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BICYCLISTS' INCLINATION AND ABILITY TO SEARCH BEHIND BEFORE TURNING LEFT

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16. Abstract

Research (Cross and Fisher, 1977) has identified a relatively high incidence (8.4%) bicycle/motor-vehicle accident type in which a bicyclist initiates a left-hand turn without searching to the rear or signaling and is struck by an overtaking motor vehicle. In order to consider countermeasures to this accident type, it was necessary to understand the frequency with which bicyclists actually search behind before turning left, and to determine the ability of bicyclists to maintain lateral stability when looking behind. Hence, two separate studies were conducted.

The first, a field-observation study, was performed to assess the frequency with which bicyclists search behind before initiating a left-hand turn. Field investigators observed and recorded data on 1,012 left-hand turns by bicyclists. The relationships between search failure and selected environmental, operator and vehicular factors are described. The percentages of search failures were found to range from 23% at locations with high traffic density to 79% at locations with the lowest traffic density.

The second experiment measured the magnitude of the inadvertent lateral deviations that accompany a rearward search as a function of the bicyclist's age and riding experience. Of major interest was the magnitude of the largest deviation from a straight line path ("maximum error"). It was found that maximum error was greater for trials involving rearward search than for those which did not. However, the absolute error was relatively small. The 99th centile error was only 20 inches. Error was lower for more experienced bicycle riders but was unrelated to age.

The totality of results indicate that it would likely not be counterproductive to promote universal rearward searches in bicycle safety education or training programs.

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Mr. Allen Hale (Dunlap) and Dr. Leland Summers (Anacapa) made important contributions during the design phase of this study.

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SECTION I

EXECUTIVE SUMMARY

This section provides a brief overview of the problem that stimulated this research, the research methodology employed, the principal research findings, and the conclusions drawn from the findings.

THE PROBLEM

In a recent study of bicycle/motor-vehicle accidents, Cross and Fisher (1977) described 25 different types of accidents that together accounted for 87% of the fatal cases and 93% of the non-fatal cases. One frequently occurring type of accident--referred to hereafter as Type 18 accidents--occurs when a bicyclist, without searching to the rear and without signaling, initiates a left-hand turn and collides with an overtaking motor vehicle. Problem Type 18 accounted for 8.4% of the fatal accidents in the sample and, by coincidence, 8.4% of the disabling injury accidents as well. Nationwide, it is estimated that about 84 fatalities and 6,700 disabling injuries result each year from Type 18 accidents. Although Cross and Fisher reported that bicyclists of all ages are involved in Type 18 accidents, bicyclists between the ages of 12 and 14 years are overrepresented in the accident group. Bicyclists between nine and 11 years of age are also overrepresented in the Type 18 accident group, but the overrepresentation is not as great as that for 12 to 14 year-old bicyclists.

RESEARCH OBJECTIVES

Cross and Fisher (1977) reported that in-depth interviews with bicyclists who had been involved in a Type 18 accident revealed little information about why the bicyclists failed to search behind before they initiated their left-hand turn. Nearly every bicyclist interviewed stated that they ordinarily search behind before turning left but could offer no meaningful explanation of why they failed to search behind on the day of the accident. A study of the accident locations along with discussions with numerous experienced bicyclists led Cross and Fisher to hypothesize that bicyclists' failure to search is due to the combined effects of (a) a belief that auditory cues will signal the presence of a nearby overtaking motor vehicle and (b) a generalized fear that the act of searching behind will cause the bicyclist to swerve dangerously or fall.

If these hypotheses are correct, it is clear that bicyclists must be taught that auditory cues do not reliably signal the presence of an overtaking motor vehicle that is dangerously close. However, it is **not** clear what bicyclists should be taught to do prior to initiating a left-hand turn. If it is true that a substantial proportion of the bicycling population is incapable of searching behind safely, they must either be trained to search behind without a loss of control or, if this is not possible, be given a safe alternative to searching behind. So, before countermeasures can be recommended for Type 18 accidents, it is necessary to obtain answers to the following questions:

- What proportion of the bicycling population is capable of searching behind safely without formal training?
- If bicyclists are capable of searching behind safely, what are the reasons for their failure to do so? If there are bicyclists who cannot search behind safely, is it possible and economically feasible to train them to perform this task with an acceptable margin of safety?
- If a significant proportion of the bicycling population cannot be taught to search behind safely, what safe and practical alternatives can be recommended to these bicyclists?

To answer the above-listed questions, it is necessary to obtain data about (a) the behavior patterns of bicyclists who are preparing to make a left-hand turn and (b) the ability of bicyclists to maintain lateral control during and immediately after a rearward search. A field observation study of left-turning bicyclists and an experimental study of bicyclists' ability to follow a straight path while searching behind were used to compile the needed data.

FIELD-OBSERVATION STUDY

Objective

The specific objective of the field-observation study was to compile data on the frequency with which bicyclists search behind before initiating a left-hand turn and, to the extent possible with limited resources, to define the relationship between searching behind (or failure to search behind) and selected operator variables and environmental variables.

Method

Trained field investigators observed and recorded data on 1,012 left-hand turns made by bicyclists. The observations were made at 28 selected locations that, together, covered a wide range of bicyclists and traffic contexts. All observations were made in the City of Santa Barbara, California, and the contiguous Cities of Goleta and Isla Vista. The data observed and recorded for each left-hand turn are as follows:

- Bicyclist's estimated age
- Bicyclist's sex
- Bicycle type
- Bicycle fit
- Body position (degree of forward incline of torso)
- Position of hands (on handlebars)
- Purpose of turn (turn left or merge left)
- Number of discrete searches
- Magnitude of longest search
- Duration of longest search
- Proximity of overtaking motor vehicles
- Proximity of oncoming motor vehicles
- Bike position in roadway
- Number of riding companions
- Distractions

The computer analysis yielded frequency counts and percentage values showing: the absolute and relative frequency with which bicyclists search behind in each of the different traffic contexts; the characteristics of the bicyclist's search behavior; and the relationship between search failure and selected environmental factors, operator factors, and vehicular factors.

Results

Incidence of Search Failure. The percent of search failures at the three different types of traffic locations are as follows:

- 79% search failures at low traffic-density locations (20-30 vehicles per hour)
- 48% search failures at medium traffic-density locations (60-100 vehicles per hour)
- 23% search failures at high traffic-density locations (300-1100 vehicles per hour)

The incidence of rearward search failure by left-turning bicyclists was examined as a function of a number of operator, vehicular, and environmental factors. The incidence of search failure was found to be unrelated to the operator's sex, the type of bicycle being ridden, the extent to which the bicycle fitted the rider, the position of the bicyclist's hands on the handlebars, and the inclination of the bicyclist's torso. The statistically and operationally significant relationships are discussed below.

A statistically significant relationship was found between the inclination to search and the age of the bicyclist. It was found that bicyclists in the four age groups did not differ in the relative frequency with which they search at low traffic-density locations. At medium traffic-density locations, elementary school bicyclists failed to search significantly more than adult bicyclists. At high traffic-density locations, adult bicyclists failed to search less often than bicyclists in the three other groups; but elementary, junior high, and high school bicyclists did not differ significantly in the frequency with which they failed to search.

The relatively weak relationship between bicyclists' age and bicyclists' inclination to search does not account for the large overrepresentation of nine to 14 year-old bicyclists in the Type 18 accident group. It must therefore be concluded that the overrepresentation of nine to 14 year-old bicyclists is due mainly to greater exposure.

The field investigators noted whether bicyclists made a full left-hand turn or merely merged with motor-vehicle traffic to the left. Although it was found that the relative frequency of search failures was greater for merges than for turns, the difference was found to be so small that it has no important implications for countermeasures development.

It has been suggested that left-turning bicyclists often rely on auditory cues to signal the presence of an overtaking motor vehicle that is near enough to pose a threat. This contention was supported by the results of the field-observation study. At all three levels of traffic density, it was found that a "threatening" overtaking motor vehicle was more often present for the bicyclists who searched behind than for those who did not search behind. The most plausible explanation for this finding is that many bicyclists searched **because** they heard an overtaking motor vehicle. In light of this finding, it seems highly probable that a significant number of Type 18 accidents are due, in part, to the bicyclist's trust of auditory cues to signal the presence of an overtaking motor vehicle.

No relationship was found between bicyclists' inclination to search and the presence of an **oncoming** motor vehicle.

It was found that only 8.6% of the bicyclists initiated their turn from the left-hand edge of the traffic lane, as is recommended by most bicycle-safety experts. Another 5.5% of the bicyclists initiated their turn from a point near the center of the traffic lane. The remaining 85.9% of the bicyclists initiated their turn from a point close to the right-hand edge of the roadway. As was expected, search failures were least for bicyclists who commenced their turn from a position as far to the right of the roadway as possible. However, even though search failures were least for this group of bicyclists, the incidence of search failures was 21% at high-density locations, 36% at medium-density locations, and 70% at low-density locations.

Cross and Fisher (1977) reported that distractions often contributed to Type 18 accidents. Distractions were also present and judged contributory in the present study. It was found that search failures were significantly more frequent when the field investigator judged that a distraction was present. About 60% of the distractions identified by the field investigator were another person with whom the bicyclist was interacting. Another 25% of the distractions were a vehicle or pedestrian the bicyclist considered a threat. Slightly over 11% of the distractions were an object the bicyclist was carrying in his hand; and, surprisingly, it was found that less than three percent of the distractions were games or play activity in which the bicyclist was engaged. Only 1.4% of the distractions were abnormal street surface conditions.

