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Factors Influencing the Effectiveness of Automotive Rear Lighting Systems

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16. Abstract

This report contains five papers discussing various rear lighting problem areas as follows:

1. "The Effect of Rear Lighting Configurations on Vehicle Traffic Flow Characteristics"
2. "The Value of Rear Lamp Shielding"
3. "A Review of the Literature Concerning the Effects of Alcohol and Other Drugs Upon Color Perception"
4. "The Incidence of Fog, Rain, Snow, and Sunlight in Various Regions of the United States"
5. "A Subjective Evaluation of Turn Signal Effectiveness"

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THE EFFECT OF REAR LIGHTING CONFIGURATIONS ON VEHICLE TRAFFIC FLOW CHARACTERISTICS

by

Paul L. Olson

This is a report of an investigation of the effects of different rear lighting and signaling configurations on measures felt to be important in determining traffic flow characteristics. Three studies are reported: two were conducted during the night and one during the day. The two nighttime studies employed three different rear lighting configurations. The first study was carried out with a two-car platoon and the second with a three-car platoon. The only significant differences were in reaction time measures. A configuration having separation of function and color coding produced shorter reaction times than the other systems tested.

The daytime study was conducted primarily to investigate the value of high-mounted signal lamps. It was found that the high-mounted signal lamps significantly shortened reaction times in multiple car-following situations.

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INTRODUCTION

In the past several years there have been a substantial number of investigations reported dealing with the optimization of automotive rear lighting and signaling systems (e.g., Finch, 1968; Nickerson, Baron and Collins, 1968; Projector, Cook and Peterson, 1969; Rockwell and Banasik, 1968; Mortimer, 1968, 1969a and 1969b).

While there is no agreement as to what kind of rear lighting system would be best, the results of this research suggest that the configuration commonly employed on domestic- and foreign-built automobiles up to the present time is not as effective as some of those which have been investigated experimentally. Those lighting systems which have proven most effective in the testing program to date have been characterized by redundancy and separation of function.

Redundancy simply means that a signal is presented in more than one way. For example, in most present day configurations at night a brake application is signaled by increasing the brightness of the presence lamps. Redundancy would result if additional lamps were turned on as well. The available research suggests that the redundant system's signals will be detected more quickly, with a lower probability of error than those of the non-redundant system (e.g., Mortimer, 1968). More than one level of redundancy is possible. The theoretical maximum is determined by the number of significant coding dimensions.

Separation of function means that different lamps are employed for different signals. In typical present-day rear lighting systems there is no separation of function, since presence, stop and turn are all produced by the same bulb. However, separation of function is not necessarily provided by extra bulbs and circuits. The display must be such that it is apparent that another bulb has been turned on to a driver following at a distance close enough to be affected by actions of the lead car. In general this means the lamps must be far enough apart to be seen as separate at a reasonable distance. [Mortimer (1969a) suggests an edge-to-edge separation of five inches for a viewing distance of 300 ft.] Theoretically, an effective display might also result from a significant change in display shape or size.

While separation of function may reduce response time, its primary benefit would be reduction of ambiguity, especially for those cases where more than one signal is being presented simultaneously.

The rear lighting research which has been conducted to date has been almost exclusively concerned with signal detection. A typical paradigm has been to have subjects drive or ride in one car and respond to signals presented by a lead car. Dependent variables have generally consisted of reaction times and identification errors.

Unquestionably, these are important criteria for evaluating the effectiveness of automotive rear signaling systems. Still there are other considerations of consequence. As an example, there is a question as to how effective some of the more complex systems would be in real-world environments where there are many similarly equipped vehicles as well as lights, advertising signs and other forms of background clutter. A quite different question concerns the effect of different signal systems on traffic flow characteristics.

Clearly, answers to problems such as those listed would be helpful in making recommendations concerning improved vehicle rear signaling systems. The study reported in this paper is a step in this direction.

PURPOSE

The work to be described in this report was carried out in an effort to determine whether meaningful differences in traffic flow characteristics could be associated with different rear lighting and signaling systems.

STRUCTURE

Three studies were conducted. The procedures in each were as identical as possible, the major differences being that study 1 involved two vehicles, a lead vehicle, which presented the signals, and a subject vehicle, while the other two studies each involved three vehicles. Studies 1 and 2 were run at night, study 3 was run during the day.

STUDY 1

METHOD

INSTRUMENTATION. Two vehicles were involved in this study. These shall be referred to as the lead car and following car. A picture of the lead car is given in Figure 1. A picture of its master control panel is shown in Figure 2. By means of switches, potentiometers and function generators this vehicle's lighting control system can be programmed to provide a wide variety of intensities, flash rates, duty cycles and special codings related to deceleration, etc. The color of the lamps is changed by colored filters. Intensity may be regulated through use of neutral density filters and/or potentiometers. In the latter case special circuitry keeps illumination rise time constant. The vehicle may be used in either "simulate" or "actual" mode. In the former case signals can be presented by the experimenter without regard for vehicle actions. In the latter case signals are presented based on vehicle action (e.g., a brake application is signaled only by depressing the brake pedal).

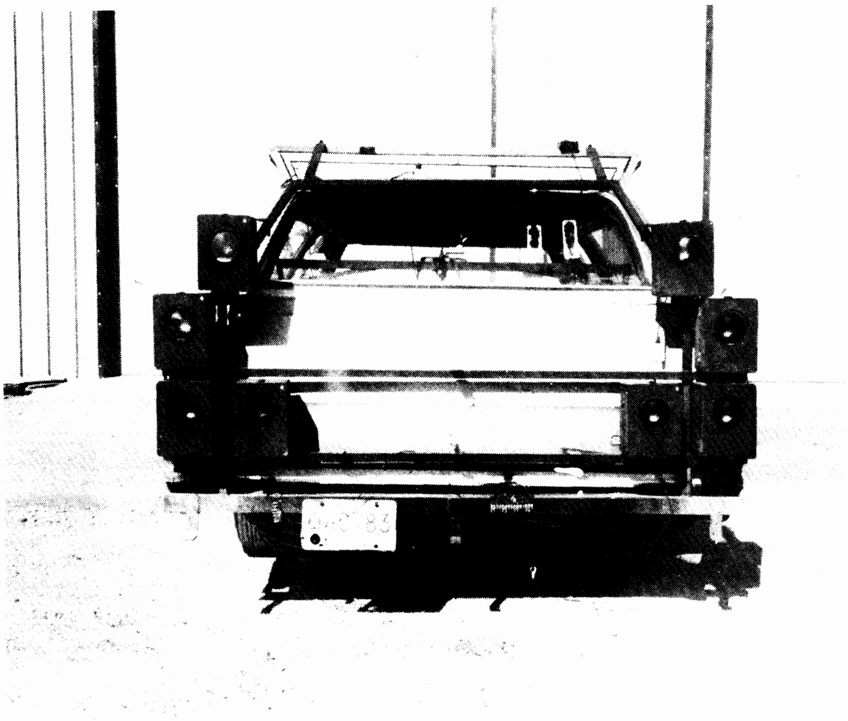


Figure 1. Photograph of rear lighting car used in this investigation.

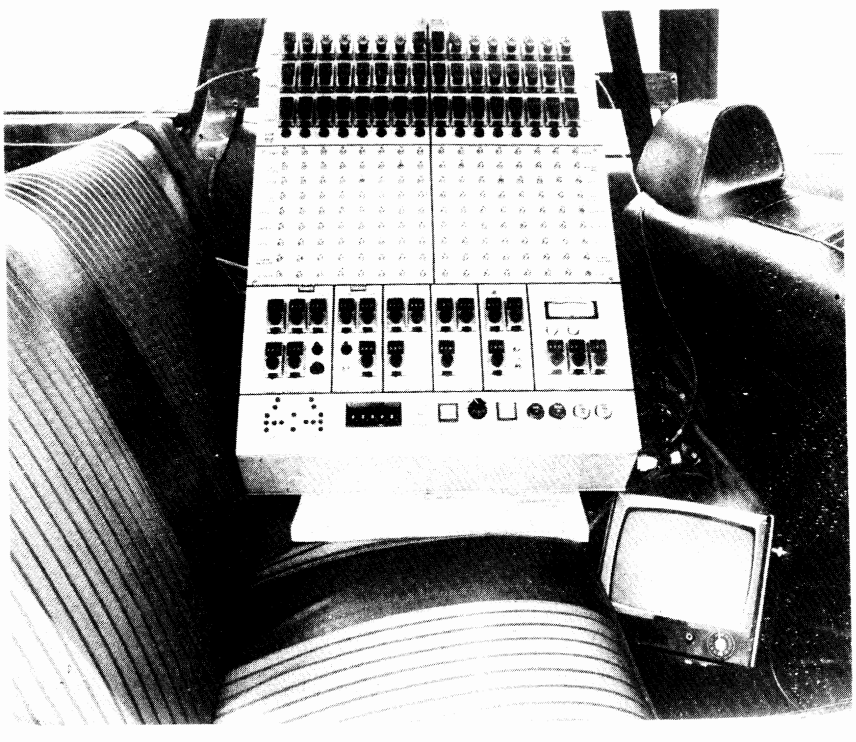


Figure 2. Master control panel in rear lighting car.

Speed and speed changes are signaled to the driver of this vehicle be means of the hood-mounted meter pictured in Figure 3. The driver maintains an appropriate speed or acceleration by keeping the needle on this meter centered at all times. In operation, the experimenter in the back seat of the rear lighting vehicle programs the desired maneuver and then notifies the driver that all is ready. The driver is responsible for determining when the maneuver may be safely carried out. He then presses a button which initiates a function generator which drives the needle at a rate required to achieve the desired acceleration or deceleration to the next programmed speed. The driver maintains the necessary accelerator or brake pressure until the target speed is obtained. Coincident with the onset of the signals (not necessarily with the actuation of the initiate button) start pulses are telemetered to the following car to start clocks which measure response time.

Data are recorded on video tape in this vehicle. Presented in digital form are information relating to subject number, trial number, programmed speed for trial start and trial end, programmed level of acceleration, vehicle speed, distance to subject vehicle and relative speed between the lead and the subject vehicles. Also shown on the display is a picture of the following car. This is used to provide information relating to control actions by the subject (in a manner to be described shortly) and as a back-up source of headway information (via image size).

The subject drives the following car and the experimenter occupies the back seat. This vehicle is equipped with clocks which measure to an accuracy of 1/100th second the time from the onset of a signal by the lead car until the subject has responded appropriately. Appropriate responses are pressure on a button mounted on the steering wheel yoke to indicate turn signals and pressure on the brake pedal to indicate stop signals.

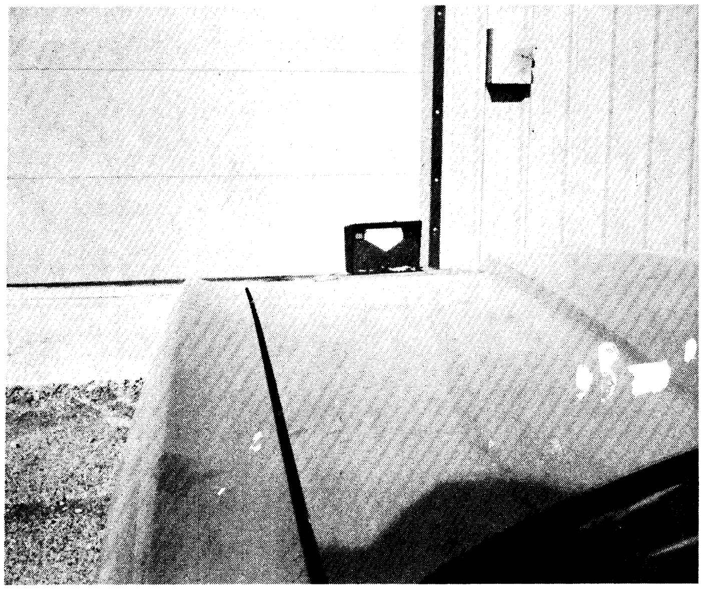


Figure 3. Speed control display for drivers of rear lighting car.

Logic circuitry is incorporated to detect inappropriate responses. These do not stop the clock but do turn on a light to indicate error.

The vehicle is equipped with forward-facing lamps mounted at bumper height which are switched on to indicate accelerator or brake pedal actuation. These are visible to the TV system in the lead vehicle.

Distance between the vehicles is provided by special equipment which measures independently the distance traveled by each car. This information is telemetered from the subject vehicle to the lead vehicle where it is subtracted from the distance traveled by the lead vehicle. The difference is displayed in digital format. This system is zeroed at the start of each run by bringing the cars as close together as possible. Accumulated error is registered at the end of each run by again bringing the two cars together as close as possible and recording the discrepancy. The theoretical limit of resolution of this equipment is 0.1%. However, in runs lasting 80,000 feet or more, errors in excess of 30 feet were seldom encountered. The bulk of this error seemed to be accumulated in turning maneuvers which were necessary to clear the road before the calibration could be made.

The cars were equipped with two-way radio gear. The experimenter in the subject car wore headphones so that transmissions from the lead car were not heard by the subject.

SUBJECTS. Twelve subjects participated in this study. All were licensed drivers with normal vision (at least 20/40 far acuity). Their ages ranged from 18 to 45 years.

INDEPENDENT VARIABLES. Three lighting systems were tested in this investigation. These are illustrated in Figure 4.

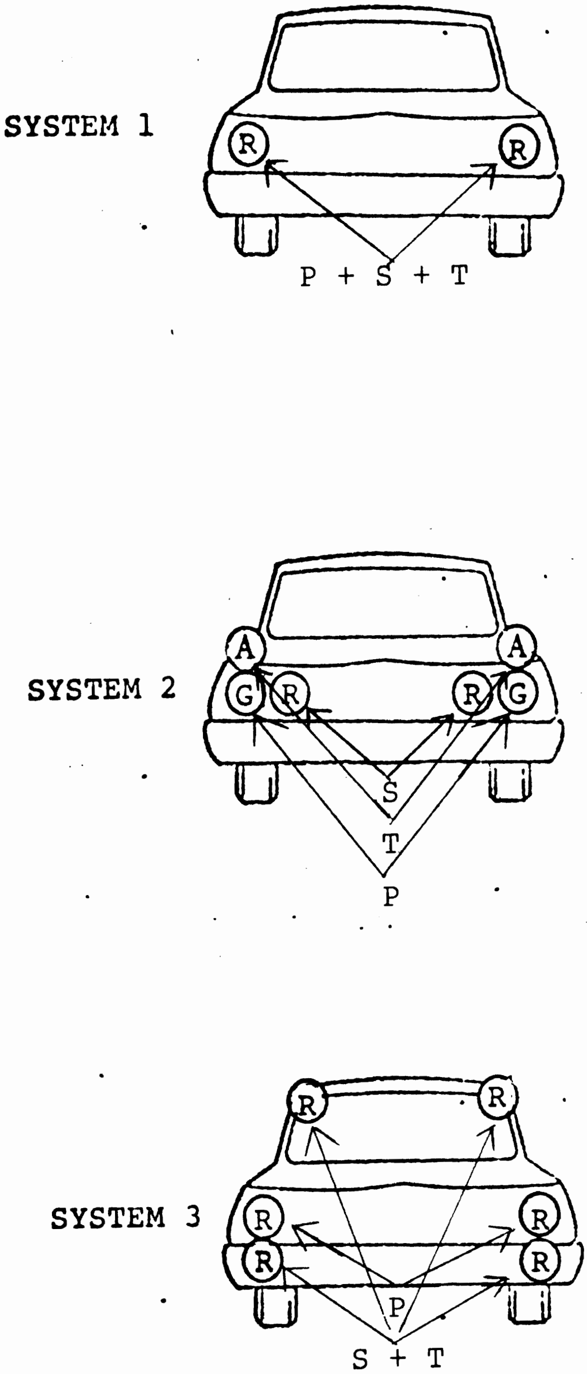


Figure 4. Lighting systems tested in study I.

System 1 is intended as a simulation of typical rear lighting systems employed on most cars today. System 2 is a functionally separated color coded system which has consistently proven to be the best of all rear lighting systems tested over the years by HSRI. System 3 is a partially functionally separated system featuring high-mounted lamps. Use of high-mounted lamps was indicated by the nature of the follow-on studies. It was felt that such a system would have a distinct advantage because of the greater ease with which the high-mounted lamps could be seen through the windows of the intervening vehicle. There is also some evidence to the effect that a vehicle having a four-lamp configuration of the type given by system 3 would make it easier for the driver of a following vehicle to detect spacing changes even in the absence of signals (Mortimer, 1969a).

In all these systems signal lamps operated at 130 candelas and presence indications were at 10 candelas. An exception was the high-mounted lamps on system 3, where intensities were set at 5 candelas for presence and 60 candelas for signals. The signals were operated at 120 cpm, and 50% on time.

Six different maneuvers were presented to the subjects in the course of this investigation. Four of these were signaled: brake application (B), turn signal (T), brake application followed by turn signal while the brake signal remained on (B→T) and turn signal followed by a brake application while the turn signal remained on (T→B). In addition, there were two actions which were not marked by signals: accelerations and coasting maneuvers. Accelerations covered either a 10 or 20 mph range and, as in the case of all brake maneuvers, were accomplished at 0.1 g. The deceleration levels associated with coasting maneuvers depended on the road geometry and the speed at which the maneuver was initiated. All coasting and brake maneuvers covered a 10 mph range. The subjects were instructed to maintain a 100 foot spacing.

DEPENDENT VARIABLES. The following measures were used as a means of evaluating the relative effectiveness of the three lighting systems:

A. Reaction Times To Signals - Reaction times were measured from the onset of a signal presented by the lead car until the subject responded correctly. In the case of combination signals (i.e., brake followed by turn and turn followed by brake) reaction time was measured from the onset of the second signal. For brake followed by turn configurations in the case of systems 1 and 3 this led to an artificial lengthening of the reaction time by 0.25 second. The reason was that the turn signal flasher operated in a "start-on" mode. Thus, if the brake signals were already on, the turn signal yielded no discernable change until it had completed the first half cycle and the lamp switched off. At 120 cycles per minute, 50/50 duty cycle this resulted in a 0.25 second delay before the subject could possibly see the signal. The standard duty thermal flasher with which most American cars are equipped operates in a "start-on" mode. Thus, the delay in responding to turn signals when the brake lights are on is typical. So-called "heavy duty" flashers operate in a "start-off" mode and would not suffer from delayed recognition under the circumstances described. However, they would be characterized by a recognition delay equal to 0.5 cycle when the brake lights were not on. The point of this discussion is not to make a case for either type of flasher from a safety point-of-view but merely to point out the source of 0.25 second difference in response time comparing system 2 with systems 1 and 3 for stop followed by turn signals.

B. Errors. Errors were defined as indicating a turn when a stop would be appropriate and vice versa. Errors were so infrequent that they did not constitute a meaningful measure.

C. Vehicle Control Measures. Several vehicle control measures were utilized.

1. Headway - both overall mean headway and mean headways in response to specific inputs by the lead car.
2. Headway variance.
3. Relative speed.
4. Relative speed variance.

PROCEDURE. When a subject appeared at the test site he was seated in a test vehicle, shown the various controls, told to adjust his mirrors and put on his seat belts. He was then read the instructions reproduced in the Appendix of this report. Questions were answered and the test run began. At the start of the run the subject was coached to a 100-foot headway and then given several miles practice maintaining that separation. The experimenter in the back seat of the vehicle could monitor headway by means of a spacing gauge installed on the right side of the windshield. He prompted the subject to speed up or slow down until the appropriate spacing was obtained. Throughout the study the experimenter continued to monitor headway. When the spacing became less than about 70 feet or more than about 150 feet the experimenter suggested to the subject that he make an appropriate speed change to get within the desired headway range.

When the subject seemed to understand what was required in terms of headway maintenance, the lead car began the signal sequence. Normally the first several signals were responded to more slowly than subsequent signals. These were regarded as practice and were readministered at the end of the sequence.

Subjects were exposed to four each of the six signals described earlier, making a total of 24 signals per rear lighting configuration. Signals were presented in a modified random sequence within the constraints set by the speed range desired for operation (30-50 mph). Three such presentation orders were generated and were systematically rotated among the lighting systems. The order of presentation of the lighting systems was also changed systematically as determined by a Latin Square.

Prior to the start of each trial the experimenter in the lead car advised the experimenter in the subject car about trial number and maneuver. He also provided a start warning.

RESULTS

Figure 5 shows the mean response time to various signals as a function of rear lighting systems. The statistical analysis revealed that the differences between system 2 and the other two systems were significantly different ($p \leq .01$) for B→T and T→B signals. However, it should be noted that the performance of systems 1 and 3 for the B→T signal suffers from the artifact discussed earlier. Accordingly, it would be appropriate to subtract 0.25 second from the reaction times indicated in the figure for the B→T signal for systems 1 and 3. If this is done, the reaction times for systems 1, 2 and 3 become 0.83, 0.80 and 0.79 second respectively. These differences are not significant. However, this artifact does not affect the T→B signal.

Figures 6 through 11 show mean headways associated with each system for each of the six maneuvers. Each curve shows mean headings for each system for ten seconds prior to initiation of the signal (first signal in the case of multiple signals) and for twenty seconds afterward. It will be noted that the curves representing station keeping associated with the three systems follow one another very closely. None of the indicated differences between systems are statistically significant.

DISCUSSION

With respect to reaction time and error measures the

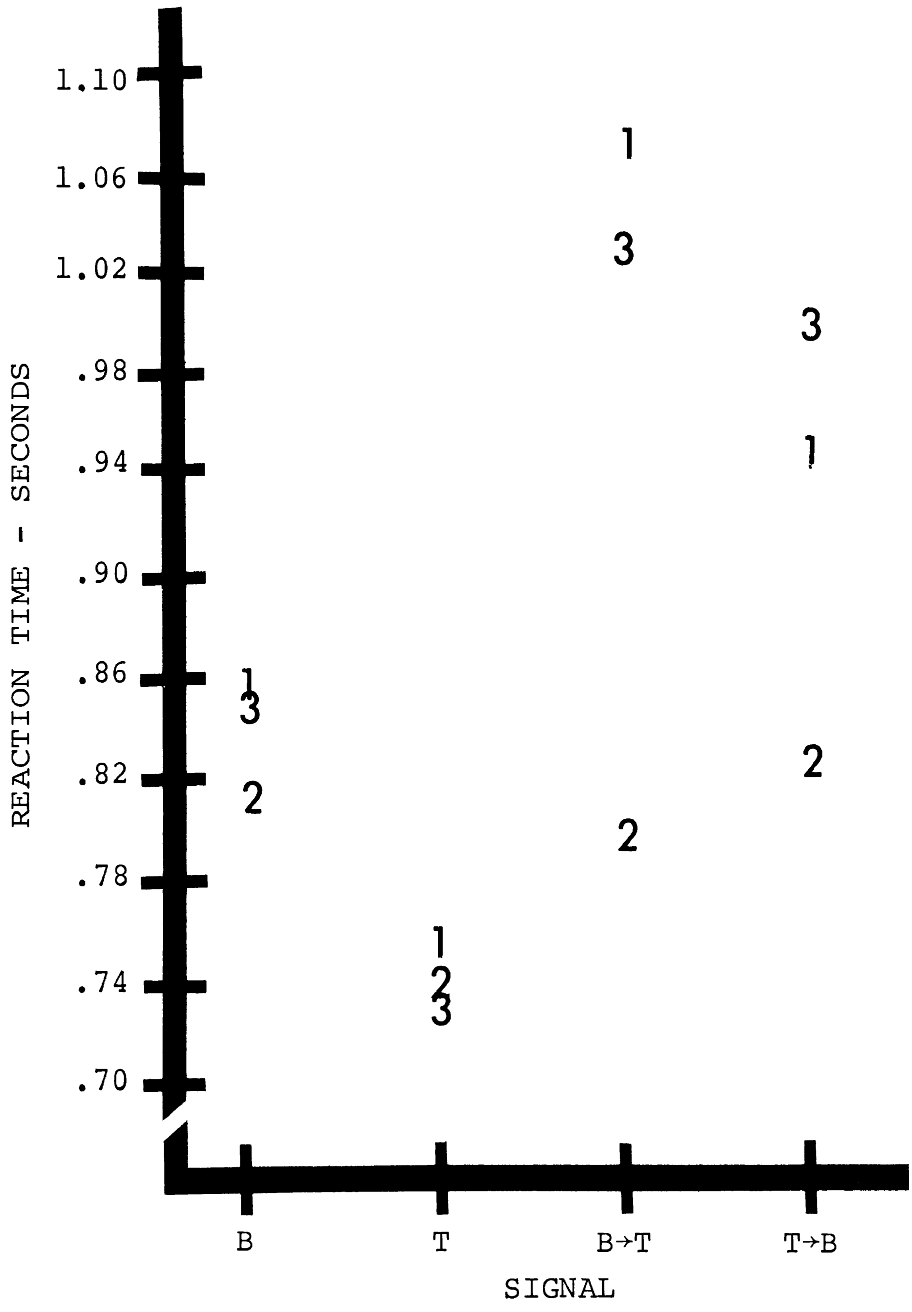


Figure 5. Study 1: Mean response time to signals as a function of lighting systems. Systems identified by number.

