | 1.21 (57) | 1.21 (13) |
| | Single-High-Mounted (S) | 1.09 (23) | 1.20 (39) | 1.00 (8) | 1.00 (42) | 1.35 (28) | 1.18 (7) | 1.12 (51) | 1.19 (12) |
| | Dual-High-Mounted (D) | 1.15 (36) | 1.21 (32) | 1.77 (11) | 1.23 (43) | 1.30 (36) | 1.45 (7) | 1.20 (57) | 1.42 (15) |
| B | C vs. S | | | | | | | | |
| | C vs. D | | | | | | | | |
| | S vs. D | | | S | | | | | |
| | C+S vs. D | | | C+S | | | | | |
| | C+D vs. S | | | S | | | | | |
| | S+D vs. C | | | | | | | | |

Table 4

A. Mean reaction times for each brake-light system according to the subject's car size, and the presence/absence of a lane change as a part of the response. The numbers in parentheses are the corresponding frequencies.

B. Results of _t_ tests for contrasts. Each of the first three contrasts involves a comparison of one system against another system. Each of the last three contrasts involves a comparison of two systems against a third system. An entry indicates the system(s) with significantly shorter reaction time. Lack of an entry indicates an absence of a statistically significant difference.

| | Brake-Light System | Subject's Car Size | | | | Lane Change | |
|---|---|---|---|---|---|---|---|
| | | Small | Medium | Large | Pickup/ Van | Yes | No |
| A | Control (C) | 1.40 (13) | 1.30 (28) | 1.14 (22) | 0.92 (11) | 1.57 (4) | 1.19 (70) |
| | Single-High-Mounted (S) | 0.85 (6) | 1.21 (25) | 1.23 (24) | 1.00 (15) | 1.25 (3) | 1.14 (67) |
| | Dual-High-Mounted (D) | 1.19 (10) | 1.19 (34) | 1.33 (26) | 1.40 (9) | 1.25 (4) | 1.26 (75) |
| B | C vs. S | | | | | | |
| | C vs. D | | | | C | | |
| | S vs. D | | | | | | |
| | C+S vs. D | | | | C+S | | |
| | C+D vs. S | | | | | | |
| | S+D vs. C | | | | | | |

Table 5

Mean reaction times (across all three brake-light systems) according to the subject's age, sex, height, and car size, and presence/absence of a lane change. The numbers in parentheses are the corresponding frequencies.

| Category | | Mean Reaction Time |
|---|---|---|
| Subject's Age | Young | 1.17 ( 89) |
| | Middle-Aged | 1.18 (104) |
| | Old | 1.43 ( 30) |
| Subject's Sex | Male | 1.15 (127) |
| | Female | 1.29 ( 96) |
| Subject's Height | Short | 1.31 ( 18) |
| | Medium | 1.18 (165) |
| | Tall | 1.28 ( 40) |
| Subject's Car Size | Small | 1.21 ( 29) |
| | Medium | 1.23 ( 87) |
| | Large | 1.24 ( 72) |
| | Pickup/Van | 1.08 ( 35) |
| Lane Change | Yes | 1.37 ( 11) |
| | No | 1.20 (212) |

## EXPERIMENT 2

### Method

The method of Experiment 2 was identical to the method of Experiment 1, except for the following: The data were collected on a multilane roadway with two lanes per direction throughout most of the utilized portion. The roadway travels through the downtown section of Ypsilanti, Michigan. It has a speed limit of 40 km/h with a small stretch of 56 km/h; the actual traffic speed was 32-56 km/h. All trials were presented at speeds of 32-40 km/h. Since these speeds are below the minimum speed at which the cruise control mechanism on the monitoring car functions properly (approx. 48 km/h), the cruise control was not used. The driver of the monitoring car ensured, via the accelerator pedal, that during a trial presentation the monitoring car remained travelling at a fixed speed. The experimenter in the rear seat of the monitoring car double-checked the speedometer to ensure that the vehicle was travelling at a fixed speed, somewhere between 32 and 40 km/h. All trials were presented at a separation of 1-2 car lengths between the lead car and the subject's car.