Characteristics of Rearward Search. The data on the characteristics of rearward searches indicate that most bicyclists search behind only once, that the rearward search is brief (less than one second), and that the search is often made with peripheral rather than with central vision. Although it may appear that many of the bicyclists' rearward searches were ineffective, there is no evidence that Type 18 accidents often occur because a bicyclist's rearward search was too brief or otherwise inadequate.

CONTROL-STABILITY EXPERIMENT

The purpose of the control-stability experiment was to measure systematically the magnitude of the inadvertent lateral deviations that accompany a rearward search and to determine the relationship between the magnitude of the lateral deviations and the bicyclist's age and riding experience.

Method

The bicyclists' task in this experiment was to ride as close as possible to a narrow line--before, during, and after a purposeful rearward search. The bicyclists who served as subjects were instructed to search to the rear as necessary to read a numeral on a stimulus card that was located about 160° to their left rear at the time their rearward search was initiated. Each of 100 bicyclists performed a total of 10 trials--five at a slow speed (about 5 MPH) and five at a fast speed (about 10 MPH). The first trial in each set of five was a control trial in which the bicyclist was not required to search behind. These trials are referred to hereafter as "no-search trials." All subjects rode a familiar bicycle, usually their own.

On each trial, members of the research team recorded: the track of the bicycle through the entire length of the 48-foot-long test trap, the magnitude of the maximum rotation of the head and torso during the rearward search, the time taken to ride through the test trap, and a rating by the bicyclist of his stability during the trial. Video recordings of the bicyclist riding through the test trap were made for Trials 2, 3, 6, and 7. A subsequent study of the video recordings provided a precise measure of the duration of the bicyclist's rearward search.

The 100 bicyclists who served as subjects in this experiment were paid volunteers who responded either to printed solicitations posted in local public schools or to signs posted near the test site. Volunteers were accepted sequentially, without regard to age or sex, until 20 bicyclists had been run for each of the following groups:

- 1st through 3rd grade
- 4th through 6th grade
- 7th through 9th grade
- 10th through 12th grade
- University students and other adults

A device for making a semi-permanent record of the bicycle track was constructed from a plastic one-quart water bottle and a link of flexible plastic tubing. The plastic tubing was inserted into a hole cut in the water bottle and sealed so that the entire contents of the bottle would drain through the tubing. The water bottle and the tube were taped onto the left side of the front fork in such a way that the water from the tube drained onto the front tire of the bicycle. The wet tire, in turn, left a distinct track on the dry pavement.

The main dependent variable analyzed in this study was the magnitude of the single largest deviation from the command path that occurred during a given trial. This performance measure, referred to hereafter as "maximum error," was judged to be more highly related to risk than other performance measures traditionally used to assess performance on a continuous tracking task.

Results

Response Bias. Although there were a small number of subjects who consistently swerved to the same side of the command path, their bias was as likely to be on the right as on the left side of the command path. When the data were summed over subjects, trials, and speeds, the response bias was found to be only about one-half inch. In light of these findings, it can be concluded that maximum error is distributed symmetrically around the command path. These findings fail to support the hypothesis that searching to the left rear causes bicyclists to veer to the left more often than to the right.

Maximum Absolute Error. As expected, maximum absolute error was significantly greater for the search trials than for the no-search trials. The maximum absolute error, averaged over trials and subjects, was 7.5 inches for the search trials and 3.9 inches for the no-search trials. However, more important than the average error is the magnitude of the extreme errors. It was found that about five deviations in 100 equaled or exceeded 15 inches and that about one trial in 100 equaled or exceeded 20 inches.

Maximum absolute error for the search trials was found to be unrelated to bicycle type and to the number of years the bicyclist had been riding. However, maximum absolute error was found to be related to bicycle speed (high vs. low), bicyclist's age, and riding frequency (number of hours spent riding per week).

Maximum absolute error was found to be statistically greater for the slow trials than for the fast trials. This inverse relationship between bicycle speed and maximum absolute error was found for both the search and the no-search trials. These findings suggest that it may be counterproductive to instruct bicyclists to slow their speed considerably before attempting to search behind. However, before such a recommendation is made, a follow-on study should be performed to define the relationship between speed and lateral error over a larger range of speeds.

Maximum absolute error was found to be related to bicyclists' age, but the relationship was not a simple one. When maximum absolute error is averaged over trials and subjects, lateral deviation tends to be greater for the youngest group (grades 1 through 3) and for the oldest group (college students and other adults), and roughly equivalent for the three intermediate age groups. However, when the extreme values of the error distribution are considered, the differences among age groups disappear. That is, the 95th centile error and the 99th centile error are very nearly the same for all age groups. This is an important finding because it suggests that attempts to decrease the incidence or magnitude of extreme errors must be directed at all age groups rather than at just the youngest and oldest groups.

A statistically significant correlation was found between maximum absolute error and the number of hours the bicyclist spent riding during an average week. As would be expected, the correlation coefficients were negative, indicating that error tends to decrease as the number of hours spent riding per week increases. These findings suggest that maintaining lateral control of a bicycle during and after a rearward search is a skill that deteriorates without regular practice.

Characteristics of Rearward Searches. The rearward searches performed by the subjects in this experiment were remarkably uniform in both magnitude and duration. The mean head/torso rotation during a search varied only from 140° to 149°—a difference of only nine degrees. Search duration for the entire sample of observations varied only from .5 to 1.1 seconds. The duration of the searches exhibited by the bicyclists were nearly as short as is physically possible and yet were long enough to enable the subjects to recognize the numeral printed on the stimulus card with near 100% accuracy. Although the search durations were found to be very brief, there is no reason to believe that they were considerably more brief than the duration of the rearward searches observed in the field study.

MAJOR CONCLUSIONS

Assuming that Santa Barbara, California, bicyclists are representative of bicyclists elsewhere, it can be concluded that a failure to perform a rearward search before turning left is **not** an unusual event. It can be expected that at least 20% and as many as 80% of the bicyclists will fail to search behind before turning--depending upon the age of the bicyclist and the density of motor-vehicle traffic at the location of the turn. In light of these findings, there can be no doubt that there is a great need for methods to induce bicyclists to search behind before every turn.

It can be concluded from the results of the control-stability experiment that the magnitude of the lateral swerves that follow rearward searches is **not** dangerously large when the bicyclist is traveling on a relatively wide street. When space is available, motorists almost always maintain a separation distance greater than the 99th centile search-induced swerve. The same conclusion cannot be drawn about more narrow streets. Although no empirical data are available about motorists' behavior on narrow streets, casual observations and discussions with experienced bicyclists suggest that every community has a substantial number of locations where motorists overtake and pass a bicyclist with a separation distance as small as 12 inches. It is therefore concluded that the magnitude of the search-induced swerve is dangerously large on streets where the total space available from the center of the roadway to the right-hand edge of the roadway (or to the left edge of the parking lane) is 12 feet or less.

Based upon the composite information available, it is concluded that countermeasures aimed at bicyclists' behavior should be designed to accomplish one or more of the following objectives:

- Perform tests to determine the size of search-induced swerves for each bicyclist;
- Identify bicyclists with a skill deficiency, inform them of the deficiency, and provide guidance on ways to acquire adequate skill;
- Teach bicyclists to recognize when the available travel space is or is not large enough to perform a rearward search (without undue risk); and
- Induce bicyclists to (a) perform a rearward search when it is safe to do so, and (b) stop and search or delay the left-hand turn until there is sufficient space to perform a rearward search safely.

It is concluded that countermeasures aimed at the motorists' behavior should be designed to (a) teach motorists to recognize when the available travel space is dangerously small, and (b) induce motorists to delay overtaking and passing a bicyclist until there is sufficient space to do so safely.

SECTION II

INTRODUCTION

This introductory section discusses briefly the nature of the problem that led to the design and conduct of the research reported herein. Also described in this section are the specific objectives of the research.

THE PROBLEM

In a recent study of bicycle/motor-vehicle accidents, Cross and Fisher (1977) described 25 different types of accidents that together accounted for 87% of the fatal cases and 93% of the non-fatal cases in the sample. The 25 problem types[1] varied in their frequency of occurrence and the clarity with which their cause could be explained. One problem type—Problem Type 18—accounted for 8.4% of the fatal accidents and, by coincidence, 8.4% of the disabling injury accidents as well. Nearly every case classified into Problem Type 18 is accurately characterized by the following brief scenario.

> Prior to the collision, the bicyclist is riding along the right-hand edge of the roadway, traveling in the same direction as motor-vehicle traffic in the adjacent lane. Without searching to the rear and without signaling, the bicyclist initiates a left-hand turn and collides with an overtaking motor vehicle. The overtaking motorist observes the bicyclist well in advance but has no time for evasive action once the bicyclist begins to turn.

When appraised with respect to the national toll of fatal and injury-producing accidents, it is clear that Problem Type 18 represents a serious traffic-safety problem. The National Safety Council (Accident Facts, 1978) estimates that about 1,000 fatal and 40,000 disabling injury accidents involving a car and bike are reported to U. S. police agencies each year. However, there are data available indicating that while almost all fatal accidents are reported to a law enforcement agency, as many as one-half of all injury-producing accidents involving a bike and a

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[1]Cross and Fisher used the term "problem type" to refer to a set of accidents that occurred in a similar traffic context and for similar reasons. The term will be used in this manner throughout this report.

motor vehicle go unreported (Cross & Fisher, 1977; Cross, 1978). Based on these data, it is estimated that the annual toll of bicycle/motor-vehicle accidents is about 1,000 fatalities and about 80,000 disabling injuries. Since Problem Type 18 accidents account for 8.4% of both fatal and disabling accidents, it is estimated that about 84 fatalities and 6,700 disabling injuries result each year from Problem Type 18 accidents.