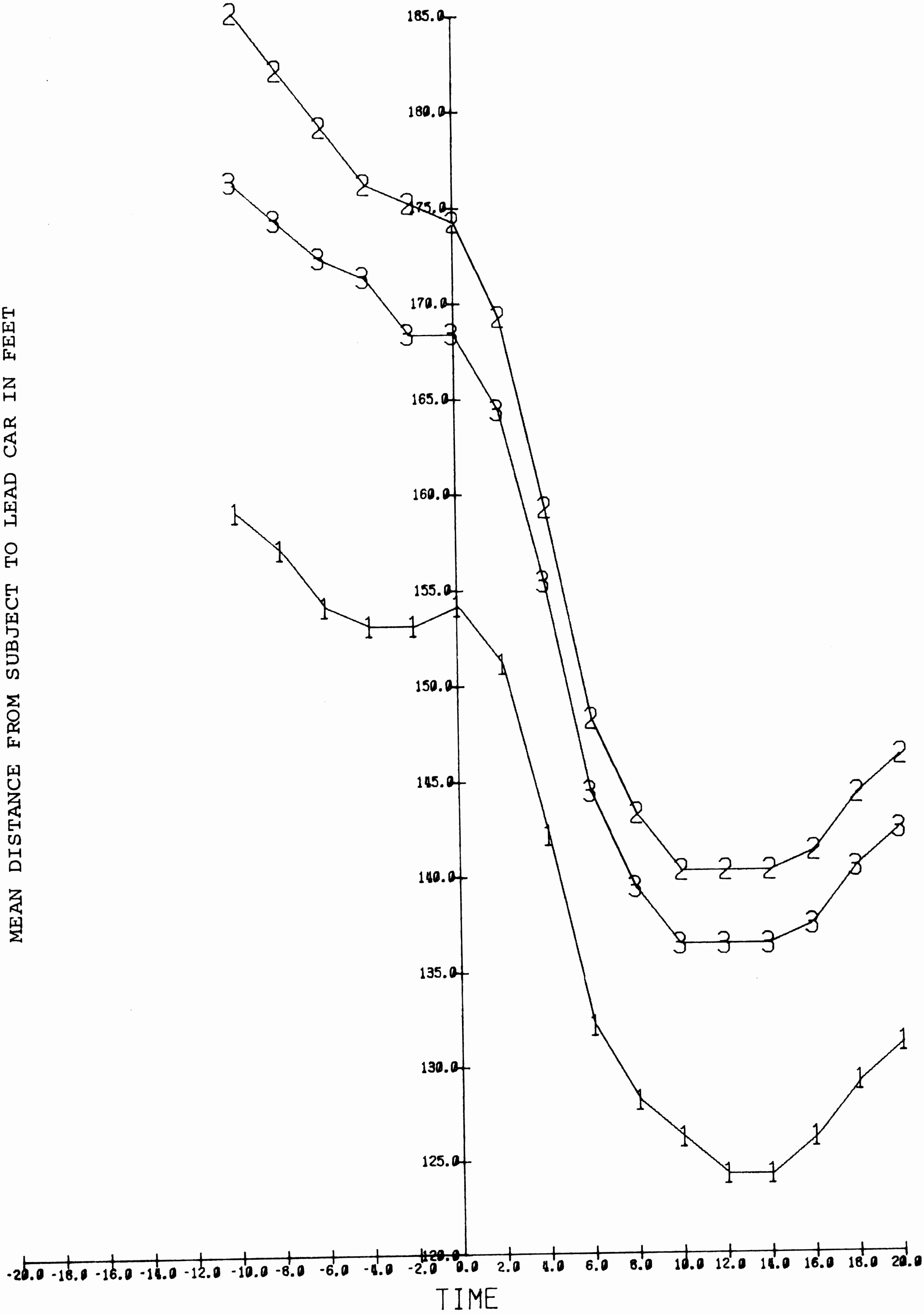


Figure 6. Study 1: Mean headway during stop maneuvers.

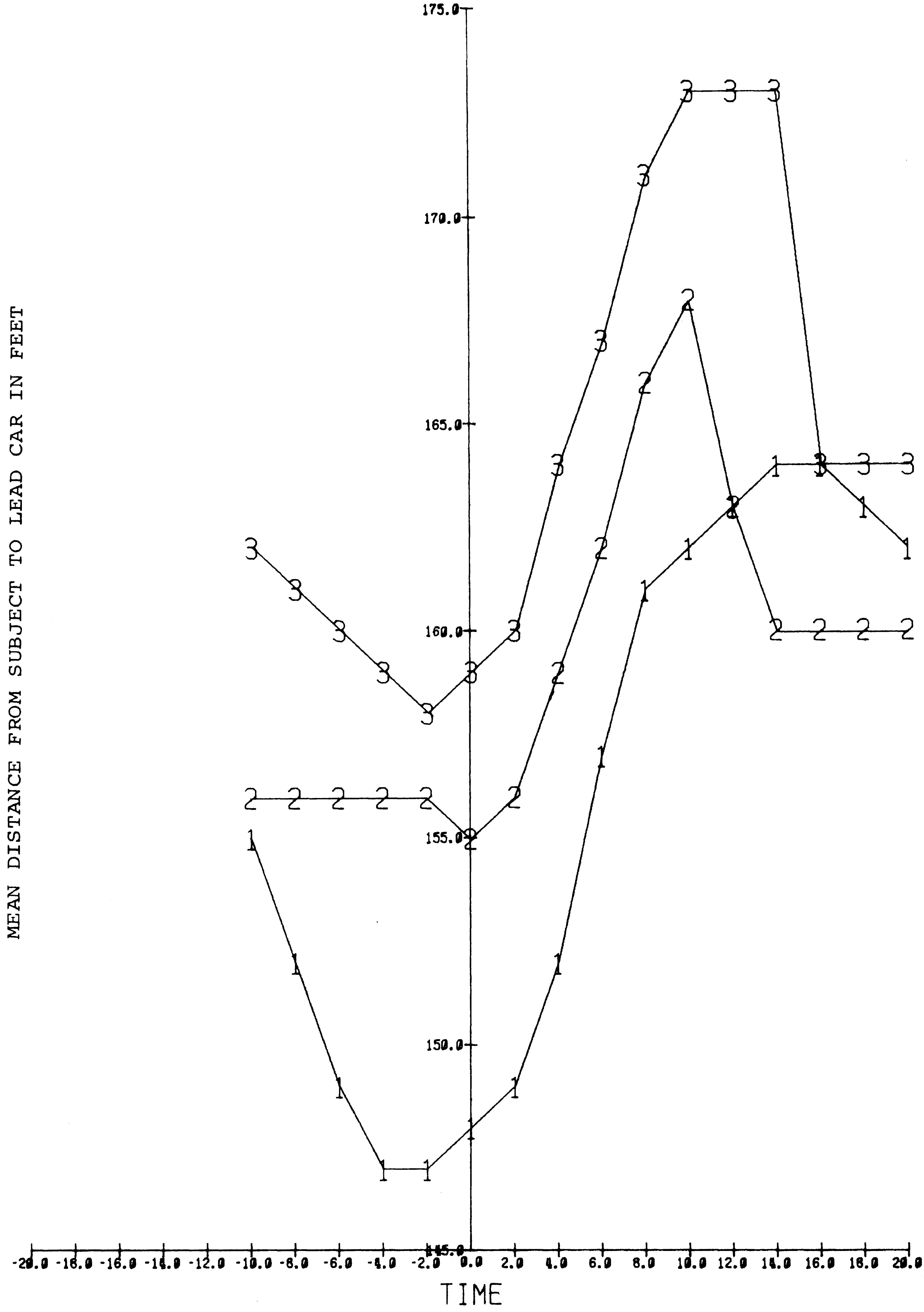


Figure 7. Study 1: Mean headway during turn maneuvers.

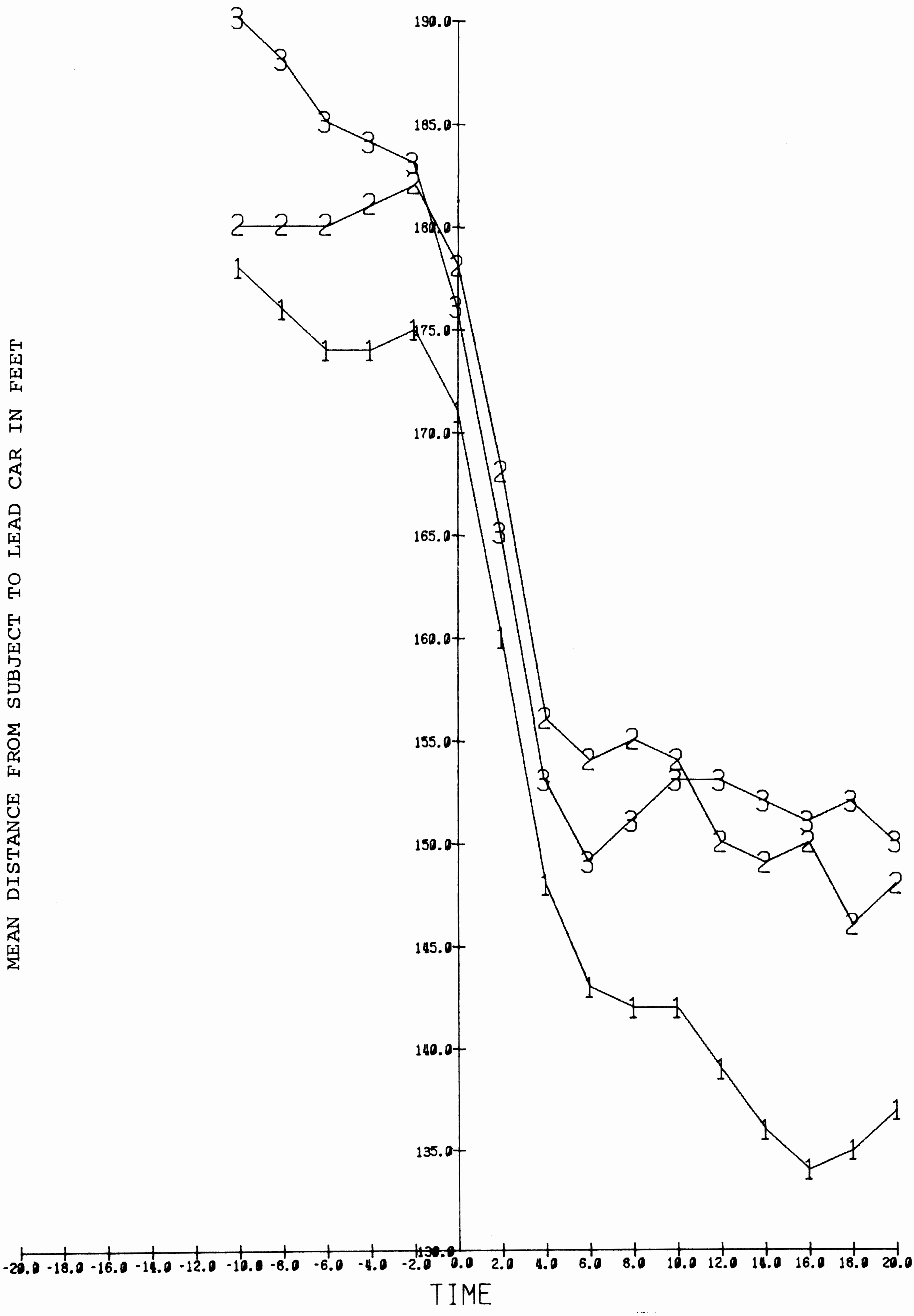


Figure 8. Study 1: Mean headway during stop→turn maneuvers.

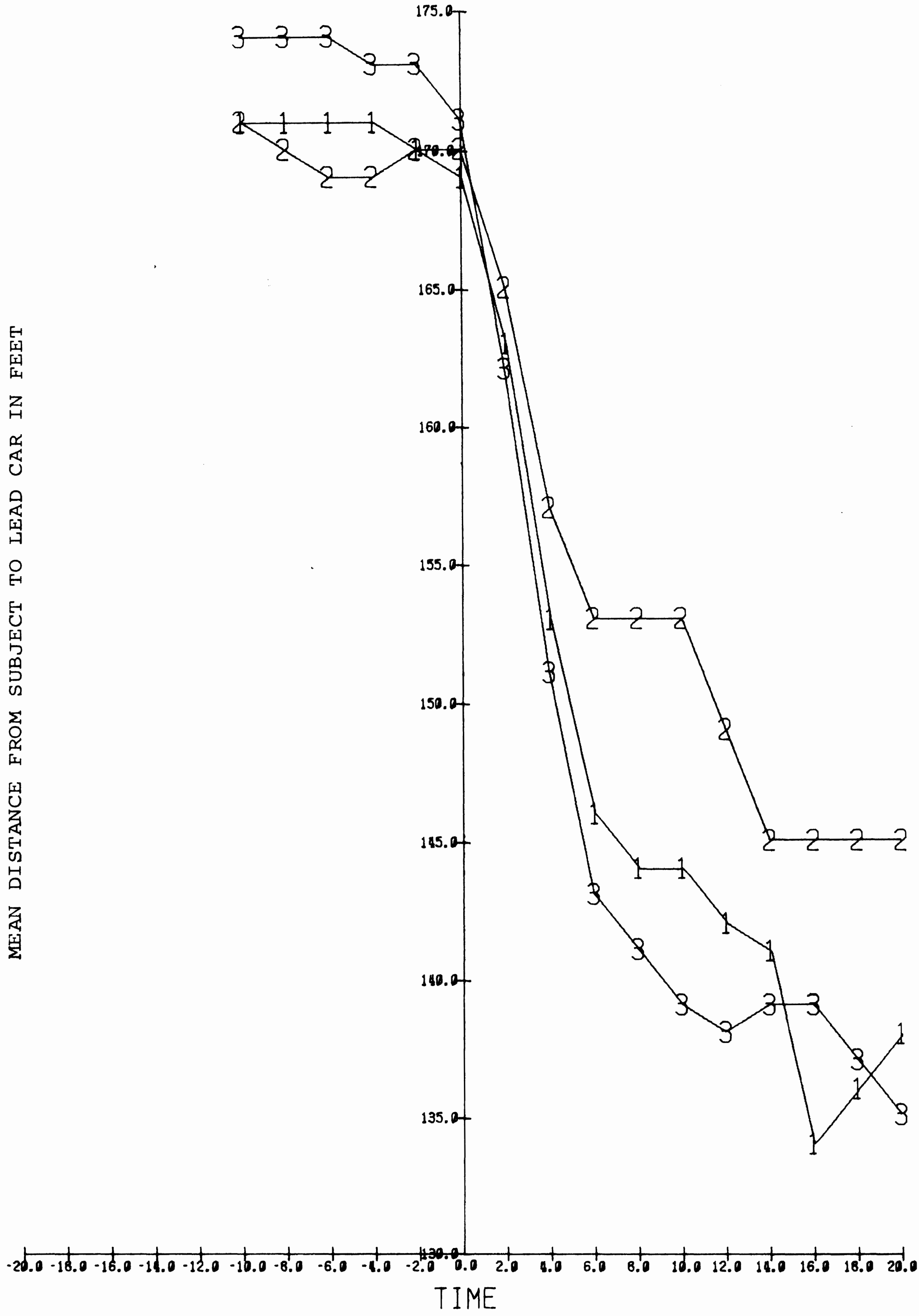


Figure 9. Study 1: Mean headway during turn→stop maneuvers.

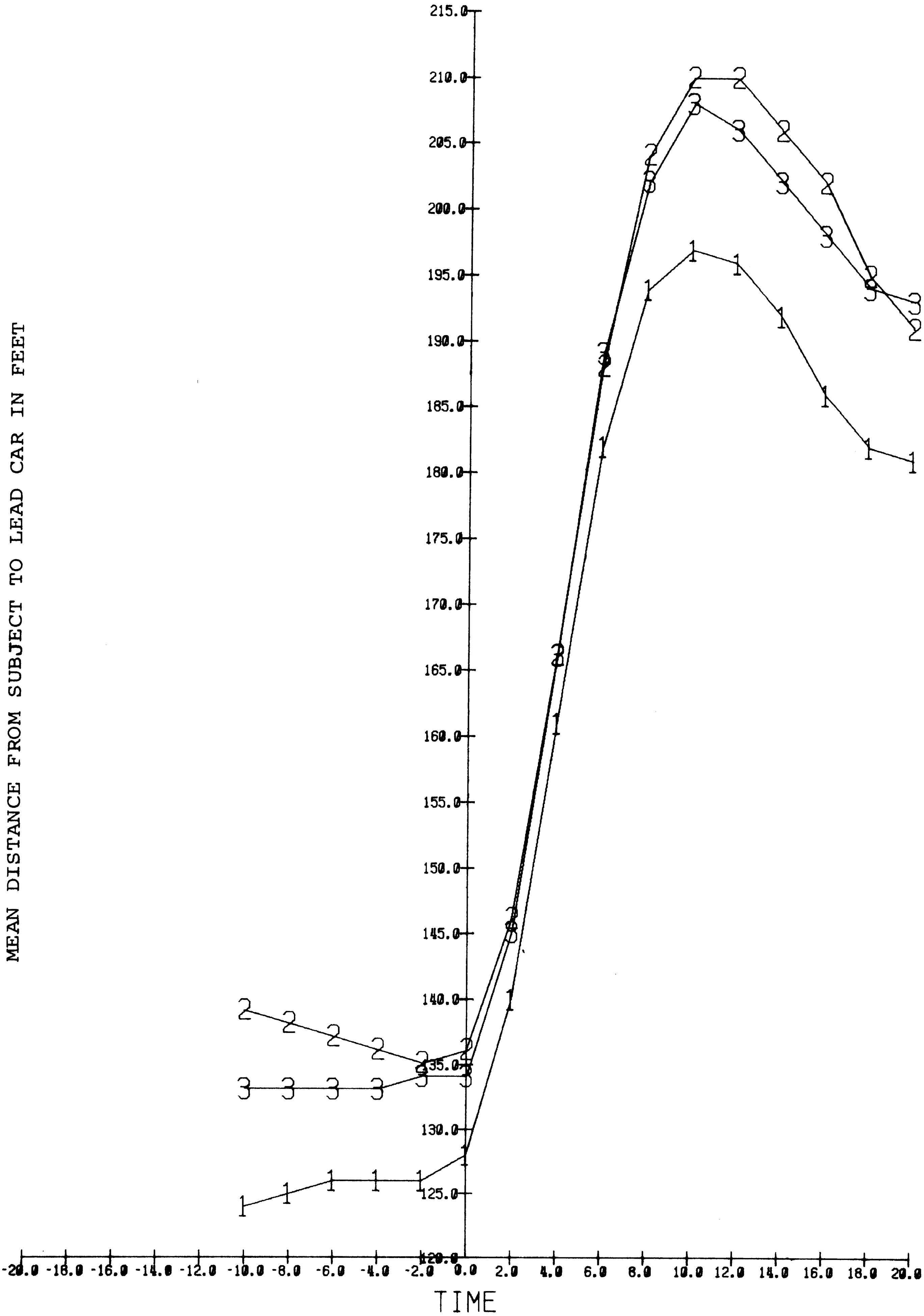


Figure 10. Study 1: Mean headway during acceleration maneuvers, 30-50 mph acceleration shown.

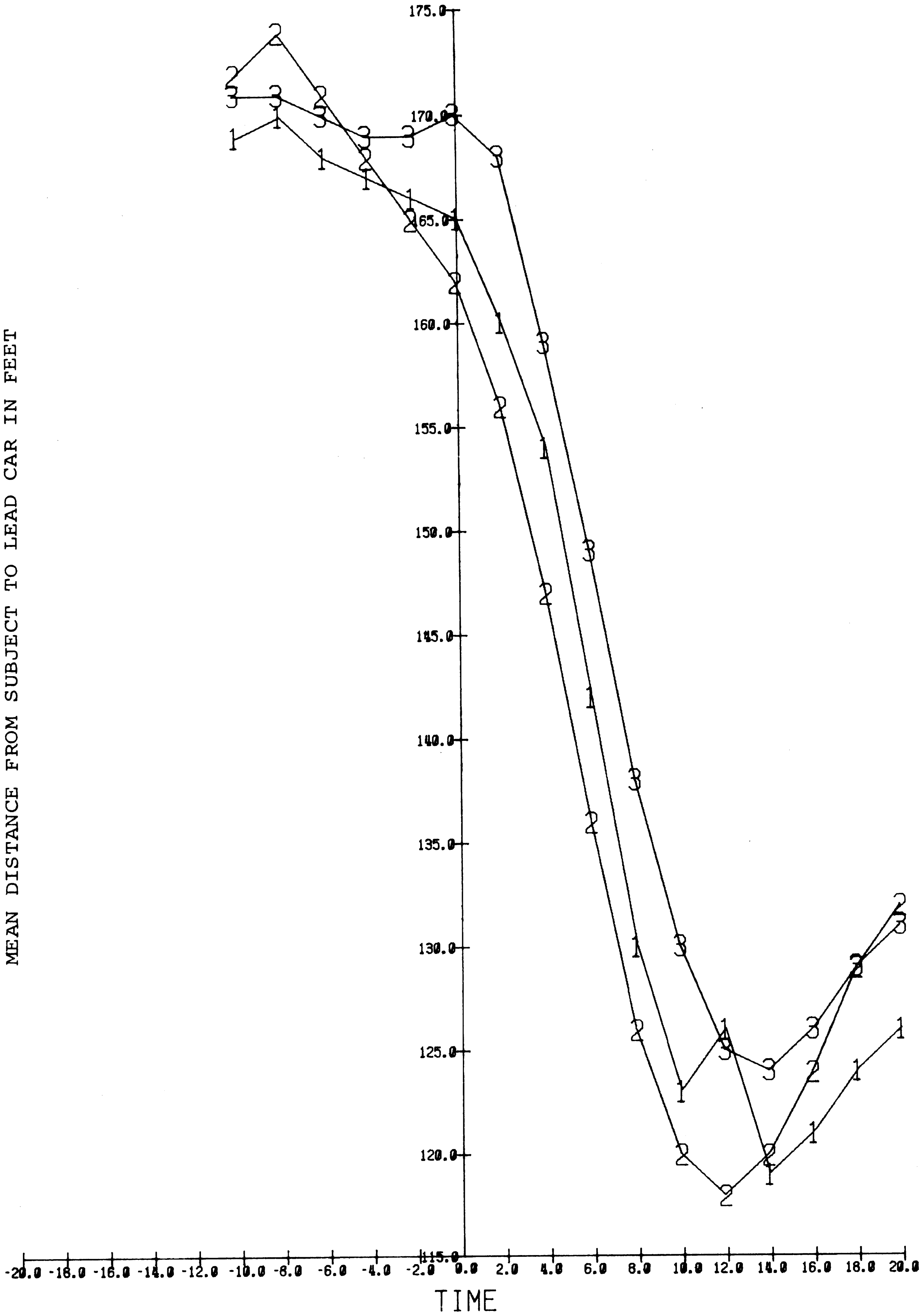


Figure 11. Study 1: Mean headway during coast maneuvers.

results of this investigation closely parallel those of other investigations of similar rear lighting systems. That is, the value of redundancy (in this case achieved by extra lamps and color coding) and functional separation are clearly demonstrated as aids to the detection of multiple signal presentations. In this context it should be noted that system 3, although it used more lamps than system 1, did not employ separation of function or redundancy in a way which would make it superior to system 1 for multiple signal presentations. That is, all the signal lamps functioned in unison, just as on system 1.