### Results

Table 6 presents, for each system tested, the number of trials in which the subjects responded by speed change (both with and without braking) to the brake signal on the lead car, as well as the corresponding mean reaction times. The Pearson test of association indicates that the probability of responding to a signal (whether by braking or otherwise) did not differ among the systems tested. On the other hand, analyses of variance and $t$ tests for contrasts indicate that the reaction times to the control system were significantly longer than the reaction times to the single-high-mounted system or to a combined group of the single-high-mounted and dual-high-mounted systems. This was the case for both the speed-change responses without braking and the total set of responses. Additionally, for the speed-change responses without braking, the reaction times to the control system were

Table 6

Types of responses, their frequencies, and the corresponding mean reaction times in seconds.

| Brake-Light System | Number of Trials | Trials Responded to by a Speed Change: With Braking | | Without Braking | | Total | |
|---|---|---|---|---|---|---|---|
| | | Number | Reaction Time | Number | Reaction Time | Number | Reaction Time |
| Control | 106 | 17* | 1.22 | 62 | 1.36 | 79* | 1.33 |
| Single-High-Mounted | 106 | 22* | 1.27 | 58 | 1.06 | 80* | 1.11 |
| Dual-High-Mounted | 106 | 29* | 1.18 | 50 | 1.19 | 79* | 1.19 |

* On six trials (one with the control system, four with the single-high-mounted system, and one with the dual-high-mounted system) there was a brake response, but no discernible speed change.

significantly shorter than the reaction times to a combined group of the control and dual-high-mounted system. However, there were no statistically significant differences among the systems for the responses with braking. The distributions of the reaction times of all responses to the three brake-light systems are shown in Table 7. These distributions suggest that the obtained statistical differences were likely due to the presence of more long reaction times to the control system and more short reaction times to the single-high-mounted system.

Tables 8 and 9 present cross-tabulations according to the brake-light system, subject's age, sex, and car size, and whether subject changed lanes in response to the brake signal. The results of _t_ tests for contrast (see Tables 8 and 9) indicate that most of these variables did not produce statistically significant interactions with the reaction times to the three brake-light systems. Three exceptions are that the young subjects responded slowest to the control system, while the subjects in small cars and the subjects who did not change lanes in response to a brake signal responded fastest to the single-high-mounted system. (These results should be interpreted with caution because of the small number of young subjects and subjects in small cars, and because the speed responses without lane change accounted for virtually all speed responses.)

The mean reaction-time data (collapsed across all three brake-light systems) are presented in Table 10. While these data show several trends, analyses of variance and _t_ tests for contrasts revealed only one difference to be statistically significant: The subjects in large cars had shorter reaction times than a combined group of the subjects in other vehicles.

Table 7

The distributions of the reaction times of all responses to the three brake-light systems.

| Interval Midpoint (s) | Frequency | | |
|---|---|---|---|
| | Control System | Single-High-Mounted System | Dual-High-Mounted System |
| 0.1 | 0 | 0 | 0 |
| 0.3 | 0 | 5 | 6 |
| 0.5 | 11 | 18 | 7 |
| 0.7 | 13 | 6 | 10 |
| 0.9 | 9 | 10 | 11 |
| 1.1 | 6 | 11 | 10 |
| 1.3 | 5 | 6 | 8 |
| 1.5 | 8 | 3 | 6 |
| 1.7 | 4 | 2 | 8 |
| 1.9 | 4 | 3 | 3 |
| 2.1 | 6 | 4 | 2 |
| 2.3 | 4 | 3 | 4 |
| 2.5 | 1 | 2 | 1 |
| 2.7 | 7 | 3 | 0 |
| 2.9 | 0 | 0 | 2 |

Table 8

A. Mean reaction times for each brake-light system according to the subject's age, sex, and height. The numbers in parentheses are the corresponding frequencies.

B. Results of *t* tests for contrasts. Each of the first three contrasts involves a comparison of one system against another system. Each of the last three contrasts involves a comparison of two systems against a third system. An entry indicates the system(s) with significantly shorter reaction time. Lack of an entry indicates an absence of a statistically significant difference.

| | Brake-Light System | Subject's Age | | | Subject's Sex | | Subject's Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Young | Middle-Aged | Old | Male | Female | Short | Medium | Tall |
| A | Control (C) | 1.48 (32) | 1.28 (39) | 0.91 (7) | 1.31 (57) | 1.37 (21) | 1.18 (5) | 1.31 (50) | 1.40 (23) |
| A | Single-High-Mounted (S) | 1.08 (28) | 1.13 (43) | 1.09 (5) | 1.12 (53) | 1.08 (23) | 1.38 (5) | 1.09 (46) | 1.08 (25) |
| A | Dual-High-Mounted (D) | 1.18 (43) | 1.22 (32) | 0.87 (3) | 1.17 (49) | 1.22 (29) | 1.07 (7) | 1.26 (47) | 1.07 (24) |
| B | C vs. S | S | | | | | | | |
| B | C vs. D | D | | | | | | | |
| B | S vs. D | | | | | | | | |
| B | C+S vs. D | | | | | | | | |
| B | C+D vs. S | | | | | | | | |
| B | S+D vs. C | S+D | | | | | | | |

## Table 9

A. Mean reaction times for each brake-light system according to the subject's car size, and the presence/absence of a lane change as a part of the response. The number in parentheses are the corresponding frequencies.