Unlike some other types of bicycle/motor-vehicle accidents, Problem Type 18 accidents usually involve a consistent sequence of events. The accident always involves a bicyclist who is riding with traffic near the right side of the roadway and who makes a sudden and deliberate left-hand turn into the path of an overtaking motor vehicle. Problem Type 18 does not include accidents in which the bicyclist swerved left as a result of a temporary loss of control or accidents in which the bicyclist swerved left to avoid an obstacle or road hazard in his path. Cross and Fisher (1977) reported that approximately one-half of the bicyclists involved in this type of accident were turning left at the junction of a roadway or driveway; the other one-half initiated their turn at a point that was not in close proximity to any type of junction. It was found that about one-half of the accidents occurred on a two-lane urban street, that about 30% occurred on a two-lane rural roadway, and that the remaining 20% occurred with about equal frequency on urban or rural roadways with more than two lanes. The general circumstances surrounding Problem Type 18 accidents are illustrated in Figure 1.

Cross and Fisher (1977) reported that 92% of the motorists involved in a Type 18 accident observed the bicyclist at a great enough distance to have easily avoided the accident if they had known of the bicyclist's intention to turn left. Only 7% of the fatal and 2% of the non-fatal accidents occurred during darkness. Therefore, it is clear that a failure of the motorist to observe the bicyclist prior to or during the left turn is not a major contributing factor for this type of bicycle/motor-vehicle accident.

In contrast to the motorists' usual awareness of the bicyclists, the bicyclists were seldom aware of the overtaking motor vehicle's presence until the accident was imminent. Ninety-four percent of the bicyclists failed to search to the rear before initiating their left-hand turn. In the remaining 6% of the cases, the

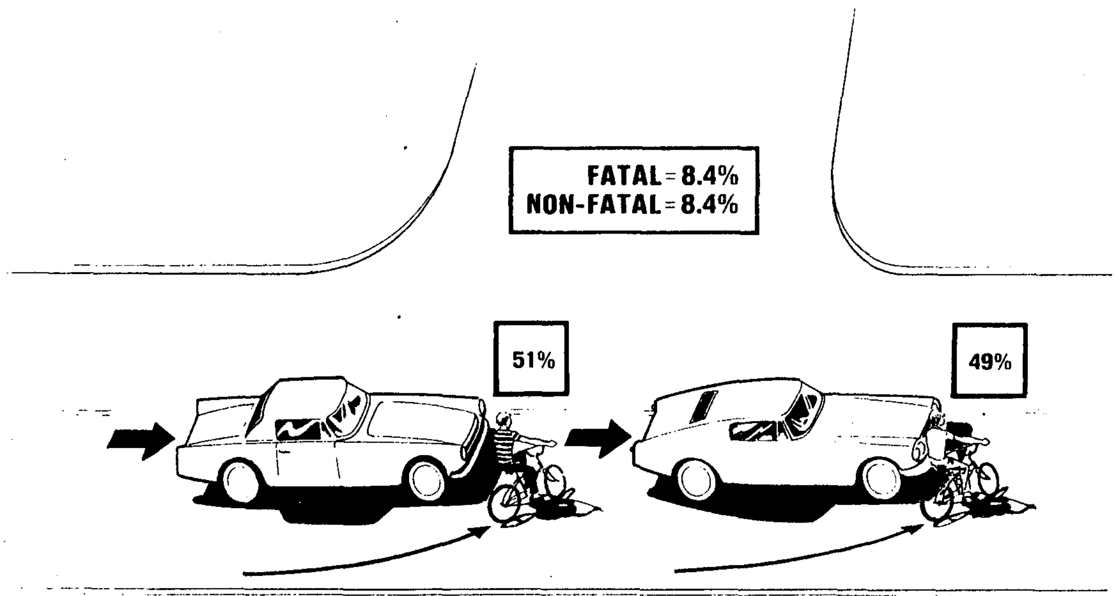

Figure 1. Illustration of Problem Type 18, **Bicyclist Unexpected Left Turn: Parallel Paths, Same Direction.**

bicyclists were aware of the presence of the overtaking vehicle but incorrectly assumed there was sufficient time to cross the traffic lane before the approaching motor vehicle arrived at the point of impact.

Another dominant characteristic of Type 18 accidents is the overrepresentation of juvenile bicyclists. The nature and extent of this overrepresentation are illustrated in Table 1, which shows:

- The age distribution of the bicyclists involved in a non-fatal Type 18 accident (Column 2),
- The age distribution of culpable bicyclists involved in a bicycle/motor-vehicle accident other than a Type 18 accident (Column 3),
- The age distribution of bicyclists involved in a type of motor-vehicle accident in which the bicyclists were non-culpable (Column 4), and
- The age distribution of the general population of bicycle users as estimated from recent survey data (Column 5).

First examine the overrepresentation of the 12-14 year-old bicyclist group. When compared with the percentage of bicycle users, it can be seen that 12-14 year-old bicyclists are overrepresented in every accident group. The overrepresentation is 7.1% for the non-culpable group, 15.7% for the other culpable group, and 30.3% for the Type 18 group. Moreover, the differences among every combination

Table 1

COMPARISON OF THE AGE DISTRIBUTION OF BICYCLISTS INVOLVED IN TYPE 18 ACCIDENTS, OTHER CULPABLE BICYCLISTS, NON-CULPABLE BICYCLISTS, AND BICYCLE USERS

BICYCLISTS' AGE	BICYCLISTS IN TYPE 18 ACCIDENTS* (N=63)	OTHER CULPABLE BICYCLISTS* (N=486)	NON-CULPABLE BICYCLISTS* (N=204)	BICYCLE USERS** (N>2,000)
5	1.6%	2.3%	1.5%	6.5%
6-8	12.7%	12.3%	2.5%	12.0%
9-11	25.4%	20.8%	6.9%	13.0%
12-14	42.8%	28.2%	19.6%	12.5%
15-17	8.0%	18.9%	21.5%	10.0%
18	9.5%	17.5%	48.0%	46.0%

*Data from Cross and Fisher study (1977).

**Extrapolated from data compiled by Barton-Aschman Associates (1974; 1975). The raw data were obtained from a survey of 2,000 households in Pennsylvania and 1,000 households in Tennessee.

of percentage values proved to be significantly different[2] at the .01 level of confidence. That is, the percentage value for the Type 18 group is significantly larger than the percentage value for the other three groups; the percentage value

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[2] Throughout this report, the following formula was used to assess the significance of differences between proportions (Guilford, 1965).

$$\bar{Z} = \frac{p_1 - p_2}{\sqrt{\bar{p}_e\bar{q}_e\left(\frac{N_1+N_2}{N_1N_2}\right)}}$$

Where: $\bar{p}_e = \frac{N_1p_1+N_2p_2}{N_1+N_2}$

$\bar{q}_e = 1 - \bar{p}_e$

N_1 = Total N on which p_1 is based

N_2 = Total N on which p_2 is based

for the other culpable group is significantly smaller than the Type 18 group but is significantly larger than both the non-culpable group and the bicycle user group; and so on. The overrepresentation in the non-culpable group indicates that 12-14 year-old bicyclists have a greater amount of exposure to accidents, either because they spend more time riding a bicycle or because they ride in more hazardous areas. The overrepresentation in the other culpable group indicates that, in addition to greater exposure, 12-14 year-old bicyclists more often engage in general accident-producing behavior.[3] The magnitude of the overrepresentation of 12-14 year old bicyclists is even greater in the Type 18 accident group than in either the other culpable or the non-culpable group. This overrepresentation reflects the combined effects of overexposure and overinvolvement in general accident-producing behavior and possibly the effects of one or more unknown factors that increase the likelihood of involvement in Type 18 accidents.

Next, examine the percentages for the 9-11 year-old bicyclists. When compared to the bicycle user group, 9-11 year-old bicyclists are underrepresented in the non-culpable group and overrepresented in both the other culpable and the Type 18 groups. The differences between the percentages for the Type 18 group and the other culpable group are not statistically significant, but the difference would probably reach statistical significance with a larger sample of Type 18 accidents. These findings clearly show that 9-11 year old bicyclists more often engage in accident-producing behavior and suggest that this behavior may contribute more to Type 18 accidents than to other types of bicycle/motor-vehicle accidents.

The remaining age groups are either equally represented or underrepresented in the Type 18 accident group with respect to their numbers in the user population. It is interesting to note that 15-17 year-old bicyclists are underrepresented in the Type 18 group, and yet they are overrepresented in both the other culpable and the non-culpable groups.

[3] "General accident-producing behavior" refers to a set of attitudinal and behavioral patterns that contribute to all types of bicycle/motor-vehicle accidents.

Perhaps the most interesting statistic in Table 1 is the dramatic decrease in the involvement in Type 18 accidents after the age of 14 years. Although 15-17 year-old bicyclists are significantly overrepresented ($p < .01$) in both the other culpable and the non-culpable accident groups, they are slightly underrepresented (not statistically, $p > .52$) in the Type 18 group. This finding leaves virtually no doubt that some dramatic behavioral change occurs in the early teens that results in an enormous decrease in the likelihood that a bicyclist will be involved in a Type 18 accident. This finding, in turn, provides powerful evidence that Type 18 accidents can, in fact, be reduced by countermeasures that enhance bicyclists' knowledge or skills or that otherwise modify bicyclists' behavior.