There is no evidence from this investigation that rear lighting systems contribute significantly to traffic flow characteristics.

STUDY II

Study II was intended to be identical in all respects to Study I except that two lead vehicles were used. There were two primary reasons for doing this:

1. Subtle vehicle interactions associated with lighting systems may be increased and made easier to detect with a three-car platoon.

2. Certain system characteristics (e.g., mounting height), which are of little or no consequence when the whole rear of the vehicle is visible, may be significant when part of the display is blocked by an intervening car. Since this is a common circumstance, it would be desirable to include it in the experimental conditions.

METHOD

INSTRUMENTATION. The lead vehicle and the subject vehicle employed in Study I were also used in this study. Their instrumentation remained the same. The third car (which will be referred to as the repeater vehicle) was inserted into the platoon between the lead and subject vehicles.

Figure 12. Photograph of repeater vehicle used in studies II and III.

The repeater vehicle, a photograph of which is shown in Figure 12, was equipped with eight lamp housings identical to those employed on the lead vehicle. It used the same lamp driver circuits as on the lead vehicle to enable close control of lamp voltages and it was equipped with special circuitry so that any one of the three test systems could be selected by the turn of a switch. It was equipped with two forward-facing lamps mounted on the front bumper which were activated when the accelerator pedal or brake pedal were depressed. These lamps were visible to the TV system in the lead car. The driver was provided with a space gauge attached to the windshield which indicated the size of the lead vehicle at the target spacing of 100 feet. All three vehicles were equipped with two-way radio gear, the experimenter in the subject vehicle monitoring the radio transmission by means of headphones so that the subject could not hear.

Headway was measured from the lead to subject vehicle, as in study I. To zero the equipment all three cars were brought as close together as possible. Thus, the actual distance between the lead and subject vehicles was greater than indicated by an amount equal to the length of the repeater car.

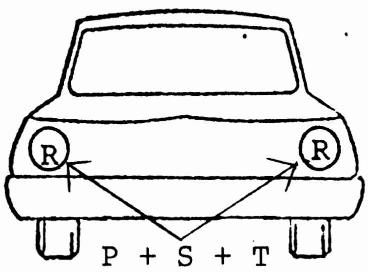
LIGHTING SYSTEMS. Systems 1 and 2 were tested again in this study. However, system 3 was changed to that shown in Figure 13. Henceforth, it will be referred to as system 3a. The primary reason for the change in system 3 was to make it more nearly representative of certain lighting systems in use today.

Figure 14 shows an exterior view of the three test vehicles.

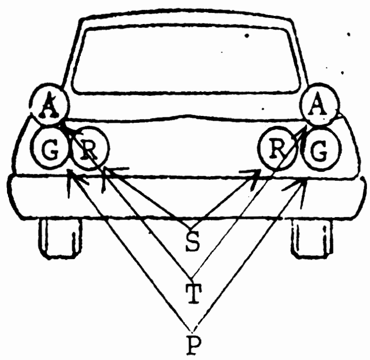
SUBJECTS. Eleven subjects participated in this study. As in the first study all were licensed drivers having at least 20/40 far acuity. Their ages ranged from 19-46 years.

PROCEDURE. The procedure for this investigation was as identical as possible to that employed in the first study. Modifications were necessary to the instructions, however, to accommodate the two lead vehicle situation. The instructions for the three-car study are given in the Appendix to this report.

SYSTEM 1



SYSTEM 2



SYSTEM 3a

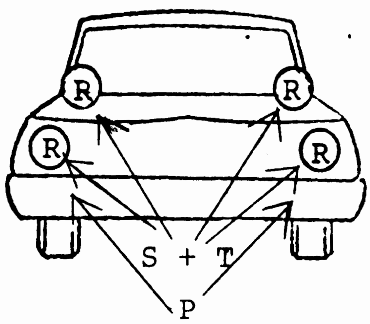


Figure 13. Lighting systems tested in study II.

Figure 14. Exterior view of three test vehicles used in studies II and III.

It will be noted that no particular emphasis is placed on which set of signal lamps the subject should attend. They were merely told that they should respond to "signals presented by the vehicles ahead." Some subjects questioned whether they were to respond only to signals presented by the repeater car. They were told that they should respond to any signal, as soon as they could detect it.

The driver of the repeater car was instructed to maintain a headway of 100 feet in normal driving conditions and respond to all signals presented by the lead car by presenting an identical signal approximately one second later.

The same treatment schedules as employed in the first study were used in this study and the same means of systematically balancing various treatment conditions.

RESULTS

The results of the analysis of reaction time data are reproduced in Figure 15. These data should be compared with the results shown in Figure 5 for the two-car investigation. The relative performance of the three systems in the two studies are strikingly similar. However, the absolute performance in the three-car study is shifted upward on the ordinate by a factor of about 1.8.

As in the two-car study, the only significant differences are for the combination signals, B→T and T→B. In these instances system 2 had significantly shorter reaction times than either system 1 or system 3a. However, it should be noted that for signal B→T the same artifact operates to the disadvantage of systems 1 and 3a as in study I. Hence, in order to make a fair comparison of reaction time from the first moment that the signal was capable of being detected, it is necessary to subtract 0.25 second from the reaction time for systems 1 and 3a. In this case the reaction times for systems 1, 2 and 3a become 1.60, 1.50 and 1.50 respectively.

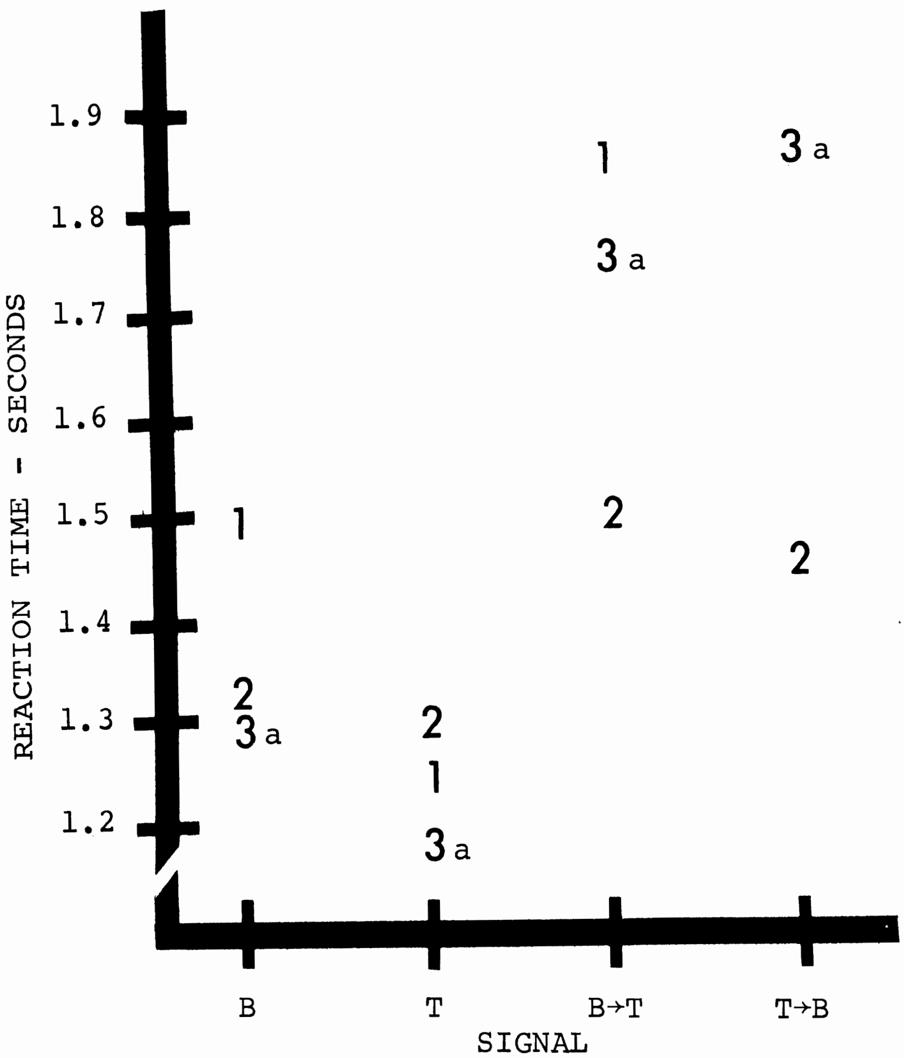


Figure 15. Study II: Mean response time to signals as a function of lighting systems. Systems identified by number.

These differences are not significant. However, the difference for the T→B signal remains valid as before.

Figures 16 through 21 show headway changes as a function of various inputs by the lead vehicle. These figures should be compared with the equivalent cases (Figures 6 through 11) from study I. It will be noted that the mean headway from the subject to the lead car for the three-car platoon is not much greater than the mean headway for the two-car platoon. The expected mean headway in the two-car case was 100 feet, but the actual means were greater than 100 feet. The expected mean headway for the three-car case was 200 feet, and the actual means were relatively close to that figure.

As in the case of study I, none of the measures of car-following capability were significant as a function of lighting system.

DISCUSSION. The results of this study add little to that already learned from two-car investigations conducted earlier. The three lighting systems under investigation yielded the same relative performance in the three-car as in the two-car case and there were no differences in car-following capability associated with lighting systems.

It appears from the magnitude of the reaction times comparing studies I and II that the subjects in study II were gaining little information from the signals presented by the lead car. The instructions, admittedly, do not emphasize the possibility of looking through or around the intervening car. Observation of the subjects during the investigation suggested to the experimenter that most subjects used the repeater car as the dominant cue source, perhaps gaining anticipatory information from the lead car.

The failure of the high-mounted signal in system 3a to outperform system 1 was rather surprising. This is felt to be

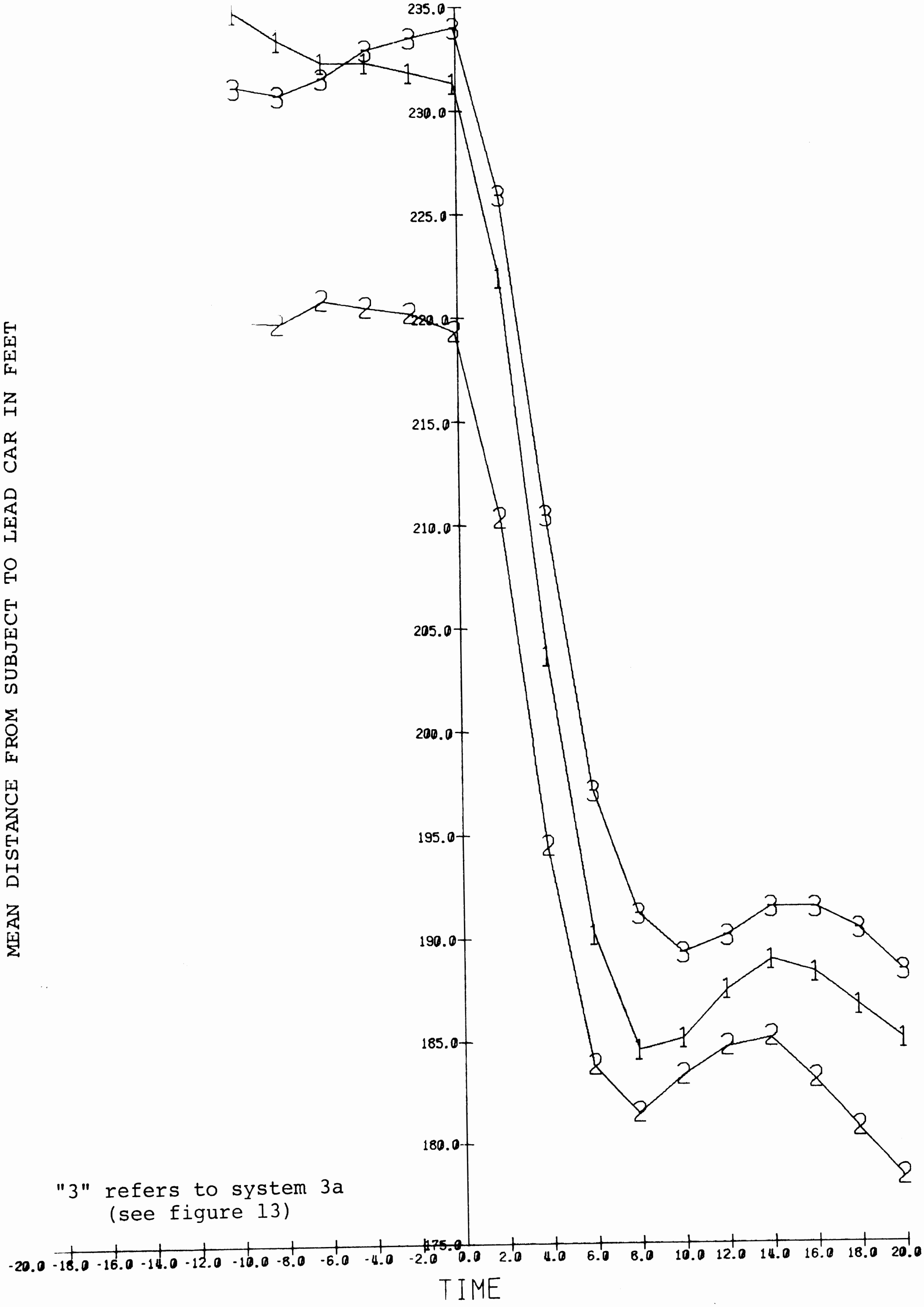


Figure 16. Study 2: Mean headway from subject to lead vehicle during stop maneuvers.

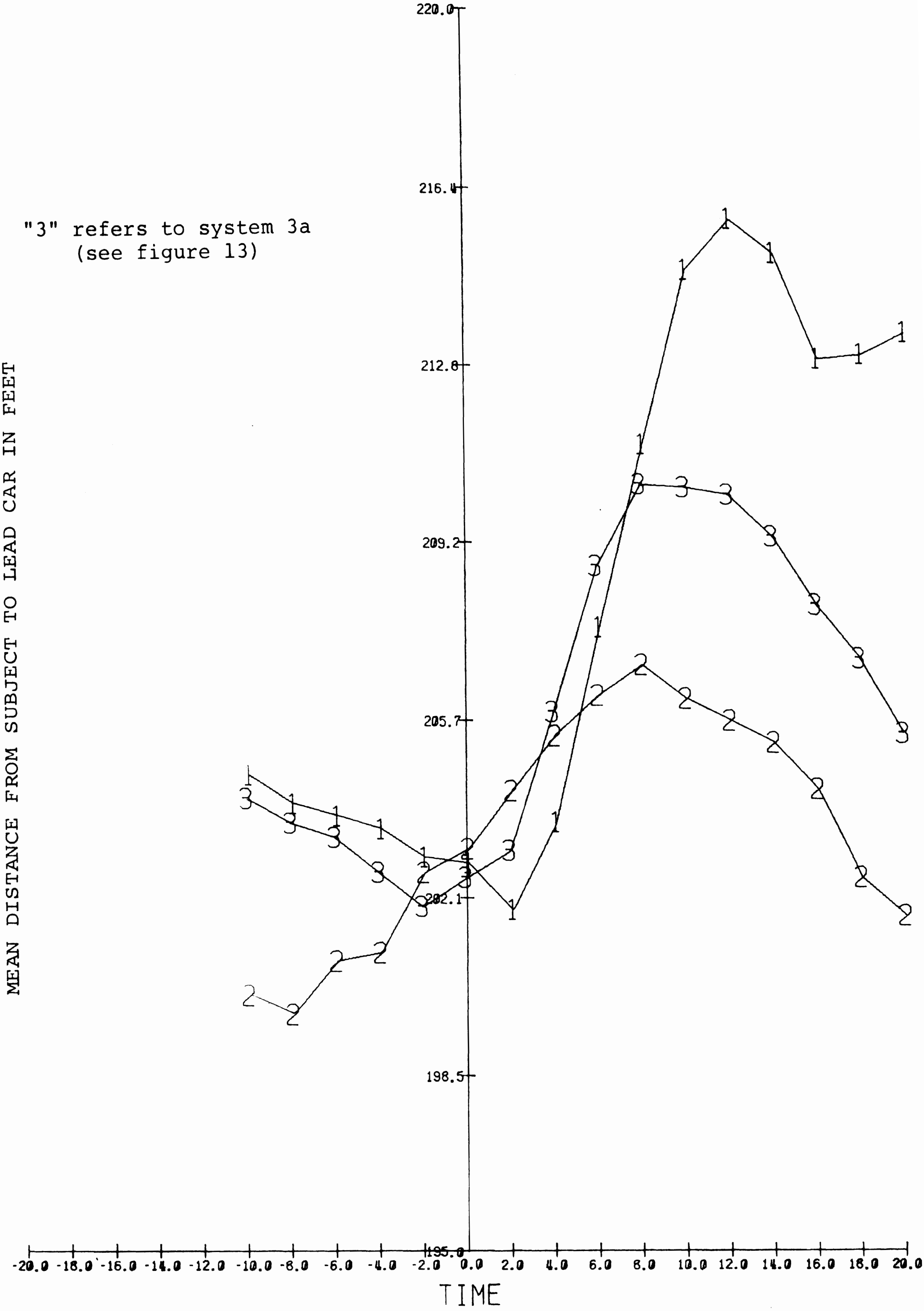


Figure 17. Study 2: Mean headway from subject to lead vehicle during turn maneuvers.

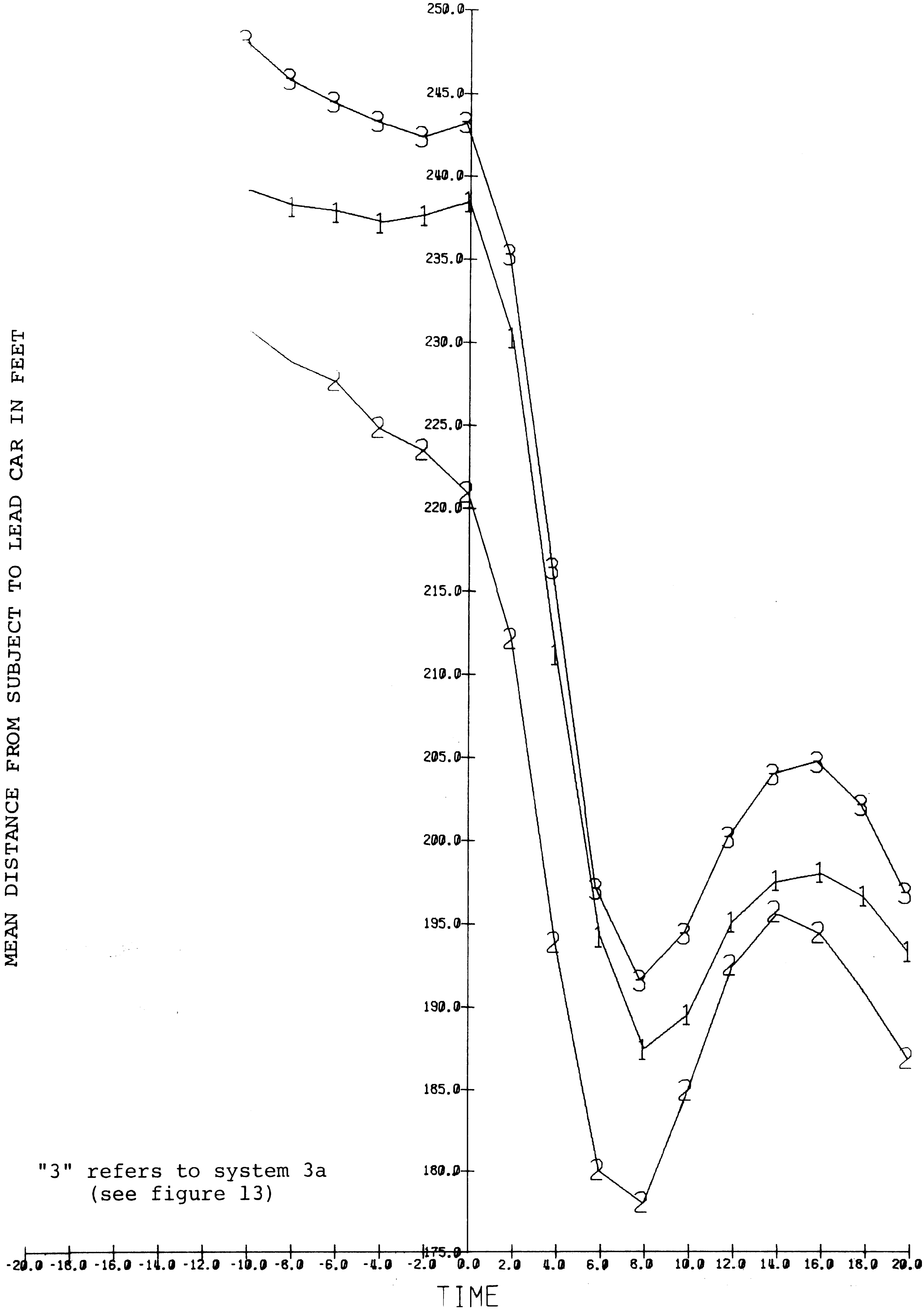


Figure 18. Study 2: Mean headway from subject to lead vehicle during stop→turn maneuvers.