B. Results of _t_ tests for contrasts. Each of the first three contrasts involves a comparison of one system against another system. Each of the last three contrasts involves a comparison of two systems against a third system. An entry indicates the system(s) with significantly shorter reaction time. Lack of an entry indicates an absence of a statistically significant difference.

| | Brake-Light System | Subject's Car Size | | | | Lane Change | |
|---|---|---|---|---|---|---|---|
| | | Small | Medium | Large | Pickup/ Van | Yes | No |
| A | Control (C) | 1.33 (5) | 1.39 (22) | 1.20 (35) | 1.52 (16) | 1.42 (2) | 1.33 (76) |
| A | Single-High-Mounted (S) | 0.70 (6) | 1.44 (16) | 0.98 (35) | 1.18 (19) | 1.32 (2) | 1.10 (74) |
| A | Dual-High-Mounted (D) | 1.70 (5) | 1.19 (34) | 0.99 (23) | 1.30 (16) | 0.53 (3) | 1.21 (75) |
| B | C vs. S | | | | | | S |
| B | C vs. D | | | | | | |
| B | S vs. D | S | | | | | |
| B | C+S vs. D | | | | | | |
| B | C+D vs. S | S | | | | | |
| B | S+D vs. C | | | | | | |

Table 10

Mean reaction times (across all three brake-light systems) according to the subject's age, sex, height, and car size, and presence/absence of a lane change. The numbers in parentheses are the corresponding frequencies.

| Category | | Mean Reaction Time |
|---|---|---|
| Subject's Age | Young | 1.25 (103) |
| | Middle-Aged | 1.21 (114) |
| | Old | 0.96 ( 15) |
| Subject's Sex | Male | 1.20 (159) |
| | Female | 1.22 ( 73) |
| Subject's Height | Short | 1.20 ( 17) |
| | Medium | 1.22 (143) |
| | Tall | 1.18 ( 72) |
| Subject's Car Size | Small | 1.21 ( 16) |
| | Medium | 1.31 ( 72) |
| | Large | 1.07 ( 93) |
| | Pickup/Van | 1.32 ( 51) |
| Lane Change | Yes | 1.01 ( 7) |
| | No | 1.21 (225) |

## EXPERIMENT 3

### Method

After no benefit of single- or dual-high-mounted systems was found under conditions of Experiment 1, the following two additional systems were tested in Experiment 3 (see Figure 5):

SINGLE-ROOF-MOUNTED - The control system (see Experiment 1), plus an additional center lamp mounted on the uppermost portion of the hatchback lid. This supplemental lamp provided a stop signal only.

DUAL-ROOF-MOUNTED SYSTEM - The control system, plus two additional lamps mounted outboard on the uppermost portion of the hatchback lid. These supplemental lamps provided a stop signal only.

In all other respects, the method was identical to that of Experiment 1.

### Results

For comparison, the results for the two roof-mounted systems are presented together with the results for the control and the two high-mounted systems tested in Experiment 1. (Experiments 1 and 3 were performed on the same route and under the same conditions.)

Table 11 presents, for each system tested, the number of trials in which the subjects responded by speed change (both with and without braking) to the brake signal on the lead car, as well as the corresponding mean reaction times. The Pearson test of association indicates that the probability of responding to a signal (whether by braking or otherwise) did not differ among the systems tested. Similarly, analyses of variance and $\underline{t}$ tests for contrasts indicate that there were no statistically significant differences in the corresponding reaction times. The distributions of the reaction times of all responses to the five brake-light systems are shown in Table 12.

Tables 13 and 14 present cross-tabulations according to the brake-light system, subject's age, sex, and car size, and whether subject


Figure 5. The lead car with single-roof-mounted system (top) and dual-roof-mounted system (bottom).