In summary, the data in Table 1 indicate that the main target group for Type 18 accident countermeasures is bicyclists between nine and 14 years of age. However, bicyclists in other age groups are involved in Type 18 accidents often enough to warrant attention as well.

So the problem is this. Each year, about 84 bicyclists are killed and about 6,700 are seriously injured in a Type 18 accident. Bicyclists between the ages of nine and 14 account for about 50% of the fatal and 68% of the non-fatal Type 18 accidents. It is known that nearly all motorists involved in a Type 18 accident observed the bicyclist early enough to have avoided the accident but failed to initiate evasive action soon enough because they had no idea that the bicyclist was going to turn. Conversely, nearly all bicyclists were unaware of the close proximity of the motor vehicle and failed to search behind and to signal before initiating a left-hand turn. The involvement in Type 18 accidents is far less for bicyclists 15 years of age or older, so it is certain that this type of action is amenable to reduction by some type of behavioral change—probably searching to the rear in a more consistent and effective manner.

RESEARCH OBJECTIVES

Cross and Fisher (1977) report that in-depth interviews with bicyclists who had been involved in a Type 18 accident revealed little information about why the bicyclists failed to search behind before initiating a left-hand turn. Most bicyclists interviewed stated that they ordinarily search behind before turning left but could offer no meaningful explanation of why they failed to search behind on the day of the accident. A study of the accident locations along with discussions with numerous experienced bicyclists led Cross and Fisher to hypothesize that bicyclists' failure to search is due to the combined effects of (a) a belief that auditory cues will always signal the presence of a nearby overtaking motor vehicle and (b) a generalized fear that the act of searching behind will cause the bicyclist to swerve dangerously or fall.

If these hypotheses are valid, it is clear that bicyclists must be taught that auditory cues do not reliably signal the presence of an overtaking motor vehicle that is dangerously close. However, it is **not** clear what bicyclists should be taught to do prior to initiating a left-hand turn. If it is true that a substantial proportion of the bicycling population is incapable of searching behind safely, they must either be trained to search behind without a loss of control or, if this is not possible, be given a safe alternative for searching behind. So, before countermeasures can be recommended for Type 18 accidents, it is necessary to obtain answers to the following questions:

- What proportion of the bicycling population is capable of safely searching behind without formal training?
- If bicyclists are capable of safely searching behind but do not do so, what are the reasons for their failure to search behind?
- If there are bicyclists who cannot safely search behind, is it possible and economically feasible to train them to perform this task with an acceptable margin of safety?
- If a significant proportion of the bicycling population cannot be taught to safely search behind, what safe and practical alternatives can be recommended to these bicyclists?

The objectives of the research reported here were to compile data with which to answer the above-listed questions: more specifically, the objectives were to obtain data about the behavior patterns of bicyclists preparing to turn left and to obtain data on the capability of bicyclists to maintain lateral control during and immediately after a search to the rear. The studies conducted to obtain these two types of data are described in Section 3 and Section 4.

SECTION III

FIELD-OBSERVATION STUDY

This section describes the methods and findings of a field study conducted to obtain data on the left-turning behavior of the general bicycling population. The specific purpose of the study was to compile data on the frequency with which bicyclists search behind before initiating a left-hand turn and, to the extent possible with limited resources, to define the relationship between searching behind (or failure to search behind) and selected operator variables and environmental variables.

The compilation of representative data on bicyclists' left-turning behavior is complicated by two related factors. The first factor is the requirement for a reasonable level of efficiency in data collection. It is simply not practical to select observation sites where left-turning bicyclists are rarely seen. The second complicating factor is that the specific physical and operational characteristics of a site surely must influence (a) the types of bicyclists who ride at that location and (b) the inclination of bicyclists to search behind before turning. Because of these constraining factors, it is not possible to select observation sites either randomly or completely factorially. It follows that it is impossible to design a practical field study of left-turning behavior that either avoids completely the confounding of important variables or that enables one to factor out the effects of all extraneous variables.

The presence of confounding does not invalidate the data for every purpose. However, the presence of confounding makes it impossible to answer some questions of interest. Although an attempt has been made to point out the limitations of the data presented in this section, the reader should remain alert to the presence of confounding and to the effect of confounding on the inferences that are stated or implied.

METHOD

Observation Sites

All observations were made in the City of Santa Barbara, California, and the contiguous Cities of Goleta and Isla Vista. The primary criteria used in selecting observation sites were: the density of left-turning bicycle traffic, the age of bicyclists riding through the site during the observation periods, and the density of motor-vehicle traffic on the roadway the bicyclists were traveling prior to turning left. No observation sites were selected at which a traffic sign or signal required the bicyclist to stop prior to turning left. A small number of observations were made at signalized intersections at which the bicyclist was required to merge left to leave a right-turn-only lane, but data were recorded only for bicyclists who arrived at the intersection during the green signal phase.

To ensure an acceptable level of data-collection efficiency, a site was judged suitable if it yielded at least three observations per hour, for a period of at least one hour per day. From locations yielding an acceptable frequency of observations, observation sites were selected sequentially in an attempt to obtain about 200 observations of bicyclists in each of four age groups and, for each age group, to obtain about one-third of the 200 observations at locations where the motor-vehicle traffic volume was "high" (300-1100 vehicles per hour), "medium" (60-100 vehicles per hour), and "low" (20-30 vehicles per hour) at the time the observations were made. The five bicyclist age groups are defined below:

- 6-11 years (elementary school)
- 12-15 years (junior high school)
- 16-18 years (high school)
- Over 18 years (adults)

Table 2 shows the distribution of observations and observation sites. The uppermost row of Table 2 shows the number of high-, medium-, and low-density sites at which observations were made. The number of observation sites for high-density and medium-density locations is somewhat misleading because nine of the sites were abandoned after only a few observations were made. For instance, 84% of the observations at high-density locations were made at only five sites; similarly, 81% of the observations at medium-density locations were made at only two sites. The reason for abandoning nine of the sites after only a few observations was that the incidence of left-turning bicyclists was unacceptably low.

Table 2

DISTRIBUTION OF OBSERVATIONS AND OBSERVATION SITES

		MOTOR-VEHICLE TRAFFIC		
		HIGH	MEDIUM	LOW
NUMBER OF OBSERVATION SITES		10*	6**	2
NUMBER OF OBSERVATIONS	ELEMENTARY	63	106	27
	JUNIOR HIGH	243	6	66
	HIGH SCHOOL	215	3	41
	ADULT	71	90	81
	TOTAL	592	205	215

*84% of the observations were made at five sites.
**81% of the observations were made at two sites.

At one medium-density site and at one low-density site, the field investigator was able to observe simultaneously more than one roadway junction at which bicyclists frequently made left-hand turns; however, the physical characteristics of all observable junctions were nearly identical to the one at which the field investigator was located.

Photographs and plan-view drawings of the 18 observation sites are shown in Appendix A. Also shown for each site is the average density of motor-vehicle traffic at the times observations were made. The low-density and medium-density sites were highly similar in their physical characteristics. At all low- and medium-density sites, the bicyclist was traveling on a two-lane, two-way paved roadway prior to his turn. The roadways were between 35 and 40 feet wide and were uncontrolled at the point where bicyclists made their left-hand turns. At one medium-density site and at one low-density site, the roadway onto which the bicyclists turned was a wide driveway serving a school. At all other medium- and low-density sites, the bicyclist turned onto an intersecting roadway that had the same physical characteristics as the roadway he had been traveling, except that it was controlled by a stop sign. The similarity in the physical characteristics of the medium- and low-density sites is due to the uniformity of roadways in Santa Barbara rather than an attempt to select similar observation sites.

The high-density sites differed considerably in their physical characteristics, but all were one of the three basic types described below. Also described below is the number of observations made at each of these types of locations.

- An orthogonal intersection of a pair of two-way, two-lane roadways. The roadway the bicyclist was traveling prior to his turn was uncontrolled; the roadway onto which he turned was controlled by a stop sign (252 observations, 42.6% of the observations at high-density sites).
- An orthogonal intersection of a two-way, four-lane and a two-way, two-lane roadway. The roadway the bicyclist was traveling prior to his turn was a four-lane, uncontrolled roadway; the roadway onto which he turned was a two-lane roadway that was controlled by a stop sign (148 observations, 25.0% of the observations at high-density sites).
- A Y-junction of a pair of two-way, two-lane roadways. In all recorded cases, the bicyclist proceeded on the left-hand leg of the Y-junction and, therefore, was required to merge with motor vehicles that were proceeding on the right-hand leg of the Y-junction (192 observations, 32.4% of the observations at high-density sites).

Time and Location of Observations

Table 2 also shows the distribution of observations as a function of type of site and age of the bicyclists. The relative number of observations in the 12 cells reflect the ease or difficulty encountered in obtaining observations for the various conditions of interest. It was found to be impossible to locate medium-density sites where significant numbers of junior-high and high-school bicyclists could be observed turning left. It was also found difficult to obtain observations of elementary-school bicyclists making left turns at low-density sites. Unfortunately, the small number of observations do not reflect the frequency with which bicyclists in the corresponding age group ride on the corresponding type of location. Indeed, all Santa Barbara bicyclists spend the majority of their riding time on roadways classified here as medium density or low density. The problem in obtaining observations on such roadways arises because there are so many medium- and low-density roadways in Santa Barbara (and other communities) that it is difficult to find any one roadway where bicycle traffic density is high enough to make data collection feasible. This limitation should be kept in mind when interpreting the findings presented later in this section.