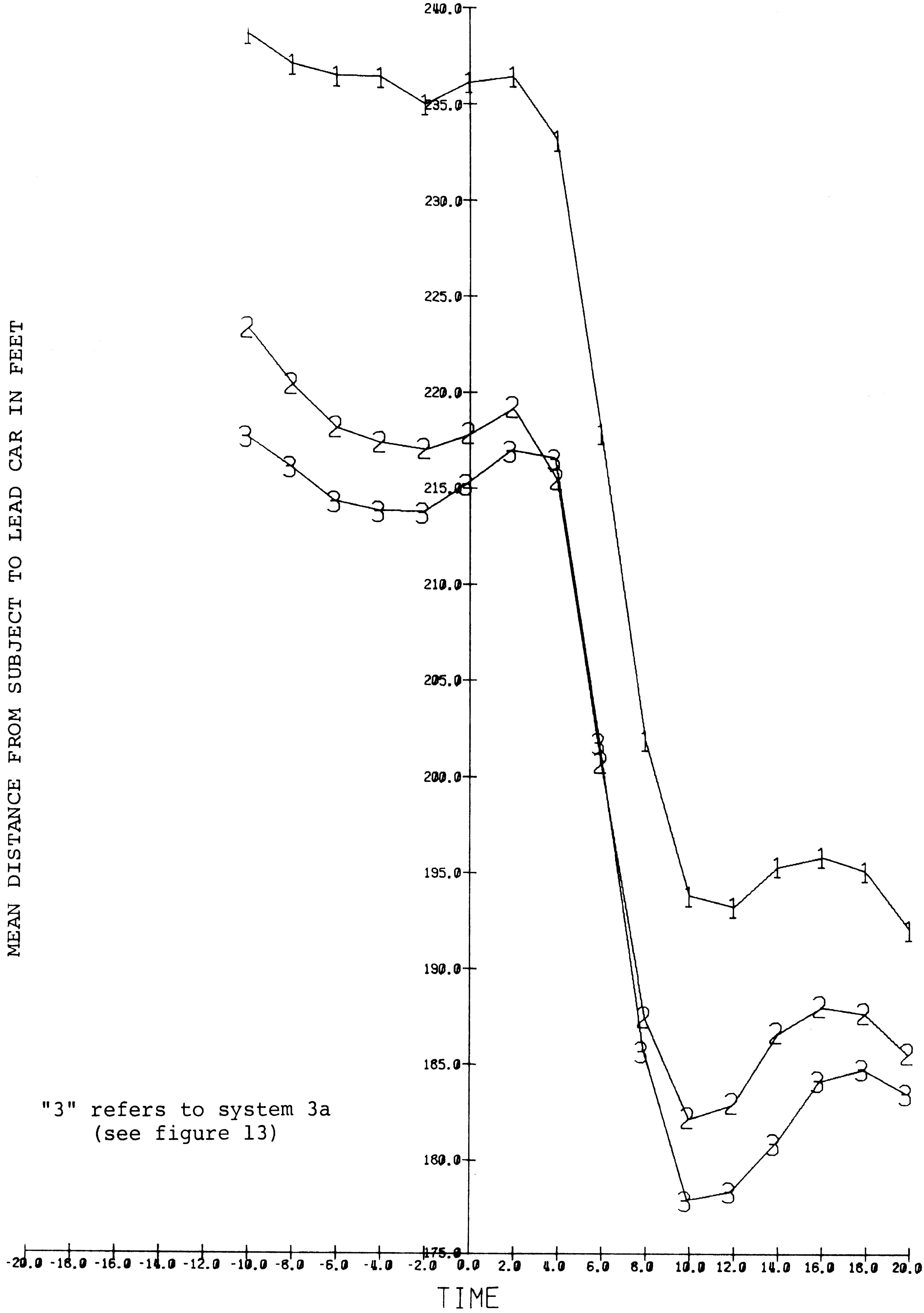


Figure 19. Study 2: Mean headway from subject to lead vehicle during turn→stop maneuvers.

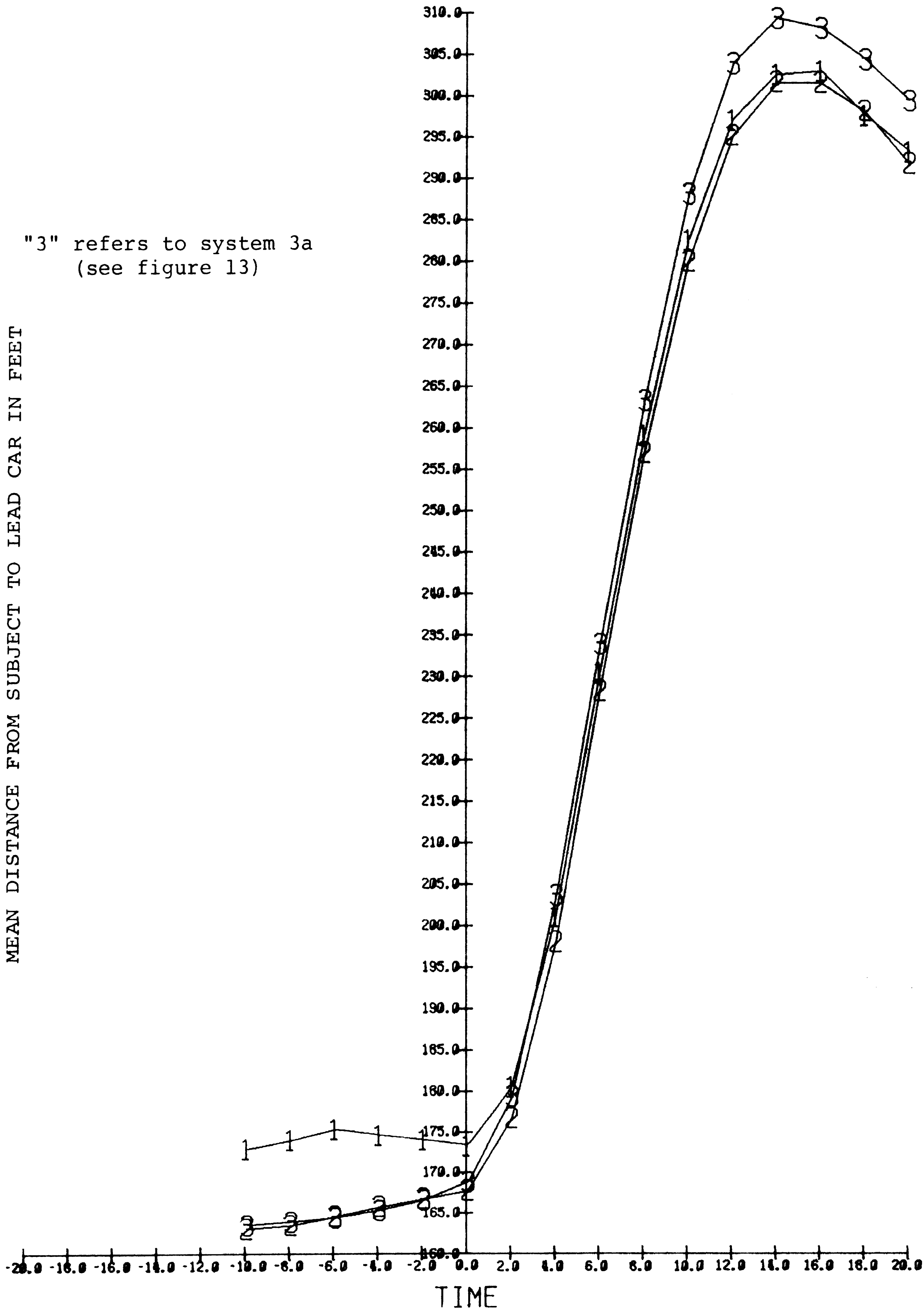


Figure 20. Study 2: Mean headway from subject to lead vehicle during acceleration maneuvers, 30-50 mph acceleration shown.

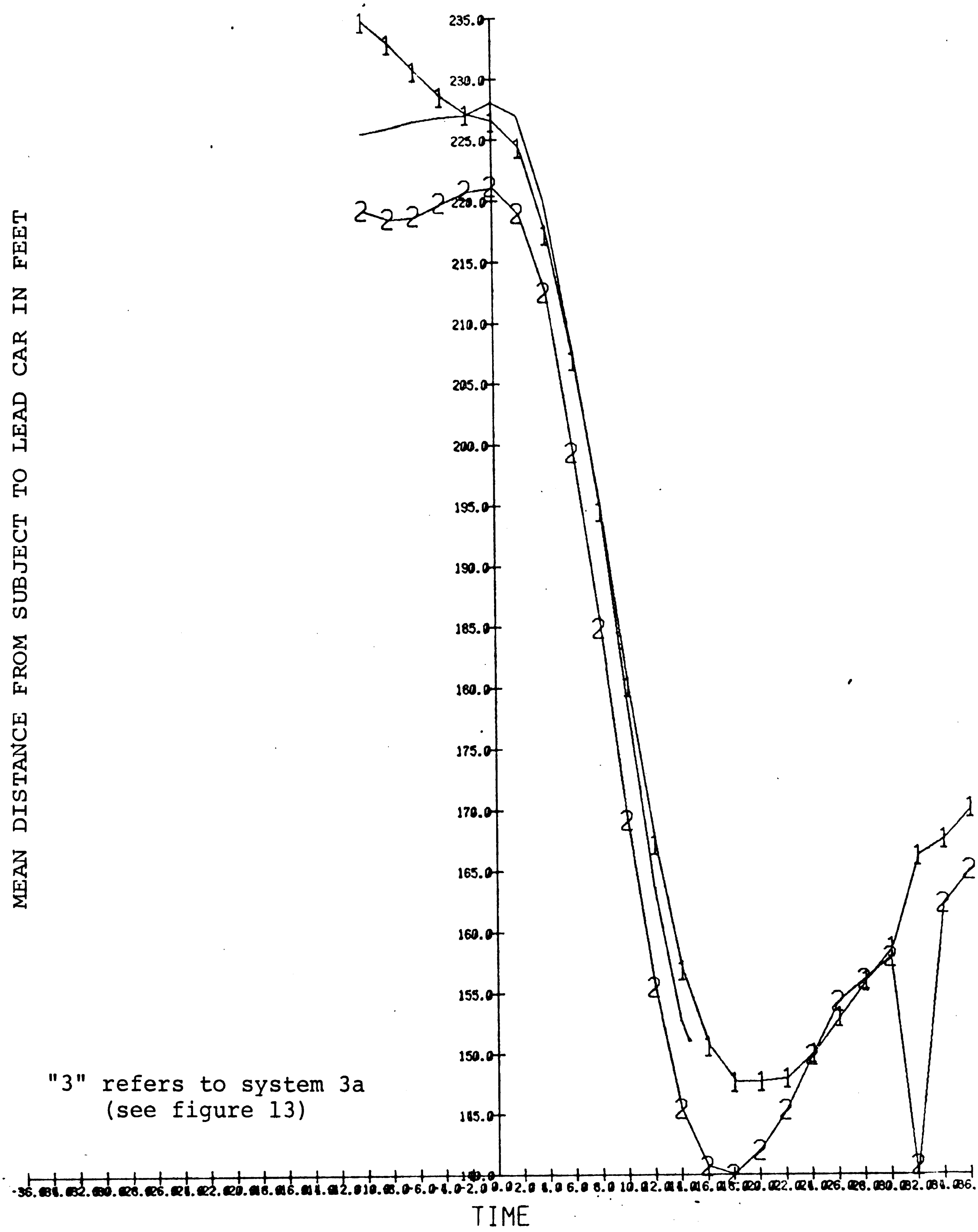


Figure 21. Study 2: Mean headway from subject to lead vehicle during coast maneuvers.

due to the fact that, under night driving conditions, there was a sufficient cue to the onset of signals by the lead car from flare visible on the windshield of the repeater car regardless of the lighting configuration. Thus, subjects who wanted to make use of the fact that a signal had been presented by the lead car could do so, if they were sufficiently attentive, regardless of the lighting configuration. This should not be the case during the day, however, and in study III it was anticipated that this phenomenon would not occur.

STUDY III

Study III differed from study II in that it was run during the day, only systems 1 and 3a were used, and the number of subjects was reduced to a total of 6. Otherwise, all instrumentation and procedures were identical. The test was run on the same stretch of roadway as the other two investigations.

RESULTS

The results of the reaction time measures in this investigation are summarized in Figure 22. It will be noted that there are differences of 0.2 second or more in reaction times between system 1 and system 3a at all signals. However, only the reaction time for the B→T signal is statistically significant ($p < .01$). The artifact which adds 0.25 second to reaction time applies equally to systems 1 and 3a and does not affect the comparison in the way it did in the first two studies.

Figures 23 through 28 show mean headways associated with each system for each of the six maneuvers. As in the other analyses, there were no significant differences associated with any of the car-following measures as a function of lighting systems.

DISCUSSION. The results of this investigation provide clear evidence that significant gains in reaction time for

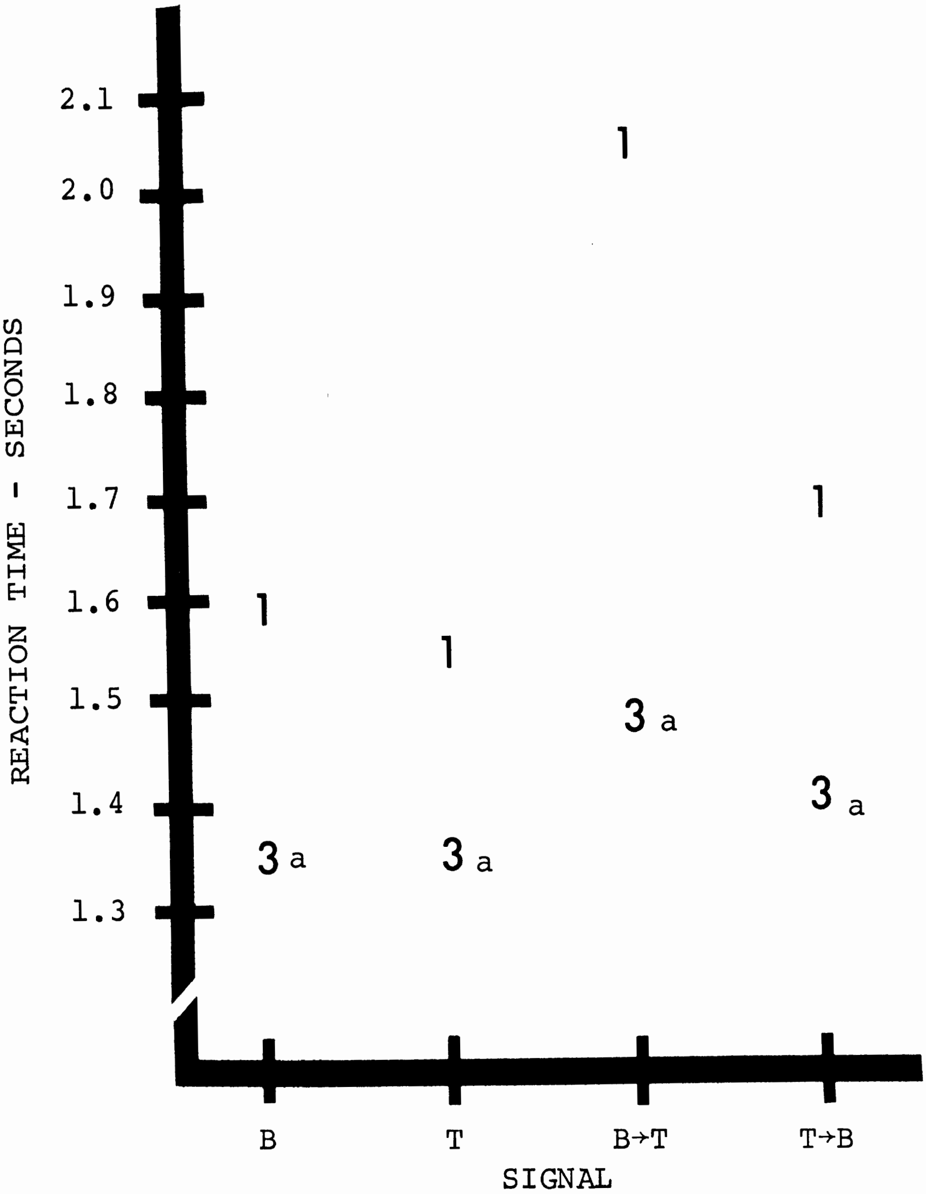


Figure 22. Study III: Mean response time to signals as a function of lighting systems. Systems identified by number.

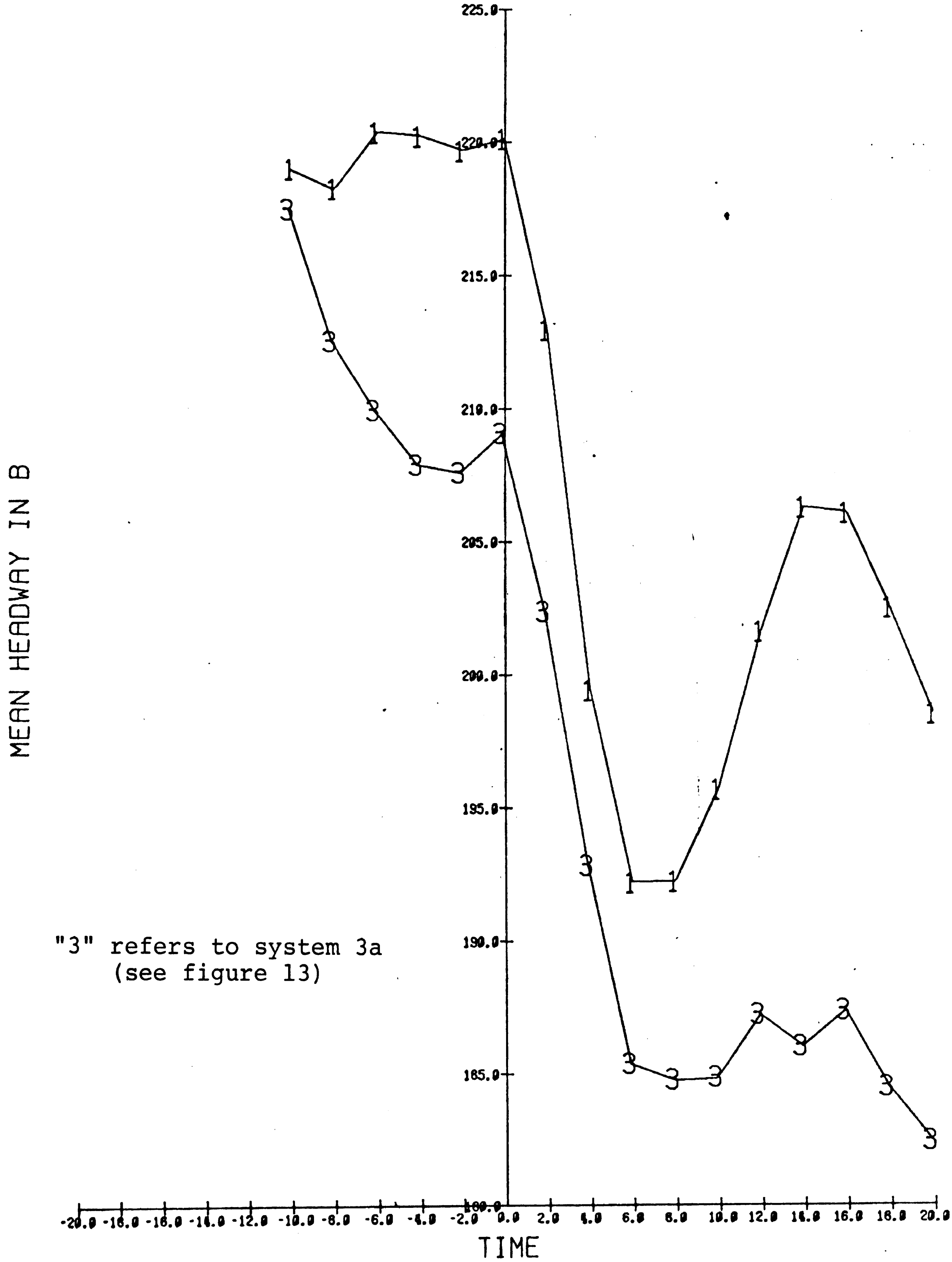


Figure 23. Study III: Mean headway from subject to lead vehicle during stop maneuvers.

"3" refers to system 3a
(see figure 13)

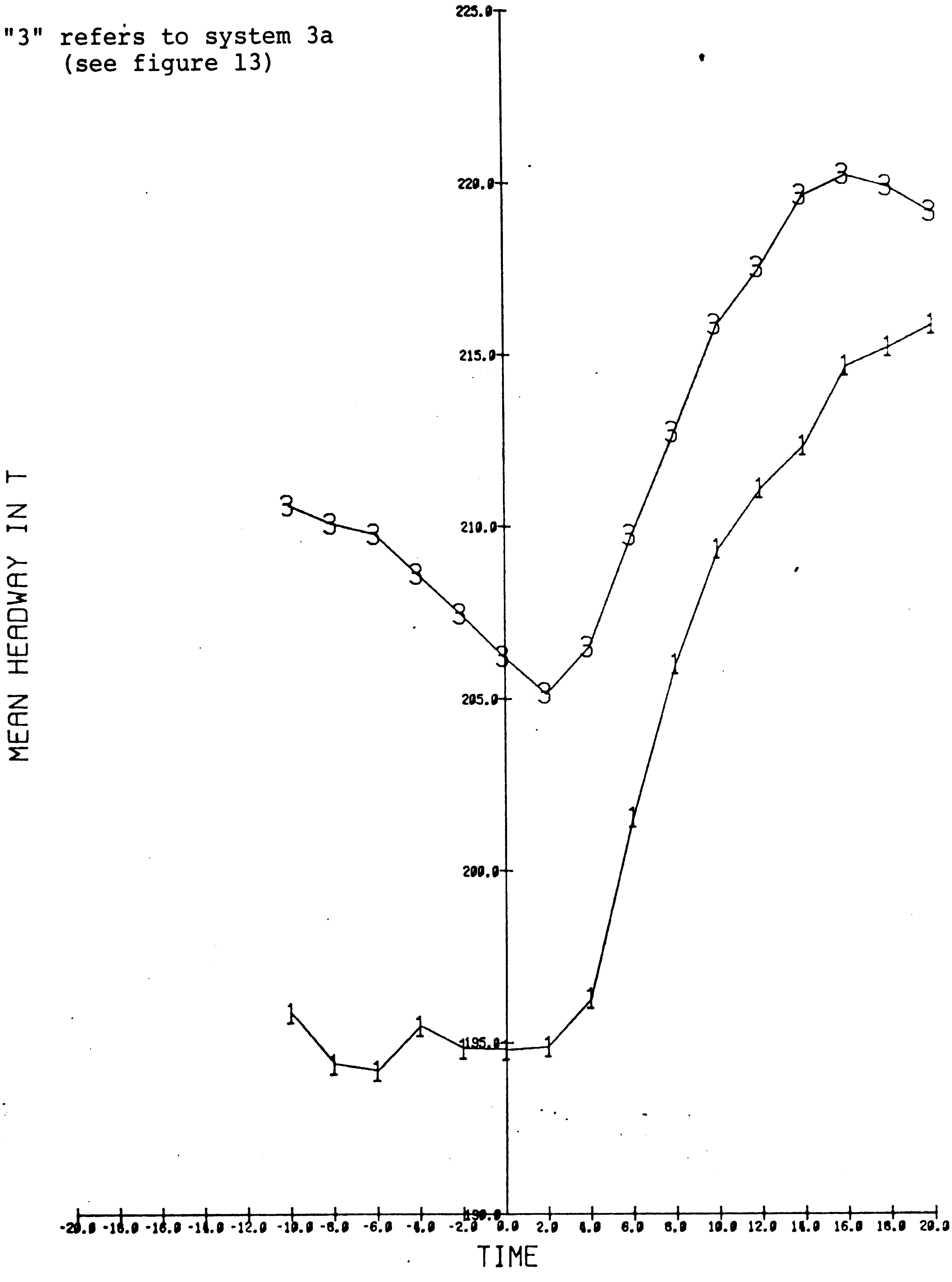


Figure 24. Study III: Mean headway from subject to lead vehicle during turn maneuvers.