Table 11

Types of responses, their frequencies, and the corresponding mean reaction times in seconds.

| Brake-Light System | Number of Trials | Trials Responded to by a Speed Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | With Braking | | Without Braking | | Total | |
| | | Number | Reaction Time | Number | Reaction Time | Number | Reaction Time |
| Control | 106 | 14 | 1.04 | 60 | 1.25 | 74 | 1.21 |
| Single-High-Mounted | 106 | 16* | 1.04 | 56 | 1.17 | 72* | 1.14 |
| Dual-High-Mounted | 106 | 14 | 1.14 | 65 | 1.29 | 79 | 1.26 |
| Single-Roof-Mounted | 106 | 10* | 1.40 | 66 | 1.27 | 76* | 1.28 |
| Dual-Roof-Mounted | 106 | 9* | 1.14 | 65 | 1.13 | 74* | 1.13 |

* On four trials (two with the single-high-mounted system and one each with the single-roof-mounted and dual-roof-mounted system) there was a brake response, but no discernible speed change.

Table 12

The distributions of the reaction times of all responses to the five brake-light systems.

| Interval Midpoint (s) | Frequency | | | | |
|---|---|---|---|---|---|
| | Control System | Single-High-Mounted System | Dual-High-Mounted System | Single-Roof-Mounted System | Dual-Roof-Mounted System |
| 0.1 | 0 | 0 | 0 | 0 | 0 |
| 0.3 | 1 | 4 | 4 | 2 | 2 |
| 0.5 | 11 | 8 | 8 | 6 | 11 |
| 0.7 | 8 | 14 | 7 | 16 | 8 |
| 0.9 | 14 | 7 | 11 | 6 | 13 |
| 1.1 | 6 | 8 | 12 | 9 | 9 |
| 1.3 | 7 | 5 | 9 | 11 | 6 |
| 1.5 | 9 | 9 | 5 | 3 | 7 |
| 1.7 | 3 | 3 | 8 | 2 | 7 |
| 1.9 | 5 | 4 | 2 | 7 | 2 |
| 2.1 | 1 | 3 | 4 | 3 | 3 |
| 2.3 | 6 | 1 | 2 | 2 | 5 |
| 2.5 | 1 | 3 | 4 | 2 | 0 |
| 2.7 | 2 | 1 | 2 | 4 | 0 |
| 2.9 | 0 | 0 | 1 | 2 | 0 |

Table 13

A. Mean reaction times for each brake-light system according to the subject's age, sex, and height. The numbers in parentheses are the corresponding frequencies.

B. Results of *t* tests for contrasts. Each of the first four contrasts involves a comparison of one system against another system. Each of the last seven contrasts involves a comparison of one or two systems against two or more systems. Lack of any entry indicates that none of the differences were statistically significant.

| | Brake-Light System | Subject's Age | | | Subject's Sex | | Subject's Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Young | Middle-Aged | Old | Male | Female | Short | Medium | Tall |
| A | Control (C) | 1.25 (30) | 1.12 (33) | 1.39 (11) | 1.20 (42) | 1.23 (32) | 1.31 (4) | 1.21 (57) | 1.21 (13) |
| | Single-High-Mounted (S) | 1.09 (23) | 1.20 (39) | 1.00 (8) | 1.00 (42) | 1.35 (28) | 1.18 (7) | 1.12 (51) | 1.19 (12) |
| | Dual-High-Mounted (D) | 1.15 (36) | 1.21 (32) | 1.77 (11) | 1.23 (43) | 1.30 (36) | 1.45 (7) | 1.20 (57) | 1.42 (15) |
| | Single-Roof-Mounted (SR) | 1.15 (32) | 1.34 (40) | 1.93 (3) | 1.30 (43) | 1.26 (32) | 1.25 (5) | 1.26 (49) | 1.34 (21) |
| | Dual-Roof-Mounted (DR) | 1.33 (23) | 1.04 (46) | 1.11 (4) | 1.20 (39) | 1.06 (34) | 1.04 (5) | 1.12 (49) | 1.19 (19) |
| B | C vs. S | | | | | | | | |
| | C vs. D | | | | | | | | |
| | C vs. SR | | | | | | | | |
| | C vs. DR | | | | | | | | |
| | C vs. S+D | | | | | | | | |
| | C vs. SR+DR | | | | | | | | |
| | S+D vs. SR+DR | | | | | | | | |
| | C vs. S+SR | | | | | | | | |
| | C vs. D+DR | | | | | | | | |
| | S+SR vs. D+DR | | | | | | | | |
| | C vs. S+D+SR+DR | | | | | | | | |

Table 14

A. Mean reaction times for each brake-light system according to the subject's car size, and the presence/absence of a lane change as a part of the response. The numbers in parentheses are the corresponding frequencies.