Table 3

FREQUENCY OF OBSERVATIONS AS A FUNCTION OF TIME OF DAY

OBSERVATION PERIOD	OBSERVATIONS	
	N	%
7:00 AM - 9:00 AM	573	56.6
9:01 AM - 2:00 PM	72	7.1
2:01 PM - 6:00 PM	367	36.3

Observations were made during the period between October 25, 1978, and January 20, 1979. Table 3 shows that 56.6% of the observations were made during the two-hour period between 7:00 AM and 9:00 AM; 7.1% of the observations were made between 9:00 AM and 2:00 PM; and the remaining 36.3% of the observations were made during the four-hour period between 2:00 PM and 6:00 PM. All observations were made during daylight hours on days when the weather was clement.

Field Investigators

Ninety-one percent of the observations were made by one field investigator; the remaining observations were made by two field investigators working as a team. The field investigators were provided detailed instructions on the behavioral factors and situational factors to be observed and to be recorded for each left-turn event. Because a moderate amount of practice was required to observe and record data on all the factors of interest, field investigators were instructed to discard the data on an entire left-turning event if they failed to observe or to recall one or more of the relevant behavioral or situational factors. It was found that the field investigators, especially the one who made most of the observations, had little difficulty with observations and data recording after the third or fourth day.

Data Observed and Recorded

The field investigators recorded data on every lone bicyclist who made a left turn or merge[4] at the observation site. When two or more bicyclists were riding as a group, data were recorded only for the lead bicyclist. The behavioral and situational factors observed and recorded are as follows:[5]

- Bicyclist's estimated age
- Bicyclist's sex
- Bicycle type
- Bicycle fit
- Body position (degree of forward incline of torso)
- Position of hands (on handlebars)
- Purpose of turn (turn left or merge left)
- Number of scans before and during turn
- Direction of longest scan
- Magnitude of longest scan
- Duration of longest scan
- Proximity of overtaking motor vehicle
- Proximity of oncoming motor vehicle
- Bike position in roadway
- Number of riding companions
- Distractions

Rather than attempt to estimate the exact age of bicyclists, the field investigator classified them into one of four age groups, based upon their estimated grade-level in the public schools: elementary (grades 1-6), junior high (grades 7-9), high school (grades 10-12), and adult. Although some bicyclists were undoubtedly misclassified, the field investigator's accuracy in classifying bicyclists was enhanced by a careful study of the type(s) of schools located near the observation sites and the hours that students commute to and from school.

Data Analysis

The data were analyzed using the Statistical Analysis System (Barr, et al., 1976) operating on an ITEL-AS/6 computer. The computer analysis yielded frequency counts and percentage values showing: the absolute and relative

[4]Hereafter, the term "left turn" will refer to both left turns and left merges unless stated otherwise.

[5]Copies of the data-recording forms and the coding sheet are shown in Appendix B.

frequency with which bicyclists searched behind in each of the different traffic contexts; the characteristics of the bicyclist's search behavior, and the relationship between search failure and environmental factors, operator factors, and vehicular factors. The test described in footnote 2 was employed when it was of interest to determine the statistical signficance of the difference between proportions. As was stated earlier, this test yields a standard score (z value). Thus, a difference is said to be significant at the .05 level if the test yields a z-value between 1.96 and 2.57; a difference yielding z values larger than 2.57 will be considered significant at the .01 level. Differences yielding a z value less than 1.96 will be considered not statistically significant.

RESULTS

The research findings are presented in two parts. The first part deals with the incidence of search failure and the relationship between search failure and selected operator factors, environmental factors, and vehicular factors. The second part deals with rearward searches rather than search failures. The characteristics of search behavior are described in terms of the incidence of multiple searches, the degree of head/torso rotation associated with a rearward search, and the duration of rearward searches.

Incidence of Search Failure

Motor-vehicle traffic density. Table 4 shows the relationship between bicyclists' search failures and the density of motor-vehicle traffic at the observation site. As would be expected, the incidence of search failures was found to vary greatly as a function of traffic density.[6] At locations where traffic density was low (20-30 vehicles per hour), nearly 79% of the bicyclists failed to search. At medium traffic-density locations (60-100 vehicles per hour), slightly fewer than 48% of the bicyclists failed to search. Nearly 23% of the bicyclists failed to search at high-density locations (300-1100 vehicles per hour).

[6]Hereafter the abbreviated term "traffic density" will be used rather than "motor-vehicle traffic density."

The bottom row of Table 4 shows that 39.4% of the 1,012 bicyclists in the sample failed to search behind. This figure cannot be considered a good estimate of the overall incidence of search failure because observations at high traffic density locations are overrepresented in the sample, and observations at both medium- and low-density locations are underrepresented. To obtain a more reliable estimate of the overall frequency of search failure, it would be necessary to compile data on the relative frequency of left-hand turns at high-, medium-, and low-density locations. Based upon casual observation of bicycles in the Santa Barbara area, the authors estimate that about 20% of all left-hand turns are made at high-density locations, that about 30% are made at medium-density locations, and that the remaining 50% are made at low-density locations. Using these estimates, along with the percentage values shown in Table 4, it is estimated that about 58% of all left-hand turns in Santa Barbara are made without the bicyclist searching to the rear before turning.

Table 4

INCIDENCE OF SEARCH FAILURES AS A FUNCTION OF MOTOR-VEHICLE TRAFFIC DENSITY AT OBSERVATION SITES

MOTOR-VEHICLE TRAFFIC DENSITY	FAILURE TO SEARCH	
	N	%
HIGH (300-1100 per hour)	592	22.6
MEDIUM (60-100 per hour)	205	47.3
LOW (20-30 per hour)	215	78.6
TOTAL	1012	39.4

Bicyclists' sex and age. In a recent survey of 1,874 Santa Barbara County households, it was found that 47.5% of the bicycling population are females, and that 52.5% are males (Wheatley and Cross, 1979). In the present study, however, it was found that only 27.1% of the left-turning bicyclists were females and that 72.9% were males. The only reasonable explanation for the underrepresentation of females in the sample of left-turning bicyclists is that female bicyclists spend less time riding a bicycle than males. These findings indicate that the average male bicyclist spends about 2.6 times as much time on a bicycle than the average female bicyclist.

More important than the sex distribution of bicyclists in the sample is the question of whether or not males and females differ in the relative frequency with which they search behind before turning. Table 5 shows, for each age group and each level of traffic density, the percentages of male bicyclists and of female bicyclists who failed to search before turning. The number in parentheses beneath each percentage value is the number of cases on which the percentage value is based. For instance, the upper left cell of the table indicates that 24.1% of the 58 male bicyclists failed to search before turning. A comparison of the pairs of percentage values in Table 5 shows that the percent search failures for females is nearly always a few percentage points less than the corresponding percentage value for males. Although differences as large as 28 percentage points are found in Table 5, none are large enough to reach statistical significance at the .05 level. When the data were pooled across all age groups and traffic-density conditions, it was found that 36.9% of the females and 40.4% of the males failed to search; this difference is not large enough to reach statistical significance at the .05 level.

Table 5

RELATIONSHIP BETWEEN SEARCH FAILURES AND BICYCLISTS' SEX

BICYCLIST'S AGE	TRAFFIC DENSITY					
	HIGH		MEDIUM		LOW	
	M*	F*	M	F	M	F
ELEMENTARY	24.1% (58)	** (5)	62.1% (66)	43.6% (39)	88.2% (17)	60.0% (10)
JUNIOR HIGH	20.8% (183)	16.7% (60)	50.0% (6)	** —	73.2% (41)	72.0% (25)
HIGH SCHOOL	30.3% (155)	25.0% (60)	** (1)	** (2)	85.7% (28)	69.2% (13)
ADULT	9.1% (55)	18.7% (16)	39.7% (63)	33.3% (27)	85.9% (64)	70.6% (17)

*M = male; F = female
**N is too small (5 or less) to compute a reliable percentage value.
NOTE: The numbers in parentheses are the numbers on which the corresponding percentages are based.

Since the differences in the incidence of search failures for males and for females failed to reach statistical significance, males and females will be pooled in all subsequent analyses.

Table 6 and Figure 2 show the incidence of search failure as a function of bicyclists' age and traffic density. The number of observations for junior high bicyclists and high school bicyclists at medium-density locations is so small that the resulting percentage values must be considered unreliable. This is why curves are not shown for junior high and high school bicyclists in Figure 2. The sample size is large enough for the comparison of all four age groups at low traffic-density locations and at high traffic-density locations. However, because of the limited sample size for medium traffic-density locations, the only statistical comparison that can legitimately be made is that between elementary school and adult bicyclists.

Table 6

BICYCLISTS' FAILURE TO SEARCH BEHIND BEFORE TURNING LEFT, AS A FUNCTION OF BICYCLISTS' AGE AND MOTOR-VEHICLE TRAFFIC DENSITY AT OBSERVATION SITES

MOTOR-VEHICLE TRAFFIC DENSITY	BICYCLISTS' AGE: ELEMENTARY N	%	JR. HIGH N	%	HIGH SCHOOL N	%	ADULT N	%	COMBINED N	%
HIGH	63	25.4	243	19.8	215	28.8	71	11.3	592	22.6
MEDIUM	106	55.7	6	50.0	3	33.3	90	37.8	205	47.3
LOW	27	78.8	66	72.8	41	80.5	81	82.7	215	78.6
TOTAL	196	49.0	315	31.4	259	37.1	242	45.0	1012	39.5

NOTE: The percentage values show the percentage of bicyclists who failed to search before turning left; the N's are the total number of left turns observed.