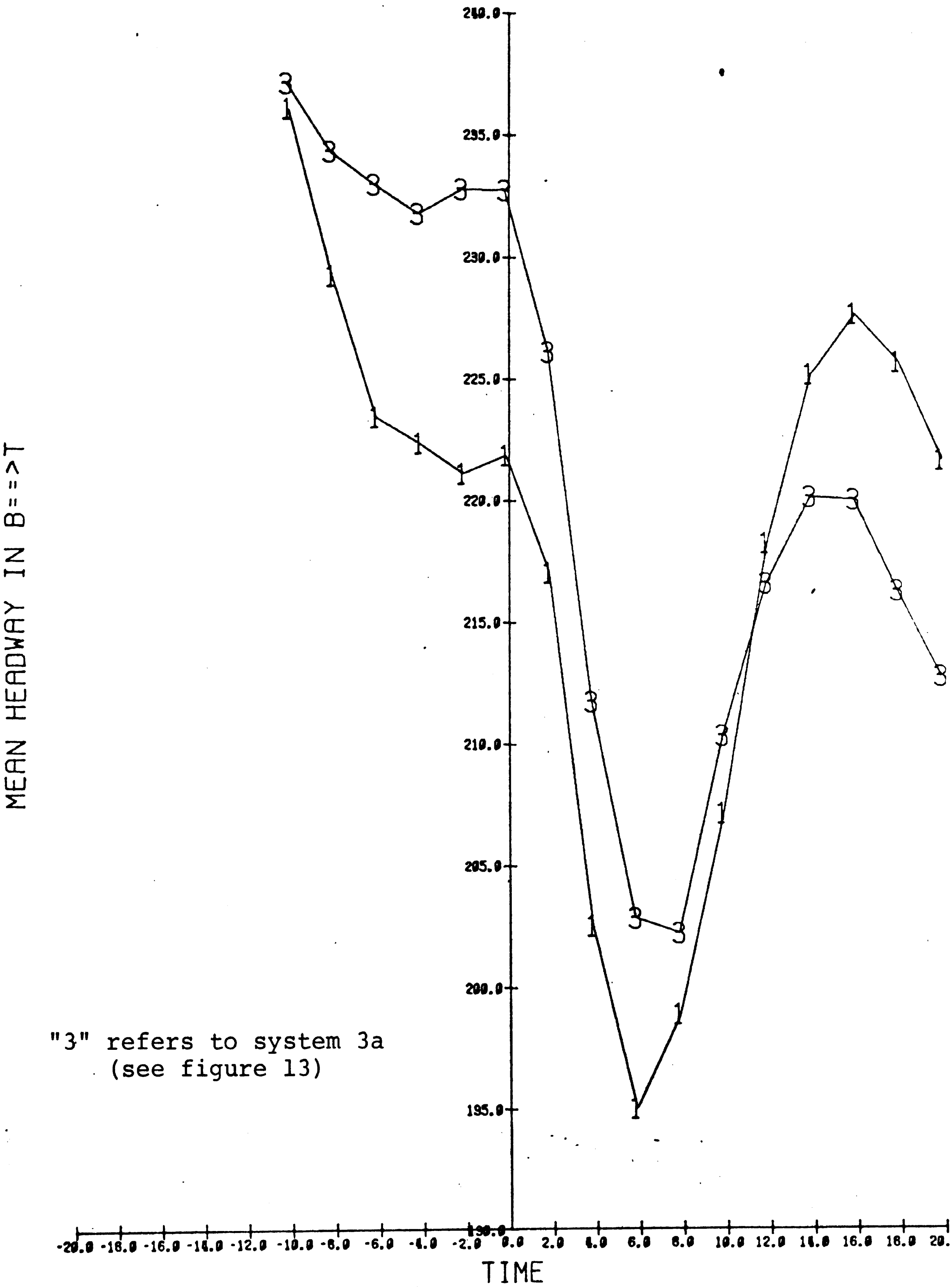


Figure 25. Study III: Mean headway from subject to lead vehicle during stop→turn maneuvers.

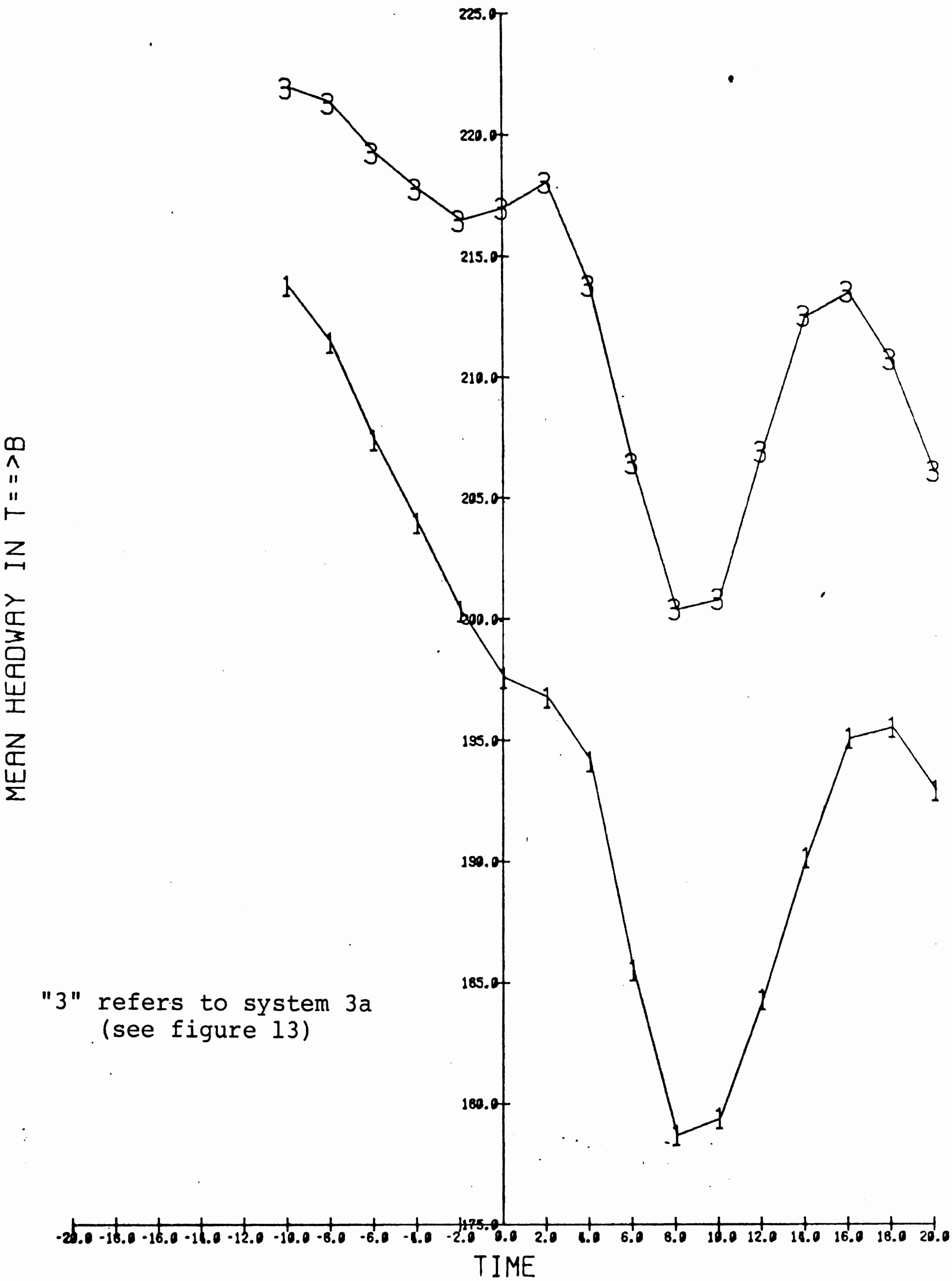


Figure 26. Study III: Mean headway from subject to lead vehicle during turn→stop maneuvers.

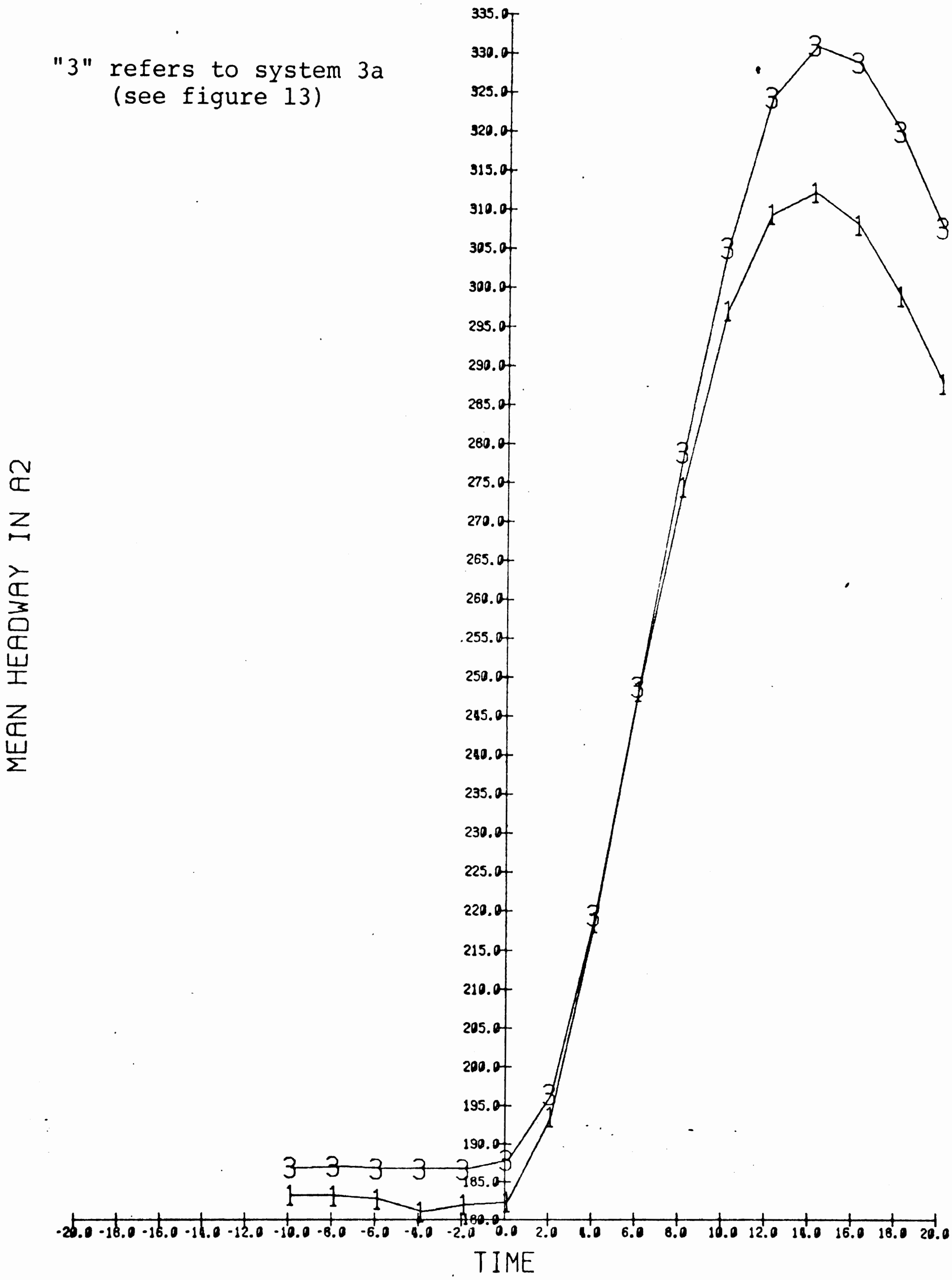


Figure 27. Study III: Mean headway from subject to lead vehicle during acceleration maneuvers, 30-50 mph acceleration shown.

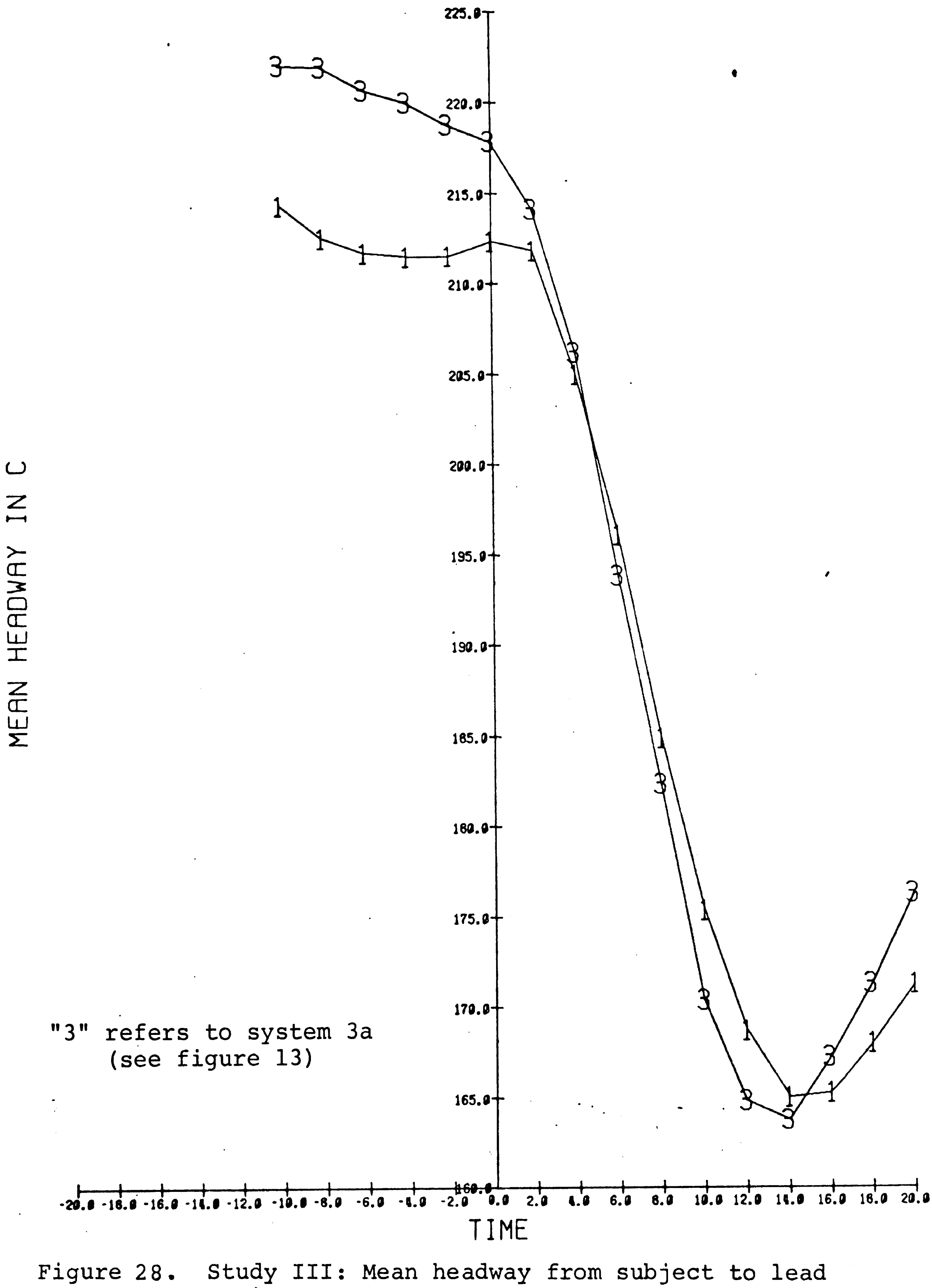


Figure 28. Study III: Mean headway from subject to lead vehicle during coast maneuvers.

multiple car-following situations may be brought about by moving signal lamps to a high enough position on the car body that they may be clearly seen through the windows of intervening vehicles.

CONCLUSIONS

The primary purpose of this investigation was to determine whether differences in car-following performance could be associated with lighting systems. On the surface it seems obvious that if subjects respond more slowly to brake signals presented by one system as compared to another system, this should produce differences in longitudinal control. Similarly, there is some information which suggests (Mortimer, 1968) that display geometry has an effect on the detection of headway changes. Again it would be anticipated this effect would result in differences in longitudinal control.

On the other hand, reaction time differences of a quarter or half a second, while they may be highly significant statistically, result in very small headway changes at moderate levels of deceleration. Further, these changes can be easily compensated for by a slight increase in deceleration by the following driver. Given the perceptual limitations of a driver in detecting relative speeds and headway changes, it is perhaps likely that subtle differences of the type sought would be lost in the rather high "noise" levels associated with car-following measures.

For whatever reason, the conditions of this study produced no reliable indications that traffic flow would be significantly affected by rear lighting systems. It remains as a possibility that different experimental conditions, especially higher deceleration levels, may have produced other results.

However, the results of these investigations have provided additional information regarding the attention-getting value of different vehicular rear signaling systems. These data support information from a variety of studies already reported in the literature (e.g., Mortimer, 1968) in demonstrating the value of redundancy and separation of function.

High-mounted signal lamps have been shown capable of significantly reducing reaction time to signals presented by cars ahead of the immediate lead vehicle. While no differences in platoon stability were demonstrated in the study, it seems likely that anticipatory information such as provided by this configuration would be of value given more severe conditions (e.g., shorter headways, higher decelerations).

These data suggest that the introduction of "upgraded" rear signaling systems would have no discernable effect on traffic flow under normal operating conditions. We can only speculate that the effect, if any, may be confined to severe maneuvers.

REFERENCES

Finch, D.M. Motor Vehicle Rear Lighting and Signaling. Final Report, Contract No. FH-11-6553, U.S. Department of Transportation, ITTE, University of California, 1968.

Mortimer, R.G. Psychological Considerations in the Design of an Automobile Rear Lighting System. Traffic Safety Research Review, 1968, Vol. 12, No. 1, 13-16.

Mortimer, R.G. Research in Automotive Rear Lighting and Signaling Systems. Engineering Publication 3303, General Motors Corporation, 1969a.

Mortimer, R.G. Dynamic Evaluation of Automobile Rear Lighting Configurations. Highway Research Record, 1969b, No. 275, 12-22.

Nickerson, R.S., Baron, S., Collins, A.M., and Crothers, C.G. Investigation of Some of the Problems of Vehicle Rear Lighting. Final Report, Contract No. FH-11-6558, U.S. Department of Transportation, Bolt, Beranek and Newman, Inc., Report No. 1586, 1968.

Projector, T.H., Cook, K.G. and Peterson, L.O. Analytic Assessment of Motor Vehicle Rear Signal Systems. Contract No. FH-11-6602, U.S. Department of Transportation, Century Research Corp., January 1969.

Rockwell, T.H. and Banasik, R.C. Experimental Highway Testing of Alternative Vehicle Rear Lighting Systems. Final Report, Contract No. FH-11-6552, U.S. Department of Transportation, Systems Research Group, Dept. of Industrial Engineering, Ohio State University, 1968.

THE VALUE OF REAR LAMP SHIELDING

by

Craig M. Jorgeson and Paul L. Olson

This paper describes an investigation of rear lamp shielding. The effect of shielding was compared with other variables, i.e., lamp intensity, color, background reflectance and signal configuration, under conditions of low and high sun angle. The results are complex, but the variable having the most effect on subject response was signal intensity. Shielding of rear signal lamps was of value, but under a more restricted set of circumstances than increased intensity.

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INTRODUCTION

A previous study (Mortimer et al., 1973) has shown that the daytime effectiveness of stop, turn and other signals provided by a rear lighting system can be significantly improved by increasing intensity. The increased brightness would be excessive at night, so a dual intensity lighting system is recommended. Since dual intensity systems will add cost and complexity, and there is concern whether they might be abused by drivers, there is a continuing interest in whether other means might be found to achieve commensurate increases in effectiveness without increasing signal intensity.

One means by which it may be possible to increase signal effectiveness is by shielding it from the sun. While shielding might prove helpful in general, it would be expected to have greatest benefit when the signal units are oriented toward the sun and the sun is low in the sky. Under these conditions sunlight reflected by the signal unit can make it difficult to determine whether the lamp is burning or not, greatly reducing the effectiveness of the signal.

This study was designed to evaluate shielding as an aid to signal effectiveness. To provide a basis for comparison, other factors were investigated as well, namely signal intensity, surround reflectivity, and signal coding. Most of the work was done with the sun low in the sky and behind the subjects, but some data were taken with the sun at zenith.

METHOD

SUBJECTS

Ten male subjects and fourteen female subjects were paid to participate in the study. One subject completed only the noontime session. Fifteen of the subjects were in their twenties, seven in their late thirties or early fourties, and two in their fifties.

APPARATUS

The primary pieces of equipment were a lamp display board with accompanying lamps and controls, a shutter in front of the subjects, the subjects' response boxes, and data recording panel.

The gray lamp display board, 70 inches wide and 60 inches in height, carried a 7-inch diameter ventilation duct, 58 inches long, placed over four 4-inch diameter lamps which were mounted at a height of 20 inches (Figure 29). A pair of lamps were placed near each end of the duct and holes were cut in the duct so the lamps were exposed. An aiming tube was placed perpendicular to the board so that the whole lamp array could be aligned with the position of the subjects. Crinkled aluminum foil was placed over the duct and lamp housings to represent a surround of high reflectivity ($\simeq$ 240%) such as a chrome bumper (Figure 30). Alternatively, black felt was placed over the duct and lamp housings to provide a flat black surround. Shields were constructed for the lamp housings which permitted two square inches of lamp surface to be viewed at 10 degrees above and below the horizontal centerline and 45 degrees left and right of the vertical centerline. These limits were selected based on Motor Vehicle Safety Standard No. 108, to provide a probable maximum of allowable shielding and minimum of angular visibility of the luminous surface of the lamps. The control panel permitted selection of the signal mode, lamp intensity, and lighting system mode of operation.

The lamp board was 250 feet in front of the subjects who were seated behind a large shutter mechanism (Figure 31). It obstructed the subjects' view of the signal lamp display except during signal presentations. The bottom panel fell at the onset of a signal presentation, allowing the lamp board to be viewed for five seconds, after which the second panel dropped, blocking the subjects' view. Each subject had a response box (Figure 32)

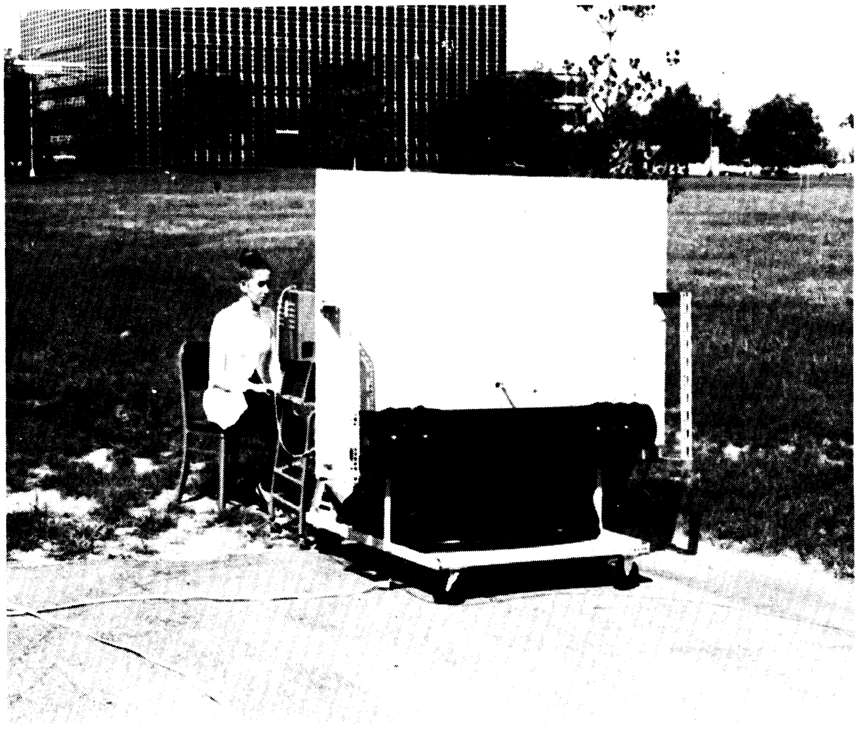

Figure 29. Photograph of lamp display board with low reflectance surround.