B. Results of _t_ tests for contrasts. Each of the first four contrasts involves a comparison of one system against another system. Each of the last seven contrasts involves a comparison of one or two systems against two or more systems. Lack of any entry indicates that none of the differences were statistically significant.

| | Brake-Light System | Subject's Car Size | | | | Lane Change | |
|---|---|---|---|---|---|---|---|
| | | Small | Medium | Large | Pickup/ Van | Yes | No |
| A | Control (C) | 1.40 (13) | 1.30 (28) | 1.14 (22) | 0.92 (11) | 1.57 (4) | 1.19 (70) |
| | Single-High-Mounted (S) | 0.85 (6) | 1.21 (25) | 1.23 (24) | 1.00 (15) | 1.25 (3) | 1.14 (67) |
| | Dual-High-Mounted (D) | 1.19 (10) | 1.19 (34) | 1.33 (26) | 1.40 (9) | 1.25 (4) | 1.26 (75) |
| | Single-Roof-Mounted (SR) | 0.96 (9) | 1.46 (26) | 1.23 (29) | 1.25 (11) | 2.16 (1) | 1.27 (74) |
| | Dual-Roof-Mounted (DR) | 0.98 (5) | 1.22 (21) | 1.15 (39) | 0.94 (8) | 1.08 (2) | 1.14 (71) |
| B | C vs. S | | | | | | |
| | C vs. D | | | | C | | |
| | C vs. SR | | | | | | |
| | C vs. DR | | | | | | |
| | C vs. S+D | | | | | | |
| | C vs. SR+DR | | | | | | |
| | S+D vs. SR+DR | | | | | | |
| | C vs. S+SR | S+SR | | | | | |
| | C vs. D+DR | | | | | | |
| | S+SR vs. D+DR | | | | | | |
| | C vs. S+D+SR+DR | | | | | | |

changed lanes in response to the brake signal. The results of _t_ tests for contrast (see Tables 13 and 14) indicate that most of these variables did not produce statistically significant interactions with the reaction times to the three brake-light systems. Two exceptions are that the subjects in small cars responded slower to the control system in comparison to the combined group of the single-high-mounted and single-roof-mounted systems, and the subjects in pickups/vans responded faster to the control system in comparison to the dual-high-mounted system. (These results should be interpreted with caution because of the small number of subjects in small cars and in pickups/vans.)

The mean reaction-time data (collapsed across all three brake-light systems) are presented in Table 15. While these data show several trends, analyses of variance and _t_ tests for contrasts revealed only one difference to be statistically significant: The old subjects had longer reaction times than a combined group of the young and middle-aged subjects.

Table 15

Mean reaction times (across all five brake-light systems) according to the subject's age, sex, height, and car size, and presence/absence of a lane change. The numbers in parentheses are the corresponding frequencies.

| Category | | Mean Reaction Time |
|---|---|---|
| Subject's Age | Young | 1.19 (144) |
| | Middle-Aged | 1.18 (190) |
| | Old | 1.43 ( 37) |
| Subject's Sex | Male | 1.19 (209) |
| | Female | 1.24 (162) |
| Subject's Height | Short | 1.25 ( 28) |
| | Medium | 1.18 (263) |
| | Tall | 1.28 ( 80) |
| Subject's Car Size | Small | 1.13 ( 43) |
| | Medium | 1.27 (134) |
| | Large | 1.21 (140) |
| | Pickup/Van | 1.09 ( 54) |
| Lane Change | Yes | 1.38 ( 14) |
| | No | 1.20 (357) |

SUMMARY

In-traffic driver responses to supplemental, high-mounted brake lights were evaluated in daytime experiments using a compact car. The supplemental brake lights were mounted just below the rear window or at roof level. Measures were taken of response frequency and reaction time. The following results were obtained:

1. Response frequency:

The frequency of brake responses and of speed changes did not differ statistically among the systems tested on either of the two routes that were utilized.

2. Reaction times:

a. Under medium-speed/long-following-distance conditions (speed: 56-72 km/h; distance: 3-5 car lengths), none of the brake-light systems with high-mounted lamps produced statistically shorter reaction times than did the control system.

b. Under low-speed/short-following-distance conditions (speed: 32-40 km/h; distance: 1-2 car lengths), a system with a single supplemental lamp, center-mounted just below the rear window, was associated with statistically shorter reaction times in comparison to the control system.

Similar experiments using a full-sized car are now being carried out. A comprehensive documentation of both sets of experiments will be presented in the final report to appear in July 1981.

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