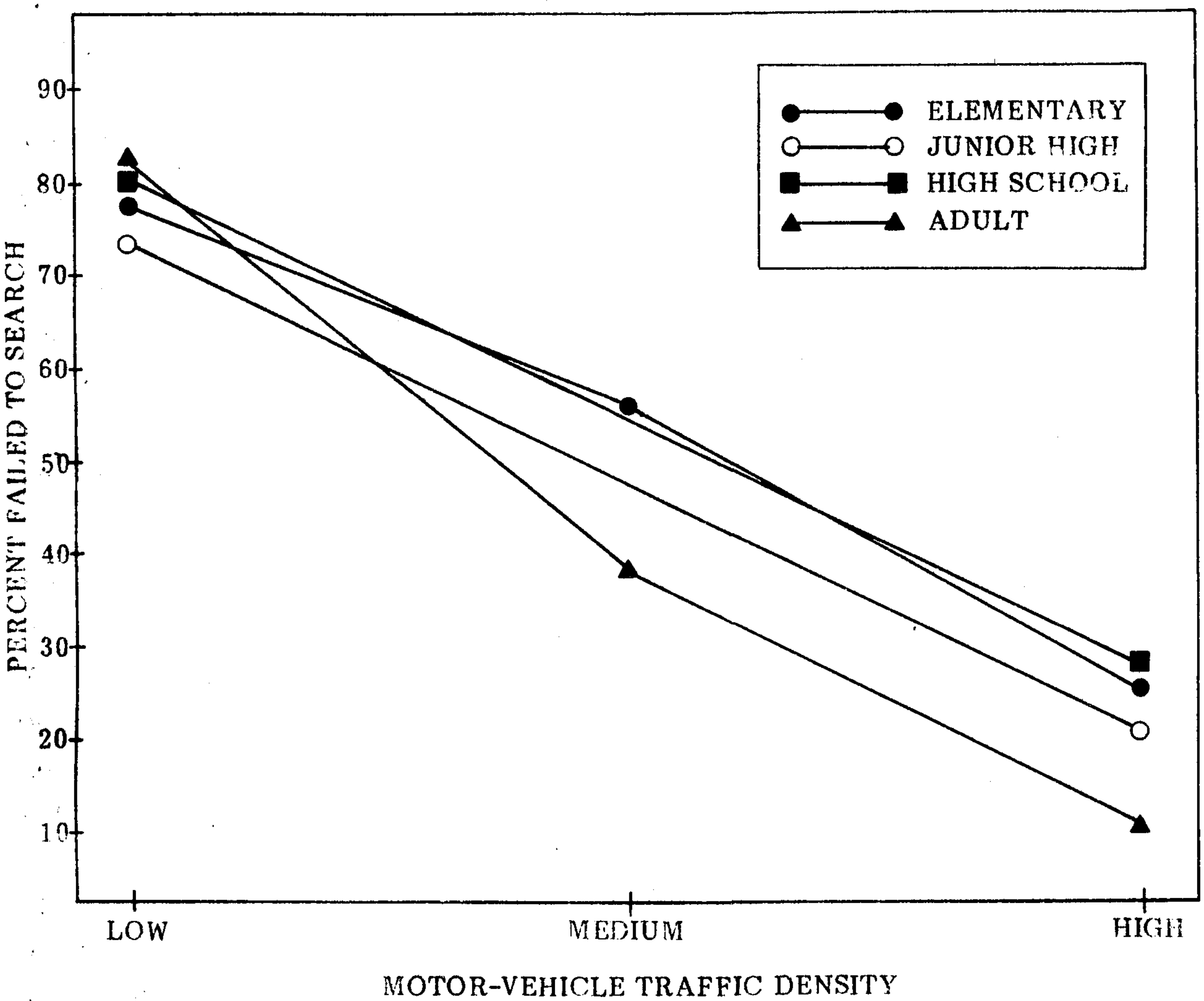


Figure 2. Failures to search as a function of bicyclist's age and motor-vehicle traffic density at observation sites.

Figure 2 and Table 6 show that the negative relationship between search failure and traffic density that was noted earlier is present for all four age groups. The next logical question is: When traffic density is the same, do bicyclists in the four age groups differ in the frequency with which they fail to search? An analysis to assess the statistical significance of differences among the four age groups revealed the following:

- At low traffic-density locations, bicyclists in the four age groups do not differ in the relative frequency with which they fail to search.

- At medium traffic-density locations, elementary school bicyclists searched significantly less often than adult bicyclists. The small sample sizes for junior high and high school bicyclists at medium traffic-density locations prevent an assessment of the statistical significance of other differences.
- At high traffic-density locations, adult bicyclists searched more often than bicyclists in the three other age groups. Elementary, junior high, and high school bicyclists did not differ significantly in the frequency with which they fail to search.

Although the inclination to search before turning *is* related to bicyclists' age, this relatively weak relationship does not account for the large overrepresentation of bicyclists between nine and 14 years of age in the Type 18 accident sample. Thus, it seems probable that the overrepresentation of bicyclists between nine and 14 is due to the amount or type of exposure for bicyclists in this age group.

Turns versus merges. About 27% of the observations in the sample were left-hand merges, as opposed to 90-degree left-hand turns. Of the 278 left-hand merges observed, 274 (98.6%) occurred at a high traffic-density location and 192 (69.0%) occurred at a "Y" junction where the bicyclist was required to merge left across the path of motor vehicles proceeding on the right-hand leg of the junction. It is not unreasonable to expect that bicyclists who intend to merge left would be less inclined to search behind than bicyclists who intend to make a 90-degree left-hand turn--particularly at high traffic-density locations. Since most of the left-hand merges occurred at high traffic-density locations, it is appropriate to compare the incidence of search failures for left-hand merges only with search failures for left-hand turns at other high traffic-density locations.

Figure 3 shows the relative frequency of search failures for left-hand merges and for left-hand turns (at high traffic-density locations). For all age groups, it can be seen that the incidence of search failures is somewhat greater for merges than for turns. However, the only difference that proved to be statistically significant at the .05 level is the one for elementary school bicyclists. With a larger sample, it is possible that search failures for merges would be significantly greater than search failures for turns for all age groups. However, it is clear from these data that search failures at high traffic-density locations do not occur only

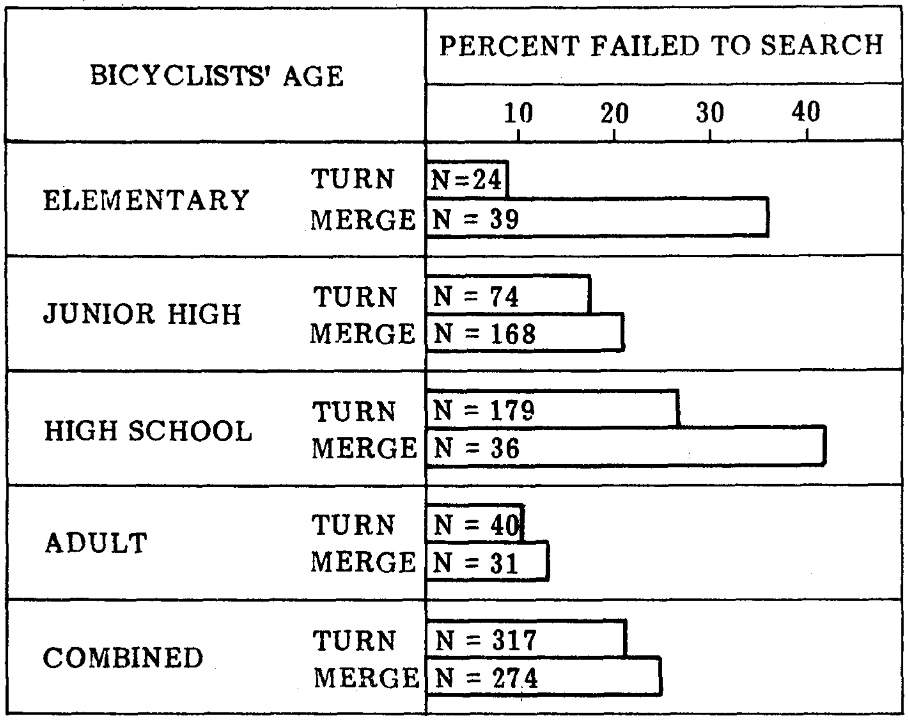


Figure 3. Comparison of search failures for left-hand merges and left-hand turns at high traffic-density locations.

when bicyclists are merging with overtaking motor-vehicle traffic. As dangerous as it appears, it can be confidently concluded that there are large numbers of bicyclists who fail to search before making a 90-degree left-hand turn at high traffic-density locations.