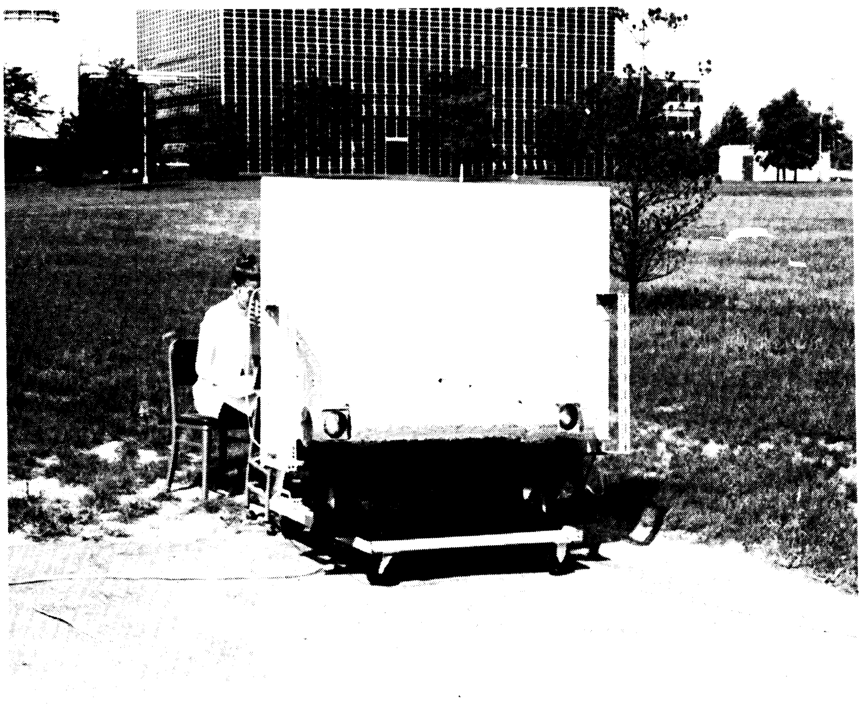

Figure 30. Photograph of lamp display board showing highly reflective surround.

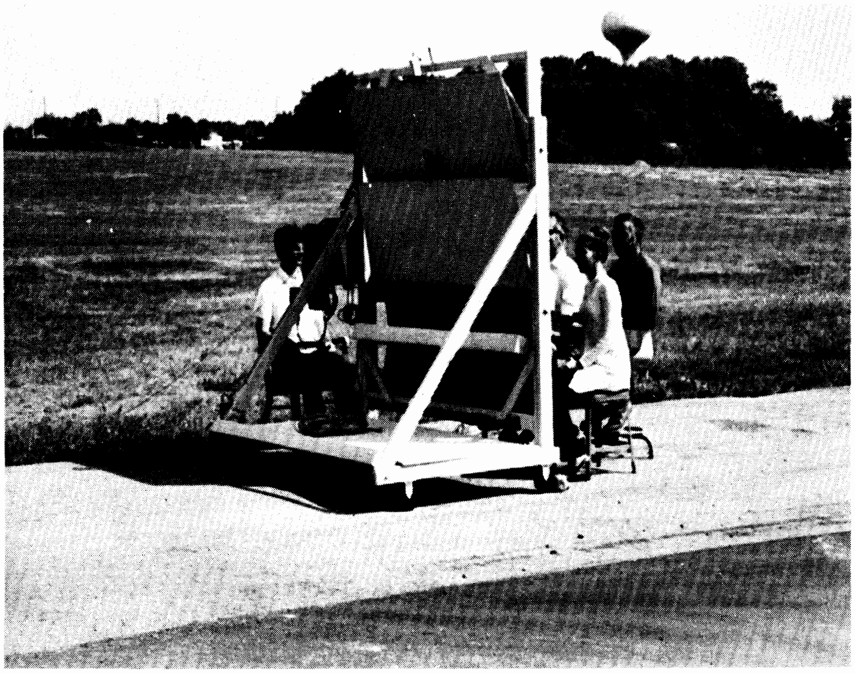

Figure 31. Shutter mechanism with subjects in position.

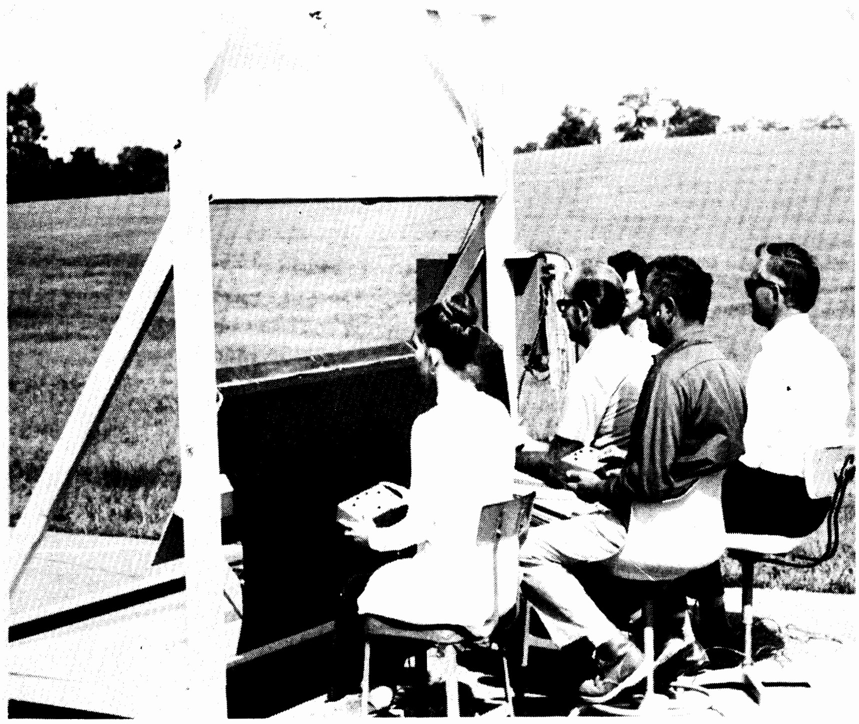

Figure 32. Shutter mechanism open for viewing. Subjects shown holding response boxes.

with four pushbutton switches. Before a signal presentation, the experimenter at the subjects' end designated the signal to be presented by turning the mode select switch on the subjects' response monitor and control panel (Figure 33). This set logic so that the reaction time clocks would not stop running after signal onset until the correct responses were made by the subjects. The panel also contained four Nixie-tube reaction timers, and lamps to monitor the responses of each subject. An intercom provided communication between the experimenters at the subjects' end and at the lamp board.

PROCEDURE

Not more than four subjects were scheduled per session. Each subject attended three sessions on the same day, weather permitting. The morning session lasted from approximately 7 a.m. to 9 a.m., the noon session from approximately noon to 1 p.m., and the afternoon session from approximately 4 p.m. to 6 p.m. The equipment was positioned so that the sun was always behind the subjects and falling on the signal lamps. Morning and afternoon sessions were considered to be the same in terms of sun angle on the lamps and simulated bumper. The purpose of a split session was to reduce the arc through which the sun moved during the sessions and to allow the subjects a substantial break, since a single session of four hours would have been too fatiguing.

Subjects were seated behind the shutter mechanism and were read the instructions, which are shown in the Appendix. These instructions requested the subjects to identify the signals that were presented by depressing the appropriate switches on the response box. The subjects then rated the presentation as "inadequate" or "adequate" in brightness, or "no signal" if they did not see a signal.

INDEPENDENT VARIABLES. The six independent variables were:

A. Sun Angle.

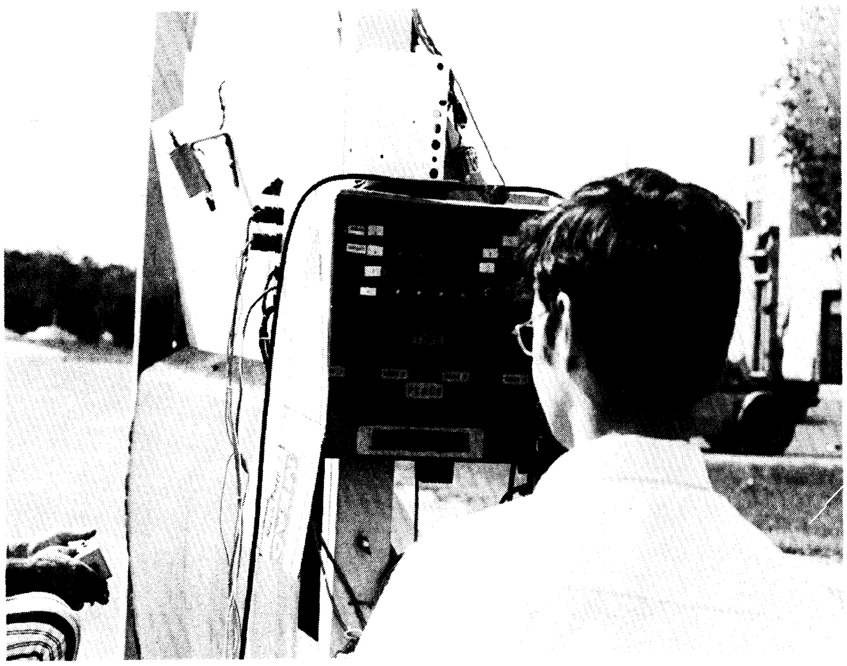

Figure 33. Experimenter's control panel.

1. Low (approx. 35 degrees: a.m. - p.m.)
2. High (approx. 65 degrees: noon)

B. Surround Reflectance
1. Black cloth (reflectance approx. 2.3%)
2. Aluminum foil (reflectance approx. 240%)

C. System
1.* Two red lamps for stop, turn, and presence.
3. Four red lamps with stop inboard, and turn combined with presence outboard.
12. Two red lamps inboard for stop combined with presence, and two amber lamps outboard for turn.

D. Signal Intensity
1. 15 cd (presence only)
2. 80 cd
3. 185 cd (stop, turn)
4. 425 cd

E. Lamp Shielding
1. Shielded
2. Unshielded

F. Signal Mode
1. Stop
2. Turn
3. Stop + Turn
4. Presence
5. No Signal

DEPENDENT VARIABLES. The dependent variables were:

A. Response time, in milliseconds, to correctly identify the signals. If no response was made, or if it did not include the correct response, the time was recorded as 10 seconds.

B. Signal Identification. The percent of signals identified correctly were analyzed. Correct responses were defined as those in which the signal mode was identified as presented,

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*These system numbers are used to be consistent with those used in other recent reports (e.g., Mortimer, 1969; 1970; 1971; 1974).

but the inclusion of a presence response to stop and/or turn signal responses was not considered an error of commission.

C. Brightness Rating. Each signal that was seen was rated for adequacy in brightness, as follows:

1. Inadequate
2. Adequate
3. No signal

After any questions asked by the subjects about the procedure were answered, approximately eighteen familiarization trials were given, using all surround-system combinations. Stop, turn, and stop + turn were presented at 185 cd with no shielding. Subjects were observed to make sure they understood the procedure and were responding reasonably.

EXPERIMENTAL DESIGN

The order of treatments that was followed throughout the experiment, randomized order within each of the variables. Hence, all signal modes for a particular surround-system-intensity-shielding condition were presented before the shielding condition was changed. Half of the 180 presentations were given in the morning and the remaining half in the afternoon. The noontime session differed in that only system 1 was presented; hence, only 60 trials were required.

RESULTS

RESPONSE TIME ANALYSIS

LOW SUN ANGLE. For the low sun angle condition a five-factor analysis of variance was conducted on the response times associated with each signal mode. The five factors were: surround reflectance, system, signal intensity, lamp shielding, and subjects. A Newman-Keuls test was then run on each interaction that was significant at $p \leq .01$.

1. Stop Mode. The mean reaction time to stop signals were

3.87 seconds at 80 cd, 2.91 seconds at 185 cd and 2.25 seconds at 425 cd. These differences are significant ($p \leq .01$). Mean reaction times with a black surround were 2.59 seconds, with a chrome surround: 3.36 seconds.

2. Turn Mode. The main effect of systems and the interaction of shielding x intensity were significant. The red turn signals of systems 1 and 3 resulted in significantly lower mean response times (means of 2.27 and 2.29 seconds, respectively) than the yellow signal of system 12 (mean of 2.55 seconds). At all signal intensities shielding was better than without shielding. In the shielded condition, there were no significant differences due to signal intensities; whereas without shielding the higher the signal intensity the shorter the mean response time (Table 1).

3. Presence Mode. The interaction of signal intensity x system x surround was the only significant effect. Across systems no significant differences occurred within surround and signal intensity, but across signal intensities, 425 cd resulted in a significantly shorter mean response time than 185 cd for system 1 when the surround was black (Table 2).

4. No Signal Mode. A significant interaction of shielding x system x surround occurred. There were no significant differences among systems with either surround when the lamps were shielded. When the lamps were not shielded, with black surround system 12 was better than 1 and 3. Also, when unshielded, with aluminum surround system 1 resulted in a shorter mean response time than system 12 (Table 3). Given a black surround, shielding was very effective in the no signal mode. It was of less consequence given a chrome surround.

5. Stop + Turn Mode. The only significant effect was on signal intensity, with mean reaction times for 185 and 425 cd (3.46 and 3.11 seconds, respectively) being less than for 80 cd (4.41 seconds) ($p < .05$).

TABLE 1. Mean Reaction Times in Seconds to Turn Signals at Low Sun Angles as a Function of Intensity and Shielding.

Signal Intensity	Shielded	Not Shielded
80	2.13	2.93
185	2.09	2.61
425	2.09	2.46

TABLE 2. Mean Reaction Times in Seconds to Presence Indications at Low Sun Angles as a Function of Surround, System and Intensity.

	Black Surround			Aluminum Surround		
Signal Intensity	System 1	System 3	System 12	System 1	System 3	System 12
80	2.85	2.90	3.06	3.28	3.35	3.89
185	3.66	2.84	3.03	3.34	3.45	4.19
425	2.34	3.08	3.01	3.98	3.40	4.46

TABLE 3. Mean Reaction Times in Seconds For No Signal Conditions at Low Sun Angles as a Function of Surround, Shielding and System.

	Black Surround		Aluminum Surround	
System	Shielded	Not Shielded	Shielded	Not Shielded
1	1.96	7.22	2.32	3.15
3	1.94	7.03	1.97	3.96
12	1.96	5.27	2.23	4.66

HIGH SUN ANGLE. The same analyses were conducted for the high sun angle as for the low sun angle. It will be recalled that only system 1 was used at noon.

1. Stop. Mean response times to stop signals varied ($p<.05$) as a function of intensity (80 cd = 3.49 secs, 185 cd = 2.39 secs, and 425 cd = 2.10 secs) and surround (black = 2.33 secs, chrome = 2.92 secs). No other effects were significant.

2. Turn. Mean reaction times for turn signals at 185 cd and 425 cd (2.08 and 2.06 secs, respectively) were significantly lower than 80 cd (2.26 secs). Black surround was a significant improvement over aluminum surround (2.05 and 2.22 secs, respectively).

3. Presence. At stop/turn signal intensities of 80 cd there were no significant differences in reaction times to the presence mode between surrounds, but at 185 cd and 425 cd the black surround was superior to the aluminum surround (Table 4).

TABLE 4. Mean Reaction Times in Seconds to Presence Indications at High Sun Angles as a Function of Surround and Signal Intensity.

Signal Intensity	Black Surround	Aluminum Surround
80	3.10	4.19
185	2.42	4.80
425	2.88	4.10

4. No Signal. The interaction of shielding and surround was significant. With black surround shielding resulted in shorter reaction times than no shielding (1.99 vs 2.93 secs, respectively), but with the aluminum surround there were no differences between shielding and no shielding (2.13 and 2.11 secs, respectively).

5. <u>Stop - Turn</u>. Mean response times varied as a function of signal intensity (80 cd = 3.75 secs, 185 cd = 3.34 secs, and 425 cd = 2.81 secs). The difference between 80 cd and 425 cd was significant ($p<.01$) as was the difference between 185 cd and 425 cd ($p<.05$).

SIGNAL IDENTIFICATION ANALYSIS

LOW SUN ANGLE. An analysis of variance was conducted on the five factors of shielding, surround, signal intensity, system, and signal mode. The analysis was based on the percent of signals identified correctly with presence a permissible addition to stop, turn, and stop + turn. Newman-Keuls tests were conducted on all significant ($p\leq.01$) interactions. The percent of signals identified correctly is shown in Table 5 for each signal mode. The most usual errors were to call a signal "presence," to call presence "stop" or "no signal," and to call no signal "presence."

In the analysis of variance of the percent of signals correctly identified, significant interactions were found for shielding x system; shielding x intensity x surround; intensity x mode; and surround x mode. Newman-Keuls tests on the shielding x system interaction showed that in the shielded condition there were no significant differences between systems (90-92% correct); in the unshielded condition system 1 resulted in significantly more signals correctly identified (90%) than systems 3 and 12 (86 and 83%, respectively). In the shielding x intensity x surround interaction, at 80cd and 425 cd with black surround, better signal identification occurred in the shielded than unshielded condition (90% vs 81% at 80 cd, 97% vs 92% at 425 cd). At 185 cd, with the aluminum surround, shielding also increased signal identification 90% vs 82%). In the remaining conditions, that is, 80 cd and 425 cd with aluminum surround and 185 cd with black surround, there were no significant effects due to shielding. For the stop mode, 425 cd resulted in relatively more signals correctly identified than at 80 cd and 185 cd (98% vs 73% and 84%, respectively), and 185 cd than 80 cd. For the turn, presence, and no-signal modes there were no significant effects of signal intensity. For stop + turn, 425 cd and 185 cd (94% and 90%, respectively) provided better identification than 80 cd (71%). The Newman-Keuls test on the surround x signal mode interaction (Table 5) indicated that more correct identifications were achieved with stop, presence, and stop + turn with a black surround than the aluminum surround. For turn and no-signal modes no significant differences between surrounds were found.

HIGH SUN ANGLE. The four factors used in the analysis of variance of the percent of signals correctly identified in the high sun angle condition were: shielding, intensity surround, and mode. The error of commission of presence to stop, turn, and stop + turn signals was considered acceptable, as before. Two significant main effects were found: surround and mode. Identification was significantly higher with black surround (91% vs 86%), and lower for the presence mode than all other modes (79% vs 85% for stop, 96% for turn and no-signal, and 86% for stop + turn).

BRIGHTNESS RATINGS

LOW SUN ANGLE. An analysis of variance of the brightness ratings was run on the five factors of: shielding, intensity, system, surround, and mode. Five interactions were significant: intensity x system x surround; shielding x intensity x mode; shielding x system x mode; intensity x system x mode; and system x surround x mode (see Table 6).

With a black surround and a signal intensity of 80 cd and 185 cd, system 1 received a significantly greater percent of adequate brightness ratings (80 cd = 86%, 185 cd = 94%) than systems 3 and 12 (80% and 85% for system 3, 48% and 69% for

TABLE 5. Percent of Correct Identifications for Various Signals as a Function of Shielding and Signal Intensity.

Signal Intensity	Stop		Turn		Presence		Stop + Turn		No Signal	
	Shielded	Not Shielded	Shielded	Not Shielded	Shielded	Not Shielded	Shielded	Not Shielded	Shielded	Not Shielded
80	70	76	100	92	84	75	80	71	99	51
185	85	82	98	96	84	71	91	88	99	53
425	98	97	97	94	81	80	96	92	99	51

TABLE 6. Percent of Signals Judged Adequate as a Function of Mode, Shielding and Intensity, Low Sun Angle.

Signal Intensity	Stop		Turn		Presence		Stop + Turn	
	Shielded	Not Shielded	Shielded	Not Shielded	Shielded	Not Shielded	Shielded	Not Shielded
80	81	74	75	42	61	42	84	52
185	92	81	92	67	54	47	94	78
425	98	94	97	81	55	43	99	88

system 12), and system 3 than system 12. At 425 cd system 1 was significantly different from 3 (95% vs 84%). With an aluminum surround, at 80 cd and 185 cd, systems 1 and 3 (59% and 75% respectively for system 1, 65% and 75% for system 3) were significantly different from 12 (46% and 60%, respectively); whereas, at 425 cd system 3 (79%) was significantly different from 12 (69%). Except for stop signals at 80 cd and 425 cd, where there were no significant differences in shielding, shielding resulted in a significantly greater percent of adequate brightness ratings than non-shielding.

HIGH SUN ANGLE. The four factors on which the analysis of variance was conducted were shielding, intensity, surround, and mode. The only significant effect was surround x mode with a Newman-Keuls test showing that the black surround resulted in more ratings of adequate brightness than the aluminum surround, for the presence mode only (73% adequate ratings with black and 17% with aluminum).

The unshielded stop signal of systems 1 and 3 was rated significantly more often as adequately bright than in system 12. The turn signal of system 12 was rated less often as adequately bright than systems 1 and 3 in shielded and unshielded conditions. The unshielded presence mode of system 1 was rated more often as adequately bright than systems 3 or 12. Unshielded or shielded stop + turn signals of systems 1 and 3 were more often rated adequately bright than system 12.

SUMMARY AND CONCLUSIONS

The factors of interest in this study were the presence or absence of shielding, signal intensity, reflectance of the surround against which the signal was presented and signal coding. Three criteria were employed: reaction time, errors and subjective opinion.

The results of the several analyses run on the data were very complex. An attempt will be made here to summarize the results in terms of the variables of interest.

The factor most often associated with significant differences was signal intensity. In general, the brighter the signal, the shorter the reaction time, the fewer errors would occur, and the higher the ratings.

Both surround reflectivity and shielding affected results, though not to the extent that signal intensity did. The presence of shielding shortened reaction times, reduced errors and improved ratings where any effect could be detected at all. Shielding tended to reduce the effect of different signal intensities, sometimes eliminating the effect altogether. It had been anticipated that shielding effects would be most marked with the highly reflective surround, but this effect did not appear to an appreciable extent. Shielding had virtually no effect at high sun angles.

The effect of background reflectivity was generally the same as shielding except for the no-signal instance, where performance was poorer with the low reflectivity surround when unshielded. This came about because reflected sunlight in the lamps could be more readily seen (and interpreted as a signal) against the dark surround.

The effect of system was mixed. The amber turn signals of system 12 performed poorly in general. Otherwise performance varied depending on other parameters and there was no clear superiority for any system.

As noted in the introduction, shielding is one way in which it may be possible to increase signal effectiveness without the problems of a dual intensity system. The most important question to be asked of the data from this investigation is "how does the relative effectiveness of shielding and increased intensity compare?" Phrased differently the question might be "at what point does increasing intensity equal the effectiveness of shielding?" Unfortunately, the answer is not as clear as one would like.

The data suggest that for most cases, excepting only when the signal lamps are oriented toward the sun, shielding would have negligible effect. Increased intensity, on the other hand, resulted generally in shorter response times. A low reflectance surround also generally shortened response times as well as reducing errors and improving effectiveness ratings.

Given a combination of low sun angle and signals oriented toward the sun, there are indications of improved effectiveness associated with shielding. The effects were not consistent, however. For example, response times were significantly shorter for turn signals and the no-signal condition when shielded, while other signals (stop, stop + turn, and presence) were unaffected. Shielding eliminated signal system effects as measured by error frequencies and generally reduced errors, especially against a low reflective surround. Ratings were also generally improved by shielding.

Thus, the results of this investigation suggest: (1) shielding may provide limited benefits under some circumstances, and (2) there appear to be no adverse performance effects associated with shielding. However, the rather limited and specific conditions under which shielding is helpful rule it out as a substitute for increased signal intensity.