Presence of overtaking motor vehicles. It has been suggested that left-turning bicyclists often rely on auditory cues to signal the presence of an overtaking motor vehicle that is near enough to pose a threat. It is possible that bicyclists use auditory cues in two different ways. First, a bicyclist may use auditory cues to replace visual search altogether. Bicyclists who use auditory cues in this manner would turn without searching in the absence of auditory cues; or when the sound of an overtaking motor vehicle was heard, the bicyclist would delay the turn until the overtaking motor vehicle had passed. If a significant number of bicyclists used auditory cues in this way, one would expect there to be no relationship between the bicyclist's propensity to search and the presence of a nearby overtaking motor vehicle. Secondly, bicyclists may use auditory cues as an indication of whether or not it is necessary to search before turning. That is, bicyclists would search behind to determine the proximity of overtaking motor vehicles only when auditory cues signalled the presence of overtaking motor vehicles. Otherwise, the bicyclist would take the absence of auditory cues as an indication that no overtaking vehicles were close enough to pose a threat and that a rearward search before turning was unnecessary. If a significant number of bicyclists use auditory cues in this way, one can expect there to be a positive relationship between the bicyclist's propensity to search and the presence of an overtaking motor vehicle.

The findings shown in Figure 4 indicate that bicyclists use auditory cues in the latter of the two ways described above. Figure 4 shows that, at all three levels of traffic density, a "threatening" overtaking motor vehicle was more often present for the search group than for the no-search group. This effect is small and not statistically significant for the observations made at high traffic-density locations. However, the effect is present and statistically significant for both the medium traffic-density locations ($p < .05$) and the low traffic-density locations ($p < .01$). The use of auditory cues as a signal to search behind is clearly a dangerous practice because auditory cues are not reliable in every traffic situation. It seems highly probable that a significant number of Type 18 accidents are due, in part, to bicyclists' conscious or subconscious utilization of auditory cues.

TRAFFIC DENSITY	PRESENCE/ABSENCE OF OVERTAKING MOTOR VEHICLE	BICYCLISTS' SEARCH BEHAVIOR	
		SEARCHED	DID NOT SEARCH
HIGH	PRESENT (N = 474)	78%	22%
	ABSENT (N = 118)	74%	26%
MEDIUM	PRESENT (N = 63)	66%	34%
	ABSENT (N = 142)	47%	53%
LOW	PRESENT (N = 30)	53%	47%
	ABSENT (N = 185)	16%	84%

Figure 4. Relationship between search behavior and the presence/absence of an overtaking motor vehicle.

Presence of oncoming motor vehicles. It has been suggested that failure to search to the rear may be related to the presence of oncoming motor vehicles. That is, the bicyclist may become so involved in monitoring traffic in the opposing lane that he neglects to search to the rear for overtaking motor vehicles. Although such a relationship seems plausible, an analysis of the data showed that bicyclists' propensity to search behind is independent of the presence and/or proximity of an oncoming motor vehicle.

Bicyclists' position in roadway. There are two reasons for compiling data on bicyclists' position in the roadway at the time they initiate their left-hand turn. One reason is to determine the extent to which bicyclists adhere to the left-turning techniques that are recommended in the bicycle-safety literature. The second reason is to determine whether or not bicyclists' inclination to search behind is related in any way to the position from which they commence their left-hand turns.

Table 7 shows that 72.3% of the bicyclists were riding as far to the right as possible when they initiated their left-hand turn--either as close as possible to the curb/shoulder (59.4%) or as close as possible to cars parked along the roadway (12.9%). Another 13.6% of the bicyclists initiated their left-hand turn from a point that was as close as possible to the right-hand edge of the traffic lane but not as far to the right of the roadway as was possible. In all of these cases, the bicyclists failed to follow the recommended practice of (a) moving to the left of the traffic lane at least 100 feet before reaching the point at which the left-hand turn is to be made, or (b) coming to a complete stop at the right-hand edge of the roadway and remaining at that position until there is a safe gap in traffic. It can be seen in Table 7 that only 8.6% of the bicyclists initiated their turn from the left-hand edge of the traffic lane, as is recommended by most bicycle-safety experts. Another 5.5% of the bicyclists initiated their turn from a point near the center of the traffic lane. This practice eliminates the requirement to simultaneously search both for overtaking and oncoming traffic, but it places the bicyclist in a more precarious position than if he were as close as possible to the left-hand edge of the traffic lane.

Table 7

BICYCLIST'S POSITION IN ROADWAY WHEN THE LEFT-HAND TURN WAS INITIATED

BICYCLIST'S POSITION IN TRAFFIC LANE	N	%
CLOSE AS POSSIBLE TO CURB OR SHOULDER	601	59.4
CLOSE AS POSSIBLE TO PARKED MOTOR VEHICLES	131	12.9
CLOSE TO RIGHT OF TRAFFIC LANE	137	13.6
CLOSE TO CENTER OF TRAFFIC LANE	56	5.5
CLOSE TO LEFT OF TRAFFIC LANE	87	8.6

Figure 5 shows the relationship between bicyclists' search failures and the positions in the roadway at which they initiated their left-hand turn. As would be expected, search failures were least for bicyclists who commenced their turn from a position as far to the right of the roadway as possible. Even though search failures were least for this group of bicyclists, it can be seen that the incidence of search failures was 21% at the high-density locations, 36% at the medium-density locations, and 70% at the low-density locations. In light of the obvious risk involved, it is difficult to account for the fact that 21% of the bicyclists who turn left at a high traffic-density location do so from a position as far to the right as possible and do so without searching behind. It would be somewhat easier to explain if all or most of the 21% of search failures were merging left rather than making a 90-degree left-hand turn. However, this was not the case. Of the 115 bicyclists who rode as far to the right as possible and who failed to search, 60 (52.2%) merged left and 55 (47.8%) made a full 90-degree turn.

For bicyclists who turned from as far to the right as possible, search failures were significantly less ($p<.05$) than for bicyclists who turned from the other three roadway positions at both the high- and medium-density locations. At the low-density locations, search failures for bicyclists turning from the right-hand edge of the roadway were significantly less ($p<.05$) than for the bicyclists who initiated their turn from the left-hand edge of the traffic lane; the remaining differences were not statistically significant.

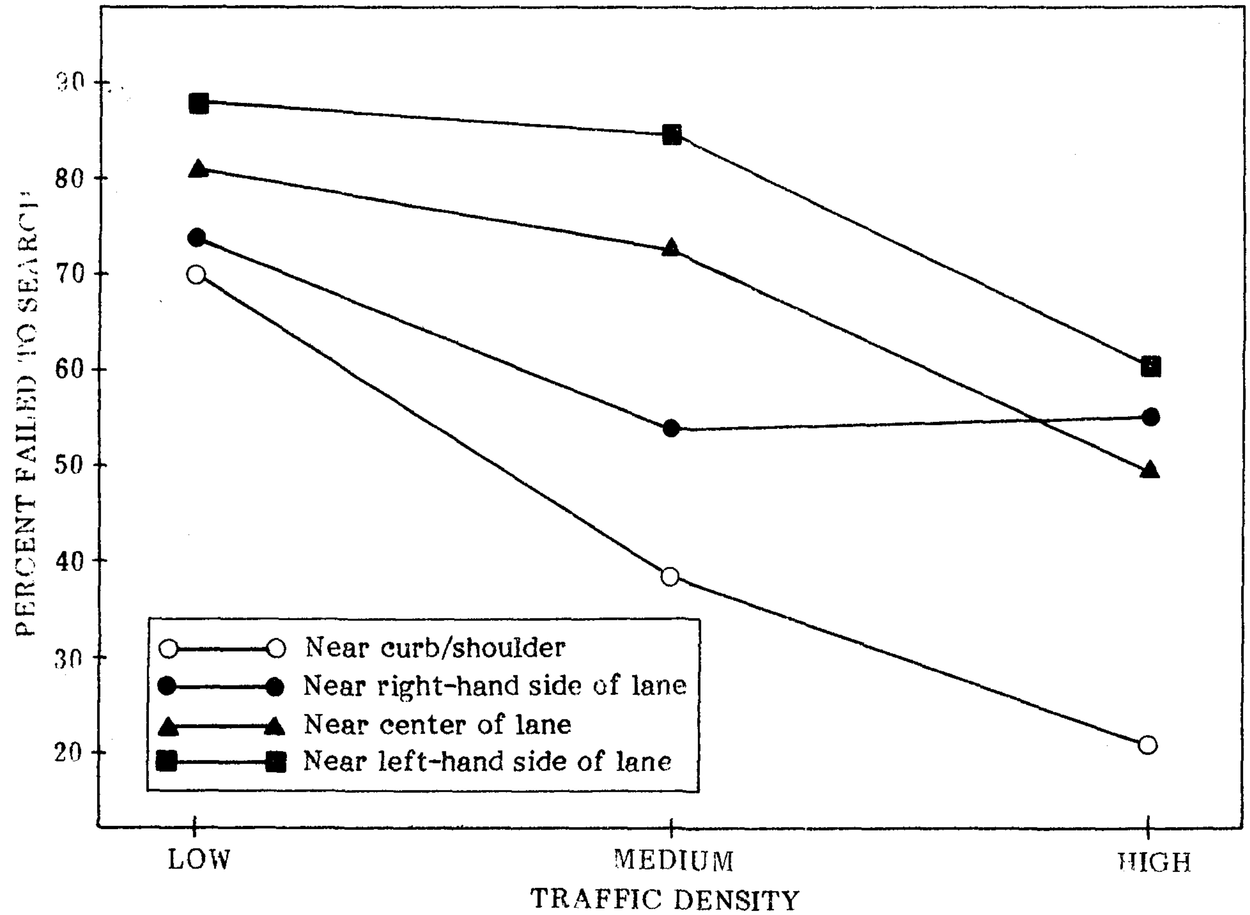


Figure 5. Percent bicyclists who failed to search as a function of bicyclists' position in traffic lane.