REFERENCES

Mortimer, R.G., Moore, C.D., Jr., Jorgeson, C.M. and Thomas, J.K. Passenger Car and Truck Signaling and Marking Research: 1. Regulations, Intensity Requirements and Color Filter Characteristics. Highway Safety Research Institute, University of Michigan, Report No. UM-HSRI-HF-73-18.

A REVIEW OF THE LITERATURE CONCERNING THE EFFECTS OF ALCOHOL AND OTHER DRUGS UPON COLOR PERCEPTION

by

Samuel P. Sturgis

This paper is a review of the literature concerning the effects of alcohol and other drugs on the perception of color. It appears that color perception is relatively unaffected by normal dosages of most common drugs. These data are somewhat incomplete, however, and much further research is required.

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A REVIEW OF THE LITERATURE CONCERNING THE EFFECTS OF ALCOHOL AND OTHER DRUGS UPON COLOR PERCEPTION

I. ALCOHOL EFFECTS

A majority of the literature concerning the effect of alcohol on color perception is characterized by a lack of precision in measurement technique, as well as inconsistencies in dose specification and administration. A number of examples follow:

Schultz (1916) using very small alcohol doses (0.03-0.15 g/kg) found the ability to discriminate brightness differences between pairs of red and green lights improved by lower doses and impaired by higher doses. Zeiner-Heinriksen (1927) in a test of color discrimination administered "at least 30 cc absolute alcohol" to an unspecified number of subjects and found decreased discrimination of "spectral" colors red, yellow, and green and increased discrimination of blue, indigo, and violet. Fatigue was found to increase the deterioration. The exact test procedure and apparatus was not described. Colson (1940) administered a bettery of tests to 21 subjects who had consumed enough scotch or rye whiskey to "reach the limits of gastric tolerance." No change in the ability to read Ishihara charts was found following the administration of alcohol. Peters (1942) mapped the peripheral fields for motion, form, blue, red, and green for one subject prior to, and following the administration of seven bottles of beer. The major effects found were contractions of the red and green fields and a total collapse of the blue field. No change was found in either the motion or form fields. All fields were found to be normal twenty hours after the cessation of drinking. A reduction in the right and left horizontal lateral field of red was reported by Mortimer and Sturgis (1975) at a blood-alcohol concentration of 0.10%. No effect was noted for white, yellow, green or blue stimuli. Popov and Popov (1953) examined the perception of color in afterimages to bright stimuli, and found only a general weakening of the effect following a dose of 1 g alcohol per kilogram body weight. Schmidt and Bingel (1953) measured the color saturation thresholds for red, blue, and green in 33 inexperienced drinkers. No change in threshold was found after the consumption of either 30 or 45 cc of alcohol, but a general raising of thresholds for all three colors which lasted for 30 minutes was found following the administration of 60 cc of alcohol. Rizzo (1957) using Nagel's anomalascope, found a diminished sensitivity of red relative to green, in sixteen subjects following a dose of approximately 1 g alcohol per kilogram body weight. Stewart (1964) found no changes in color vision as measured by Pseudo-Isochromatic plates in six subjects at BAC's of "less than 0.15%." A "slight reduction" in the extent of peripheral fields was found, however.

Several studies (Cruz-Coke, 1964, 1965; Cruz-Coke & Varela, 1965, 1966; Varela, Rivera & Mardones, 1969; Sassoon, Wise & Watson, 1970; Swinson, 1972) have reported an abnormally high incidence of color vision defects in alcoholics and alcoholics suffering from cirrhosis of the liver. This association has variously been attributed to: a sex-linked genetic factor which predisposes alcoholism and color blindness (Cruz-Coke, Varela, et al.); a depletion of vitamins or other biochemical substances necessary for normal color vision (Smith & Brinton, 1971; Fialkow, Thuline & Fenster, 1966); the use of inappropriate color vision tests and/or methodological errors on the part of the experimentors (Thuline, 1972). The fact that the association has been confirmed by a large number of independent researchers indicates that it does exist. Additionally, the color vision anomalies have been found nearly equally distributed across sex, which supports the hypothesis that the association is acquired rather than genetically determined. A large proportion of the anomalies discovered have been of tritanopic (blue-yellow blind) or protanomalous-tritanopic types (Varela et al., 1969; Swinson, 1972), which are assumed to be rarely congenital but commonly acquired (Swinson, 1972). The duration of the defects is quite unclear. Smith and Brinton (1971) and Fialkow et al. (1966) reported recovery of normal color vision in 70% to 80% of their initially diagnosed color vision defective alcoholic subjects who were treated with vitamins and nutritious meals. Swinson (1972), however, concluded that the defects he found were "semi-permanent" as his subjects were not tested until they were "physically well" and had received adequate diets for several weeks. Swinson reports that he is examining the effects of long-term sobriety on alcoholics' color vision.

II. NON-PRESCRIPTION DRUG EFFECTS

Carter (1969) examined the effects of "maximum normal doses" of alva-tranquil, empirin, dristan, excedrin, bromo-seltzer, sominex, cosanyl, donnagel, asthmador cigarettes, wyamine inhaler, and medihaler epi on color vision as measured by a A.A.A. color vision tester. The fact that no effect was found is hardly surprising, considering that the task requires naming the color of a constant brightness piece of red, green or amber traffic signal glass.

Schmidt and Bingel's 1953 study also investigated the effect of caffeine as taken in coffee on the saturation thresholds for red, green and blue. Measurements taken up to an hour after the consumption of .16 g caffeine in two cups coffee showed an improvement in the recognition of red and blue at threshold.

III. PRESCRIPTION DRUG EFFECTS

Sloan and Gilger (1947) found color discrimination under high brightness conditions to be greatly debilitated in patients taking tridone, an anti-convulsant drug used in the treatment of epilepsy. Color fields for blue and red were found to be normal when measured against a dark background, and completely collapsed when measured against a white background of high illumination.

In a color discrimination test the same subjects showed significant abnormalities with red and green stimuli, and a lessened effect with yellow and blue stimuli. The authors noted that the impairment exists only while the drug is in the system, affects cone function throughout the retina, and lessens with exposure to the drug. Grutzner (1969) reported on the effects of chloroquine (an anti-malaria drug also used in the treatment of rheumatorial arthritis), indometracin (also used to treat rheumatorial arthritis), thioridazine (a tranquilizer used to sedate persons with nervous-mental disorders), and digitalis (a cardiac stimulant). Each of the drugs were found in some cases to damage the retina and cause defective hue discrimination which generally lessened or disappeared when use of the drug was discontinued. The effects found were generally tritanopic, meaning that sensitivities to differences in hues of blues, blue-greens, and green were reduced.

Laroche (1967; 1971) has found hue discrimination to be temporarily impaired by antibiotics such as streptomycin and dihydrostreptomycin and has also found partial alleviation of congenital protanopic and deuteranopic symptoms through administration of vitamins A and B, respectively. Laroche also found chlortetracycline, spinamycine, chloramphenicol, streptomycine, difrarel 100, and aneurine to have small but measureable effects on hue discrimination. Normal color vision returned with cessation of treatment.

IV. PSYCHOTOMIMETIC DRUG EFFECTS

Hartman and Hollister (1963) studied the effects of LSD, mescaline, and psilocybin on hue discrimination, color afterimage intensity and duration, and the elicitation of subjective colors produced by intermittent light (flicker), a pure tone, and the combination of flicker and pure tone. Eighteen subjects were administered the drugs at weekly intervals, in random orders, Hue discrimination was decreased significantly by psilocybin only, while reports of colors in afterimages were increased by all three drugs. The elicitation of subjective color from flicker and tones alone were increased significantly by LSD and mescaline, while LSD was the only drug to elicit more reports of subjective color from the combination of flicker and tone. The authors interpret the results as indicating that stimuli which evoke subjective color phenomena are enhanced by psychomimetics, while the usual perception of color may be slightly impaired.

Siegel (1969, 1970) reported similar results in studies with pigeons. In the earlier study, pigeons trained to respond to color changes on a visual display increased their responding when no change had taken place after the administration of either marijuana extracts or LSD. In the later study, birds trained to respond to the presence or absence of a changing color stimulus responded more frequently to white light when under the influence of LSD. Marijuana in an alcohol solution reduced the error rate, while the administration of alcohol alone had no effect on the error rate.

V. SUMMARY

The ability to perceive color under normal conditions has been shown to be relatively resistant to impairment by normal doses of most common drugs. Normal use of alcohol in moderate doses may impair color discrimination or brightness perception at threshold levels, but has a negligible effect upon gross color vision as measured by the ability to correctly interpret Ishihara or similar isochromatic color plates. Peripheral color vision appears to be much more sensitive to deterioration under alcohol although the relationship of dose to actual impairment remains to be quantified.

Several studies have demonstrated an abnormally high incidence of color vision defects in alcoholics. While the effect appears to be secondary to the disease and is apparently reversible through the administration of vitamins and improved diet, it may be assumed that impaired color vision is disproportionately distributed in this population.

The effects of other drugs, including psychotomimetics, over-the-counter non-prescription drugs, and prescription drugs also require quantification. The fact that caffeine has been shown to increase the recognition of colors at threshold implies that stimulants as a group may improve color vision, but other stimulants have not as yet been studied. Psychotomimetics as a group apparently increase the propensity to visualize color in neutral stimuli, but may slightly impair "normal" color vision. Over-the-counter drugs require much more study with more subtle measures of color vision. Prescription drugs such as tridone, chloroquine, indomethacin, thioridazine, and digitalis have been shown to have specific effects on retinal function and color vision, but the resultant impact on behavior has not been completely examined.

REFERENCES

Carter, M.K. The effects of selected non-prescriptive drugs on specific psychophysical driving skills. Utah University, College of Health, Physical Education and Recreation, 1969.

Colson, Z.W. The effect of alcohol on vision. JAMA, 115: 1525-1527, 1940.

Cruz-Coke, R. Color blindness and cirrhosis of the liver. Lancet, 1: 1064, 1964.

Cruz-Coke, R. Color blindness and cirrhosis of the liver. Lancet, 1: 1131-1133, 1965.

Cruz-Coke, R. and Varela, A. Color blindness and alcohol addiction. Lancet, 2: 1348, 1965.

Cruz-Coke, R. and Varela, A. Inheritance of alcoholism; its association with color blindness. Lancet, 2: 1282-1284, 1966.

Fialkow, P.J., Thuline, H.C. and Fenster, L.F. Lack of association between cirrhosis and the common types of color blindness. New Eng. J. Med., 275: 584-587, 1966.

Grutzner, P. Acquired color vision defects secondary to retinal drug toxicity. Ophthalmologica (Basel), Suppl: 592-604, 1969.

Hartman, A.M. and Hollister, L.H. Effect of mescaline, LSD, and psilocybin on color perception. Psychopharmacoligia (Berlin), 4: 441-451, 1963.

Laroche, J. [Modifications of color vision in man under the action of certain medicamentous substances.] Ann. Oculist., 200: 275-286, 1967.

Laroche, J. and Garoche, C. [Modification of color vision by the actions of several antibiotics and vitamins.] Theropie, 26: 671-685, 1971.

Mortimer, R.G., and Sturgis, S.P. Effects of alcohol on driving skills, final report. HSRI, Jan. 3, 1975. 123 p. Report no. UM-HSRI-HF-75-1. Sponsored by the National Institute on Alcohol Abuse and Alcoholism. Grant nos. MH-20666 and AA-00295. (PB-240-774/0)

Peters, H.B. Changes in color fields occasioned by experimentally induced intoxication. J. App. Psych., 26: 692-701, 1942.

Popov, N.A. and Popov, C. [Contribution to the study of cortical function in man by the method of electrocortical conditioned reflexes. II. The modification by alcohol of the colors of after-images.] C.R. Acad. Sci. Paris, 237: 1439-1441, 1953.

Rizzo, P. Effetto dell'alcool sull'equazione di Rayleigh All' anomaloscope di Nagel. Riv. Med. aero., 18: 338-357, 1955.

Sassoon, R.F., Wise, J.B. and Watson, J.J. Alcoholism and color vision: are there familial links? Lancet, 2: 367, 1970.

Schmidt, I. and Bingel, A.G.A. Effect of oxygen deficiency and various other factors on color saturation thresholds. U.S. Air Force School of Aviation Medicine, Project No. 21-31-002, April 1953.

Schultz, H. [On the effects of alcohol on color vision.] Pfluger's Archiv fur die gesamte Physiologie, 164: 274-294, 1916.

Siegel, R.K. Effects of cannabis sativa and lysergic acid diethylamide on a visual discrimination task in pigeons. Psychopharm., 15: 1-8, 1969.

Siegel, R.K. Effects of cannabis sativa and LSD on pigeons in three visual environments. Percep. Mot. Skills, 30: 510, 1970.

Sloan, L.L. and Gilger, A.P. Visual effects of Tridone. Amer. J. Opthalmology, 30: 1387-1405, 1947.

Smith, J.W. and Brinton, G.A. Color vision defects in alcoholism. Quart. J. Stud. Alc., 32: 41-44, 1971.

Stewart, C.R. A demonstration of the effects of alcohol on vision. J. Am. Optometric Assn., 35: 289-290, 1964.

Swinson, R.P. Color vision defects in alcoholism. Br. J. Physiol. Opt., 27: 43-50, 1972.

Thuline, H.C. Considerations in regard to a proposed association of alcoholism and color blindness. Annals N.Y. Acad. Sci., 197: 148-151, 1972.

Varela, A., Rivera, L., Mardones, J., and Cruz-Coke, R. Color vision defects in non-alcoholic relatives of alcoholic patients. Brit. J. Addict., 64: 67-76, 1969.

Zeiner-Heinriksen, K. Sansefysiologiske ienundersrelser. Oslo: J. Bjrnstad.

THE INCIDENCE OF FOG, RAIN, SNOW, AND SUNLIGHT IN VARIOUS REGIONS OF THE UNITED STATES

by

J. Kirby Thomas

This paper is a compilation of data reflecting the incidence of weather conditions which influence the detectability of rear lighting signals. Data are presented on the incidence of fog, precipitation, snow and sunlight for the year 1970.

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INTRODUCTION

A review of meteorological records was conducted in order to evaluate the probability of exposure of drivers to fog, rain, snow, and sunlight conditions. Data on these conditions was extracted from tables in "Climatological Data - National Summary" published by the U.S. Department of Commerce for the year 1970. Numbers plotted on the following four maps of the United States indicate the number of days in the year 1970 a particular condition existed at a specific weather station. Data from a sample of weather stations was used. Stations were selected on the basis of completeness of data reported and on population of surrounding area. Stations in remote areas or stations for which data was incomplete were not selected. Localities in which a particular condition existed within some range of days were grouped together and thus general weather patterns for particular conditions across the continental United States become apparent.

FOG (Figure 34)

Data in "Climatological Data - National Summary" for fog conditions were in terms of number of days of "heavy fog" - which was not defined. The eastern and western coastal areas had a higher incidence of heavy fog than the interior regions. Extreme instances of heavy fog (over 50 days per year) occurred in relatively small isolated areas.

PRECIPITATION (Figure 35)

Data on precipitation are in terms of number of days in which 0.01 in. or more of rain accumulated. The map indicated the expected variation - southwestern area having the least precipitation (0.01 in. or more on less than 15% of days in year) and northeastern and northwestern areas having the most precipitation (0.01 in. or more on more than 40% of days in year).

SNOW (Figure 36)

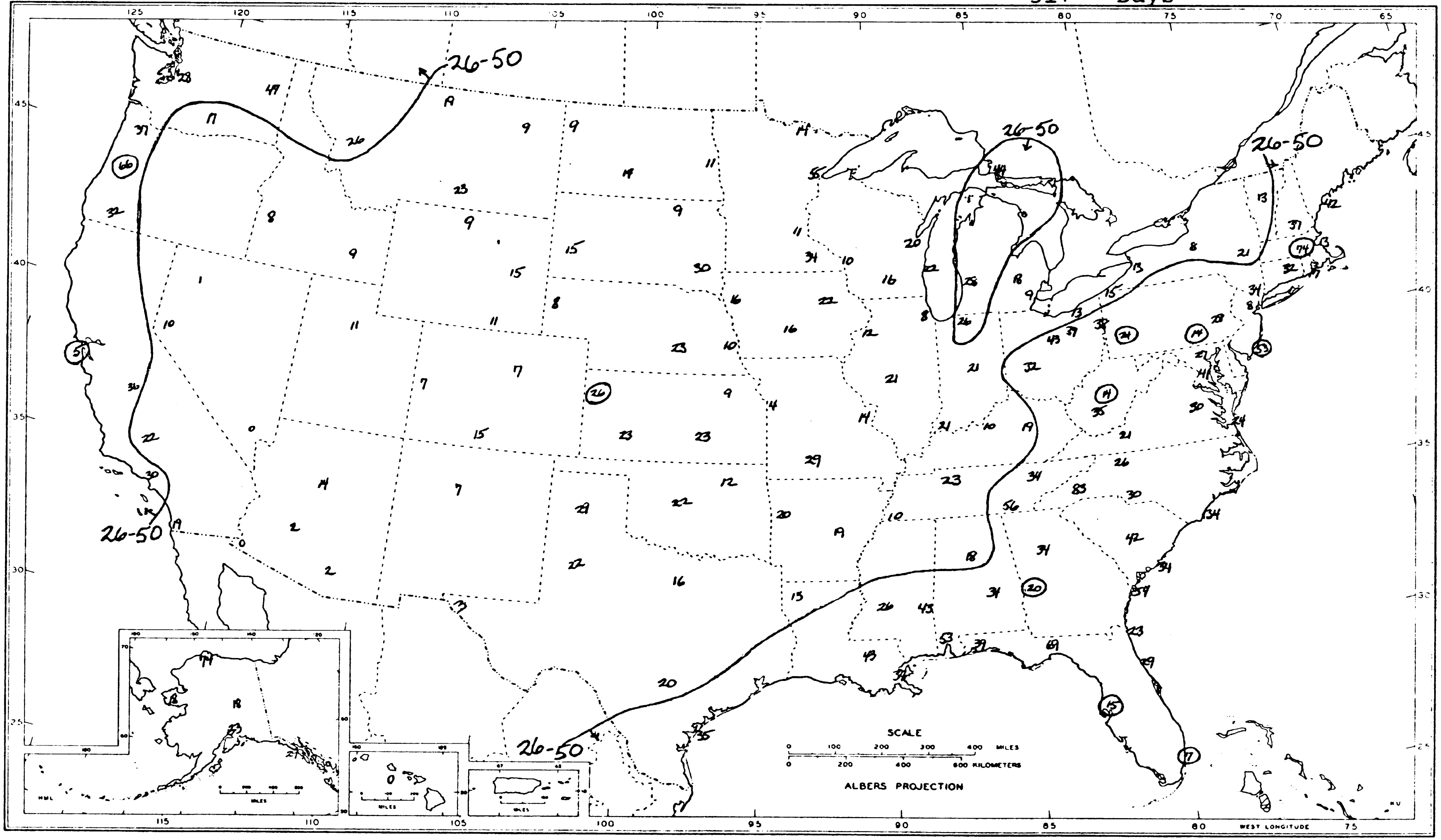
Data on snow conditions are in terms of the number of days 1.0 in. or more of snow accumulated. The term "snow" includes all forms of frozen precipitation except hail occurring alone.

SUNLIGHT (Figure 37)

Sunlight conditions are surveyed in terms of number of days in which cloud cover was between 0% and 30%. In the southwest this condition existed on more than half of the days in the year. In the northeast clear skies were recorded on only a fifth of the days in 1970.

Areas: 0-25 Days
26-50 Days
51+ Days

UNITED STATES Number of Days of Heavy Fog*, 1970. No. 110



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*"Heavy Fog" not defined.

Figure 34. Number of days of heavy fog, 1970.

Areas: 0- 49 Days
50- 99 Days
100-149 Days
150+ Days

UNITED STATES Number of Days of Precipitation .01 in. or More, 1970. No. 110

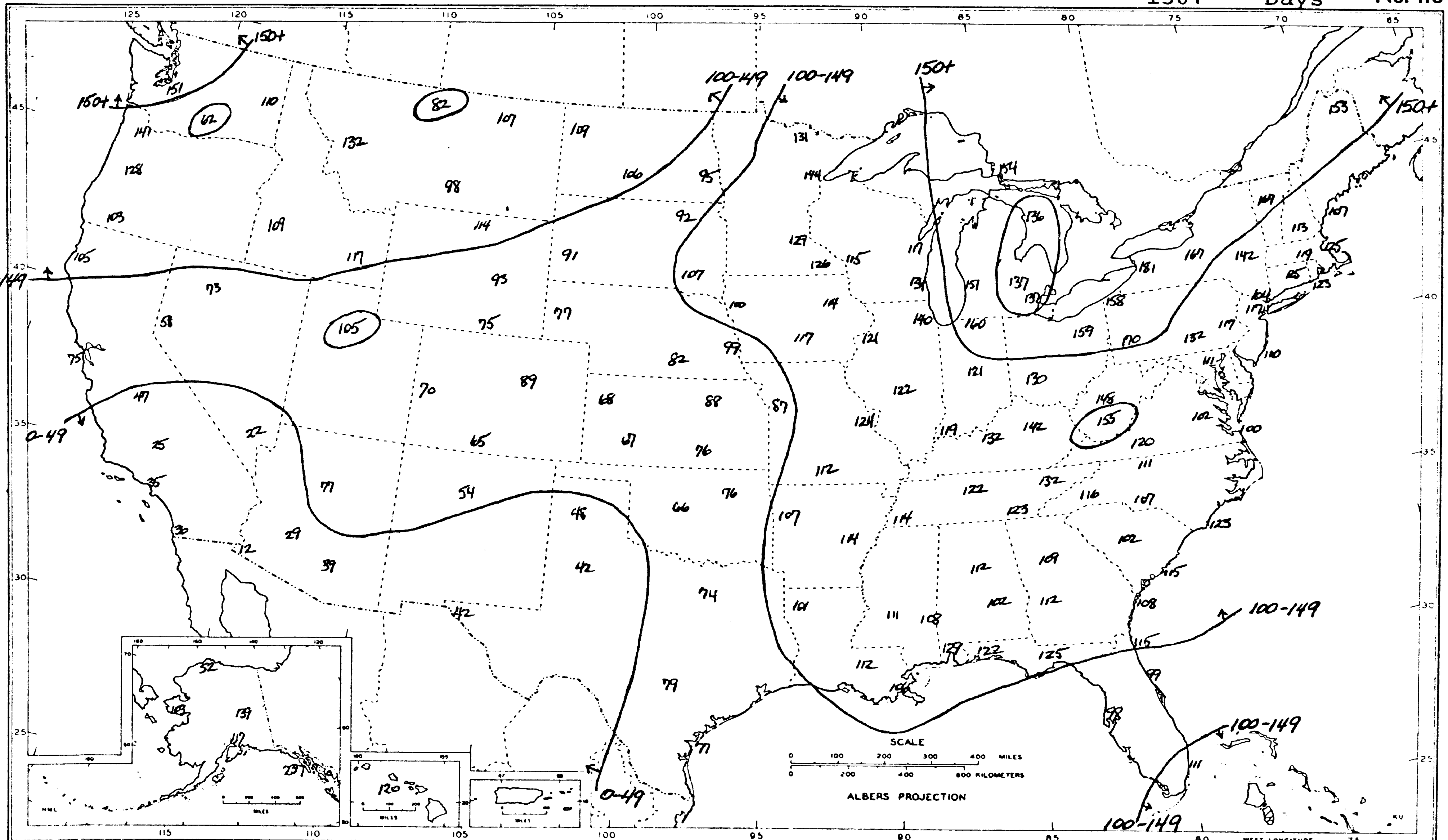

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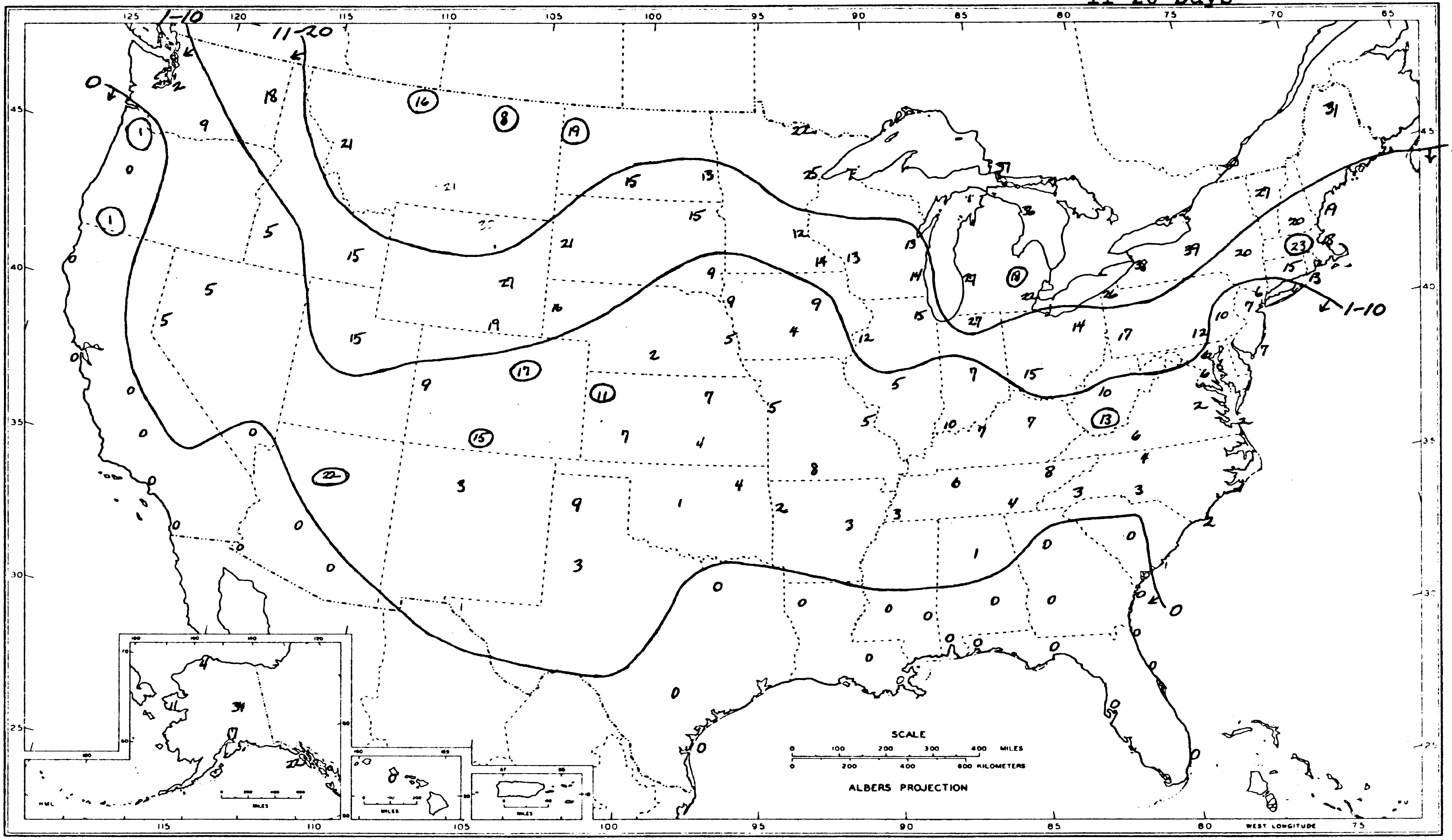
Figure 35. Number of days of precipitation .01 inch or more, 1970.

Areas: 0 Days 21+ Days
1-10 Days
11-20 Days

UNITED STATES Number of Days of Snow* 1.0 in. or More, 1970. No. 110



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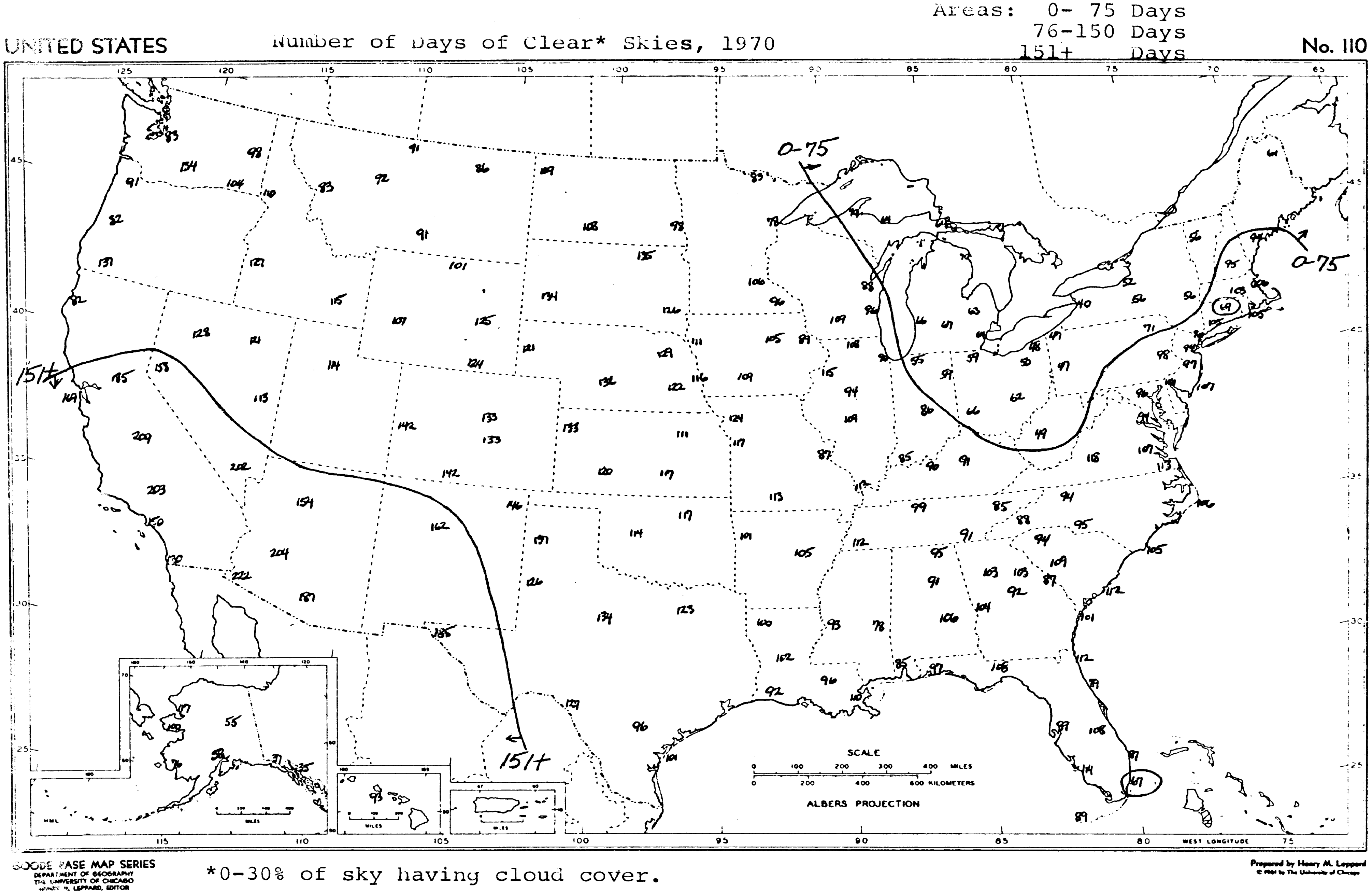
*Includes all forms of frozen precipitation except hail occurring alone.

Figure 36. Number of days of snow 1.0 inch or more, 1970.



*0-30% of sky having cloud cover.

Figure 37. Number of days of clear skies, 1970.

REFERENCES

Climatological Data - National Summary, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Annual 1970, Vol. 21, No. 13, Ashville, N.C., 1971, 23-32.

A SUBJECTIVE EVALUATION OF TURN SIGNAL EFFECTIVENESS

by
Patricia A. Domas

This paper is a subjective assessment of the effectiveness of flashing signals which go from signal intensity to off rather than from signal intensity to presence intensity. The results indicate that the former configuration would be undesirable first, because there appears to be little benefit in increased signal effectiveness by such an arrangement, second, in the event that the signal filament is burned out, one side of the car would be unmarked when the turn signals are used.

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A proposed Motor Vehicle Safety Standard, concerning Lamps, Reflective Devices, and Associated Equipment (Docket No. 69-19), would require turn signal lamps to flash from high intensity to "off." The proposed amendment states: "Turn signal lamps are much more difficult to detect when combined with a normally steady-burning lamp, when the steady-burning lamp is on, and when the ratio of the high intensity to low intensity light is near the current minimum of 5 to 1."

The present experiment evaluated subjective judgment of turn signals which flash "on" to "off," over selected high to low intensity ratios.

METHOD

DESIGN

A single two-filament lamp was used to display presence (P) and turn (T) signals, alone and in combination. The presence lamp intensity was 10 candelas. The turn signal flashed in one of two ways: "on to off" or "on to presence." These two presentations were made at three turn signal intensity levels: 80, 120 and 200 candelas. The paired comparison method was used to present all combinations of flash presentation and level of intensity.

SUBJECTS

Nineteen male and female employees of the HSRI served as paid subjects. They were run in groups of three to six.

PROCEDURE

Subjects were seated approximately 40 feet away from and facing the lamp displaying the signals. They viewed 30 trials of signals. Each trial consisted of the following sequence of signals:

$P \rightarrow T_1 \rightarrow P \rightarrow T_2 \rightarrow P$, where P=presence, T=turn

Turn signals were presented for 5 seconds, at approximately 1 cps, and the intervening presence signal was on for 4-5 seconds. Intertrial interval was 15 seconds, with a 2-minute rest given after a block of ten trials.

The subjects were asked to choose the turn signal, of the pair, that they considered to be "more effective," i.e., attention-getting in a driving situation. Equal judgments were not allowed.

RESULTS

For each subject the frequency with which each of the six possible presentation modes (three turn signal intensities x two presence, on-off, modes) were preferred was obtained. The mean preferences among these six signal conditions are shown in Table 7.

TABLE 7. Mean Turn Signal Effectiveness Ratings.

Signal Mode	Mean Rating
200 cd (ON-OFF)	4.24
200 cd (ON-P)	3.66
120 cd (ON-OFF)	2.55
120 cd (ON-P)	2.03
80 cd (ON-OFF)	1.66
80 cd (ON-P)	0.87

This indicates that the subject rated high signal intensities as more effective than low intensities, and within each signal intensity the on-off mode received somewhat higher rating than the on-presence mode.

An analysis of variance on the data using signal modes and subjects as factors (Table 8) showed a significant effect of signal modes.

TABLE 8. Analysis of Variance of Turn Signal Effectiveness Ratings.

Source	SS	df	MS	F
Between Subjects(_S_s)	0.0	18	0.0	
Signal Modes	302.3	5	60.5	29.5*
Signal Modes x _S_s	184.7	90	2.0	4.0*
Within Cells	58.0	114		
Total	545	227		

*$P \leq 0.01$

A Newman Keuls test (Table 9) showed that the 200 cd turn signal was rated significantly more effective than the 120 cd or

TABLE 9. Newman-Keuls Test on Mean Ratings of Effectiveness of Turn Signal Modes.

Signal Mode	Rated Significantly ($P \leq 0.01$) More Effective than	Signal Modes
200 cd (ON-OFF) 200 cd (ON-P)	" " "	120 cd (ON-OFF) 120 cd (ON-P) 80 cd (ON-OFF) 80 cd (ON-P)
120 cd (ON-OFF) 120 cd (ON-P)	" " "	80 cd (ON-P)

80 cd intensities. At 200 cd there was no significant difference in the ratings whether the presence filament was left on or turned off. The 120 cd signals were rated significantly more effective than the 80 cd signal operated with the presence filament remaining on, but not significantly different when the presence filament was turned off. There was no significant difference ($P \leq 0.01$) between the 80 cd signal operated either with the presence remaining on or going off.

DISCUSSION

In this study significant differences in ratings of turn signal effectiveness were not obtained whether the presence filament remained on or was turned off at the onset of voltage being applied to the turn signal, for any of the three turn signal intensities used. There were significant differences in the ratings attributable to the intensities used, with higher intensities being rated significantly more effective than lower intensities, between 200 and 80 cd. However, since the 120 cd signals were not rated as significantly different from the 80 cd signals when presented in the ON-OFF mode, whereas the 120 cd signals were rated significantly more effective than the 80 cd signals operated in the ON-P mode, the data suggest that at the lower intensities, or lower intensity ratios, there appeared to be some benefit of the ON-OFF mode at the 80 cd level.

The findings on the effect of turning off the presence filament when the turn signal is energized suggests that there may be some benefit only for turn signals that are operated at the minimum allowable intensity of 80 cd. This benefit seems to be lost as signal intensity is increased to 120 cd or above, based on a presence intensity of 10 cd.

In observing the operation of the signal in the ON-OFF mode, the benefit of turning off the presence filament is not apparent until the signal is in its second cycle, at the earliest. This is due to the fact that when the turn signal is turned on its' filament begins to increase in intensity at the same time that the presence filament is decaying, such that both of these effects cancel each other out. The benefit of turning out the presence filament can, therefore, only be noticed at the second cycle when the presence filament has sufficiently cooled.

Another consideration in employing this technique is the condition which occurs in the event of a turn signal flasher malfunction resulting in the turn signal filament not being energized, or if the turn signal filament is open. In that case, operating the turn signal level would produce a situation where the presence filament would be deactivated and the lamp on the turning side would remain dark. Thus, the vehicle will not be marked on the turning side, and this is a highly undesirable situation. For this reason deactivation of the presence filament is not recommended.

While it is certainly desirable to improve the effectiveness with which signals are displayed it is questionable that the approach tested provides a significant degree of improvement. Since the turn signal is coded in two ways, namely by intensity change and by flashing, it has a degree of redundancy built into it which should provide a reasonable degree of conspicuity under most conditions. In fact, our field studies show that relatively few turn signals were missed when combined with the presence lamp, although the response times to the turn signals, particularly when combined with stop signals, were relatively poor. However, it is worth re-emphasizing that the miss rate was low. This can also be shown by comparison of the miss rate of the turn signal when combined with a stop signal, compared to the miss rate on the stop signal when it is preceded by a turn signal in the currently used U.S. rear lighting system. In our previous work (Mortimer, 1970) it was found that the bulk of the missed signals occurred on the stop signal, when it was preceded by a turn signal.

Based on these considerations and the findings of this study it would appear to be undesirable to turn off the presence filament when the turn signal is activated because: (1) there appears to be little benefit in increased effectiveness of perception of the turn signal, except at the lowest signal intensities, and (2) in the event that there is a turn signal flasher malfunction or the filament is open, the vehicle will be unmarked on the turning side.

An alternative approach would involve flashing the presence and the turn signal filament in phase, which will obtain the same effect as deactivating the presence filament, but has the advantage of redundancy in turn signal operation in that a signal will be maintained on the turning side if the major, turn filament should be open. Other types of malfunctions, such as affecting the flasher itself, will not be covered by this technique.

It is concluded that maintaining adequate marking of the vehicle is more important than the small benefits that may be obtained in turn signal conspicuity by either deactivating the presence filament or combining it with the turn signal filament. Other procedures for obtaining improved turn signal performance. have already been demonstrated in our other work (Mortimer, 1970; Campbell and Mortimer, 1972) involving the separation of function of the turn signal lamp from the presence lamp. This would provide improved signaling integrity under malfunction conditions, and will reduce the time required to detect the signal by a following driver (Mortimer, 1970).

REFERENCES

Campbell, J.D. and Mortimer, R.G. The HSRI Part-Task Driving Simulator for Research In Vehicle Rear Lighting and Related Studies. Contract UM-7101-C128, Motor Vehicle Manufacturers Association, Inc., Highway Safety Research Institute, University of Michigan, Report No. UM-HSRI-HF-72-12, 1972.

Mortimer, R.G. Automotive Rear Lighting and Signaling Research. Final Report, Contract No. FH-11-6936, U.S. Department of Transportation, Highway Safety Research Institute, University of Michigan, Report No. HuF-5, 1970.

APPENDIX

SUBJECT INSTRUCTIONS

SUBJECT INSTRUCTIONS: TWO-CAR STUDY

The purpose of this study is to determine how well you can respond to signals presented by a car up the road ahead of you. Your primary task is to maintain a constant distance between the lead car and the car you are driving. When we start the test I would like you to drop back to 100 feet behind the car ahead of you. I will tell you when you are at 100 feet and will give you practice maintaining that distance as we start the test.

As the lead car accelerates or decelerates you should try always to maintain a constant separation distance of 100 feet. I emphasize the separation distance because it is very important. We will be asking you to respond to signals presented by the lead vehicle, and the time that it takes you to respond depends a great deal on how far away you are from the car. In order to keep things as constant as possible as regards your response time it is necessary that you stay as close to 100 feet as you can. I will monitor headway for you during the test and if you stray too far from the target distance I will instruct you to close up or fall back as appropriate. I might point out that we have not scheduled any severe maneuvers on the part of the lead vehicle. However, we are operating on a public road, and there is a possibility that another driver may do something which will require a severe response. So, drive as you would normally and be alert.

Several different signals will be presented by the car up ahead of you and we would like you to respond to these as quickly as possible. For example, whenever a turn signal is presented you should indicate that you have seen it by depressing the left button on the steering wheel yoke for a left turn signal and the right button for a right turn signal. On the other hand, when a brake signal is presented, you should indicate that you have seen it by depressing your brake pedal as quickly as possible, since we are recording brake response time from the brake pedal. Should it happen that you do not need to actually slow down, tap the brake pedal lightly, as this is the only way we have of knowing that you have seen the signal.

It will sometimes happen that a brake signal will quickly follow a turn signal or a turn signal will quickly follow a brake signal. In these cases simply respond to each signal individually as soon as you see it. If you keep your thumbs over the turn signal buttons as you drive along you will be able to respond faster to the turn signals.

We will be collecting all of our data on Carpenter road between this point and the town of Milan, about ten miles south of here. You should always try to maintain 100 feet between your car and the lead car unless we tell you otherwise. There will be occasions when we will have to pull off to the side of the road in order to clear traffic behind us or to get ready to turn around and come back in the other direction. In these cases we will ask you to pull up very close behind the lead vehicle. You should not be particularly concerned about this, however, since we will tell you well in advance any time such a maneuver is required.

Three different rear lighting systems will be used on the car ahead of you during the test. We will familiarize you with the way each system works before we take it out on the road. Do you have any questions?

SUBJECT INSTRUCTIONS: THREE-CAR STUDY

The purpose of this study is to determine how well you can respond to signals presented by vehicles up the road ahead of you. Your primary task is to maintain a constant distance between the vehicle immediately ahead of you and the car you are driving. When we start the test I would like you to drop back to 100 feet behind the second of the two cars ahead of you. I will tell you when you are at 100 feet and will give you practice maintaining that distance as we start the test.

As the lead vehicles accelerate or decelerate you should try alway to maintain a constant separation distance of 100 feet behind the car immediately in front of you. I emphasize the separation distance because it is very important. We will be asking you to respond to signals presented by the two cars ahead of you and the time it takes you to respond depends a great deal on how far you are away from these cars. In order to keep things as constant as possible as regards your response time it is necessary that you stay as close to 100 feet as you can. I will monitor headway for you during the test and if you stray too far from the target distance I will instruct you to close up or fall back as appropriate. I might point out that we have not scheduled any severe maneuvers on the part of the lead vehicles. However, we are operating on a public road, and there is a possibility than another driver may do something which will require a severe response. So, drive as you would normally and be alert.

Several different signals will be presented by the cars ahead of you and we would like you to respond to these as soon as possible. For example, whenever a turn signal is presented by the vehicles ahead of you you should indicate that you have seen it by depressing the left button on the steering wheel yoke for a left turn signal and the right button for a right turn signal. On the other hand, when a brake signal is presented, you should indicate that you have seen it by depressing your brake pedal as quickly as possible, since we are recording brake response time from the brake pedal. Should it happen that you do not need to actually slow down, tap the brake pedal lightly, as this is the only way we have of knowing that you have seen the signal.

It will sometimes happen that a brake signal will quickly follow a turn signal or a turn signal will quickly follow a brake signal. In these cases simply respond to each signal individually as soon as you see it. If you keep your thumbs over the turn signal buttons as you drive along you will be able to respond faster to the turn signals.

We will be collecting all of our data on Carpenter road between this point and the town of Milan, about ten miles south of here. You should always try to maintain 100 feet between your car and the car immediately ahead of you unless we tell you otherwise. There will be occasions when we will have to pull off to the side of the road in order to clear traffic behind us or to get ready to turn around and come back in the other direction. In these cases we will ask you to pull up very close behind the lead vehicle. You should not be particularly concerned about this, however, since we will tell you well in advance any time such a maneuver is required.

Three different rear lighting systems will be used by the lead vehicles during this test. We will familiarize you with the way each system works before we take it out on the road. Do you have any questions?

SHIELDING STUDY INSTRUCTIONS

In this experiment I want you to imagine that you are driving down this road and that there is another car ahead of you (that you are following) in the same lane. Each time the shutter opens in front of you you will see lamps and a bumper mounted on a panel representing the rear of the car you are following. Imagine that these lamps are the rear lamps of the vehicle in front of you. The purpose of this experiment is to learn how well you can identify what is being shown to you on the back of the car ahead of you. Each time the shutter in front of you opens you will have five seconds to view the lamps. A signal will not always be presented when the shutter opens, but when a signal is presented you will see taillights (or as I shall refer to them, presence lights), stop lights, turn signal lights, or combinations of these.

Presence or taillights are shown on a normal car when the headlights are turned on. Stop lights come on when the brakes are applied and turn signal lights when the turn signal lever is actuated. Please rest the response box on your knee during the study.

I want you to identify what is being presented by pushing the appropriate button on the box in front of you. The buttons are labeled above the button with: STOP, TURN, PRESENCE, and NO SIGNAL. Pushing any single button or combination of buttons should allow you to indicate the lack of a signal, a single signal, or a combination of signals. I am interested not only in your identifying the signal or lack of signal correctly but in your identifying it as quickly as possible. Therefore, I am recording the buttons you push and how long it takes you to push the correct button or set of buttons. If you find that you have made a mistake you can correct it up until just after the view is blocked by the shutter by pushing the correct button or buttons.

Use your index finger to push the buttons. When I say "ready" you should push the start button with your index finger and look straight ahead for the presentation. When the start button is pushed the lamp on the side of your response box will light. After you have responded and I have had a chance to record your responses I will ask you to rate the signal you just saw as inadequate or adequate in brightness by pushing the appropriate button corresponding to the label below the button on the response box. An adequate brightness is one that would attract your attention in traffic; an inadequate brightness would not attract your attention. Please do not rate the signal before I ask you to. If you think "no signal" was presented push the "no signal" button instead of the inadequate or adequate button.

Several rear lighting systems will be shown to you. For example, you will see displays using two red lights, four red lights, and two red and two amber lights.

Please do not smoke or wear tinted glasses during this study.

Let's try a few trials now to get into practice. Do any of you have any questions?