The incidence of search failures was about the same for bicyclists who were riding to the left, in the center, or to the right of the traffic lane. The only exception is that the incidence of search failures was significantly greater ($p<.05$) for the bicyclists who turned from a position at the left of the traffic lane than those who turned from a position at the right of the traffic lane. The relatively high incidence of search failures for bicyclists who turned from a position within the traffic lane may be due to their belief that they "own" the traffic lane they are riding in and that motorists are responsible for avoiding a collision when they are overtaking and passing bicyclists who are occupying the traffic lane. This belief is entirely consistent with the traffic laws.

These findings clearly show that a large proportion of left-turning bicyclists failed to use the recommended procedure for executing left-hand turns. To compound the problem, an alarming number of bicyclists who initiate their turn from the right-hand edge of the roadway fail to search behind even once before initiating their turn. In light of these findings, it is surprising that the incidence of Type 18 accidents is as low as it is. Apparently, alert motorists are responsible for avoiding numerous accidents with left-turning bicyclists.

Bicycle type and fit. It is possible that certain bicycle design characteristics influence the ease with which bicyclists can search behind while maintaining control of their bicycle. For instance, it has been suggested that searching behind on a lightweight bicycle is difficult because head rotation is severely constrained by the shoulders when the bicyclist's torso is inclined forward and when both hands are grasping the dropped handlebars. Searching behind on a lightweight bicycle may also be made difficult by the bicycle's light weight, its high center of gravity, and its high degree of responsiveness to small control movements and to minor shifts in weight. Similarly, it has been suggested that the highrise bicycle is inherently less stable than other types of bicycles because of its short wheel base. If searching behind is indeed more difficult on some types of bicycles than others, there should be a measurable relationship between bicycle type and the rider's inclination to search behind.

Although perfectly reasonable, the assertion that the inclination to search behind is related to bicycle type is not supported by the data. Figure 6 shows, for each age level and type of bicycle, the percent of bicyclists who failed to search, None of the differences depicted in Figure 6 are statistically significant. Moreover, even the trends that appear in Figure 6 are different from the ones that would be expected. For instance, the relative frequency of search failures for riders of lightweight bicycles was equal to or less than for riders of all other types of bicycles. In light of these findings, it can be concluded that any effect that bicycle design characteristics have on bicyclists' inclination to search behind is so small that it is completely obscured by the operator factors and environmental factors that influence the bicyclist's inclination to search.

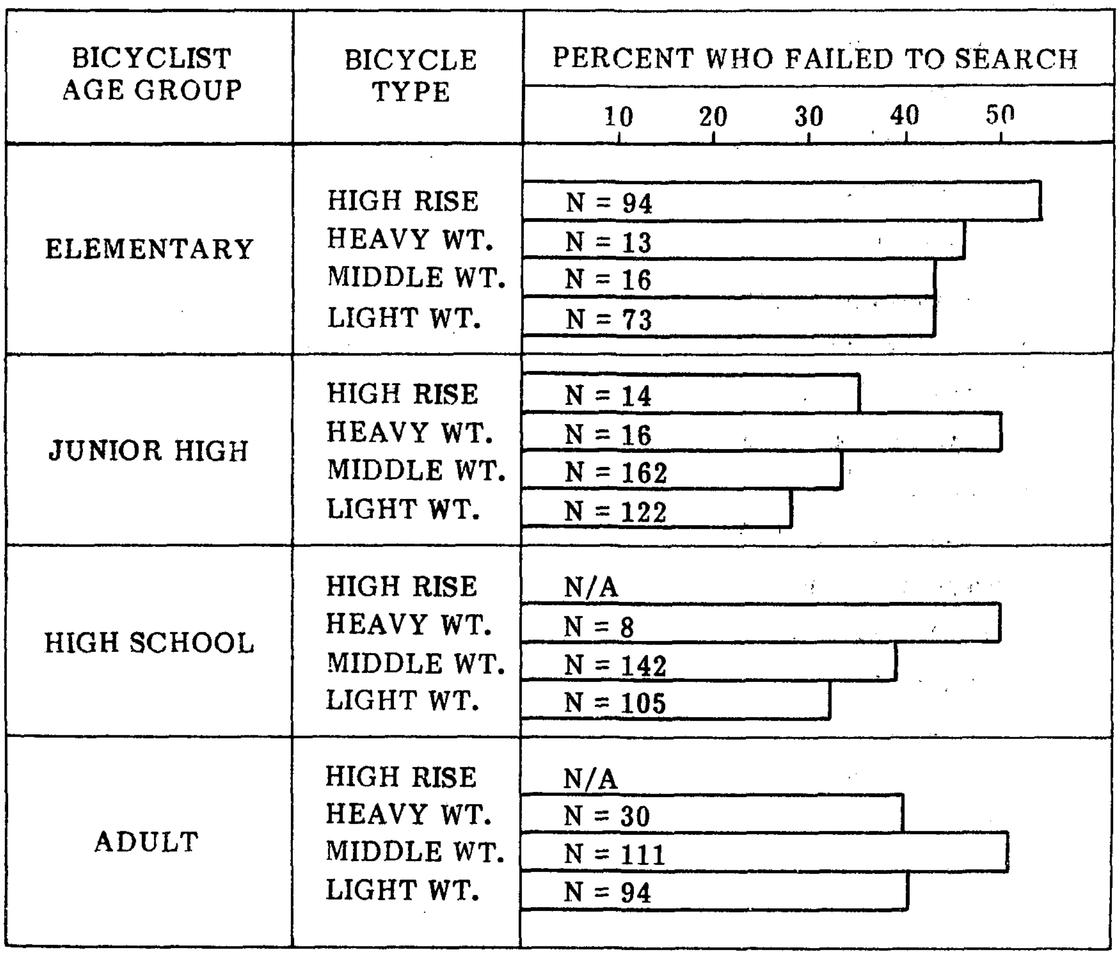


Figure 6. Percent bicyclists who failed to search as a function of bicycle type.

If a bicyclist's inclination to search is less when riding an unstable bicycle, it seems reasonable to expect that bicyclists who are riding an ill-fitting bicycle would be less inclined to search than bicyclists who are riding a bicycle of the proper size. However, the sample included only 18 observations of bicyclists who were riding a bicycle that was too small and only six observations of bicyclists who were riding a bicycle that was too large. As a consequence, the sample size is too small to address the question of whether or not bicyclists' inclination to search behind is related to bicycle fit.

Position of hands and torso. Most bicyclists who ride a lightweight bicycle agree that it is difficult and troublesome to search behind when their torso is inclined forward and both hands are grasping the handlebars. Consequently, it is reasonable to suppose that bicyclists who are riding in this position would fail to search more often than bicyclists who are riding in some other position. No evidence of such a relationship was found in the data. The relative frequency of search failures was found to be totally independent of the degree of inclination of the torso and the position of the hands on the handlebars.

Distractions of attention. Distractions of attention were identified as contributing factors in about one-third of the Type 18 accidents investigated by Cross and Fisher (1977). For this reason, it is of interest to determine the frequency with which distractions contribute to search failures and to identify the types of distractions that are most often present. Unfortunately, the presence of distractors and the effect of distractors on search behavior cannot be determined through field observations alone because all internal and some external distractors cannot be observed. Even when potential distractors can be observed, it is impossible for the field investigator to positively establish that there is a causal relationship between the distractor and the bicyclist's search behavior. All that can be accomplished through field observations is to establish a concurrent correlation between certain types of potential distractors and the bicyclist's failure to search behind before turning. On site interviews with bicyclists would be required to determine the presence of internal distractors and to establish a causal relationship between distractors and search failures.

Since it has been found that the bicyclist's attention is often distracted by a riding companion (Cross & Fisher, 1977), the field investigator was instructed to record the presence or absence of a riding companion for each left-hand turn event, whether or not the riding companion was judged to be a distraction by the field investigator. Figure 7 shows the relationship between search failure and the presence of one or more riding companions. It will be recalled that when two or more bicyclists were riding together, the search behavior of only the lead bicyclist was recorded. Thus, the incidence of search failure shown in Figure 7 was not influenced by the trailing bicyclists' assumption that the lead bicyclist would search behind and proceed to turn left only when it was safe to do so.

TRAFFIC DENSITY	RIDING WITH COMPANION?	PERCENT FAILED TO SEARCH (20 40 60 80)
HIGH	NO (N = 392)	19%
	YES (N = 114)	53%
MEDIUM	NO (N = 153)	42%
	YES (N = 52)	62%
LOW	NO (N = 140)	76%
	YES (N = 75)	84%

Figure 7. Percent of bicyclists who failed to search as a function of whether or not the bicyclist was riding with a companion.

It can be seen in Figure 7 that the incidence of search failure was higher when a riding companion was present than when the bicyclist was riding alone. Although this trend is present for all levels of traffic density, the difference is statistically significant only for the high-density and the medium-density locations. This relationship was found to be present and statistically significant for all age groups.

In addition to noting the presence or absence of a riding companion, the field investigators were instructed to make a judgment about the presence of any type of distraction that influenced the bicyclist's search behavior. Figure 8 shows the relationship between bicyclists' search failures and the presence or absence of a judged distraction. It can be seen that, for all three traffic-density locations, search failures were more frequent when the field investigator judged that a distraction was present. However, the difference proved to be statistically significant only for the high traffic-density location.

Table 8 shows the types of distractions identified by the field investigators. It can be seen that nearly 60% of the distractions were another person with whom the bicyclist was interacting. Although relatively more frequent at low traffic-density locations, interaction with another person was also an important distractor at both the high-density and the medium-density locations. About 25% of the

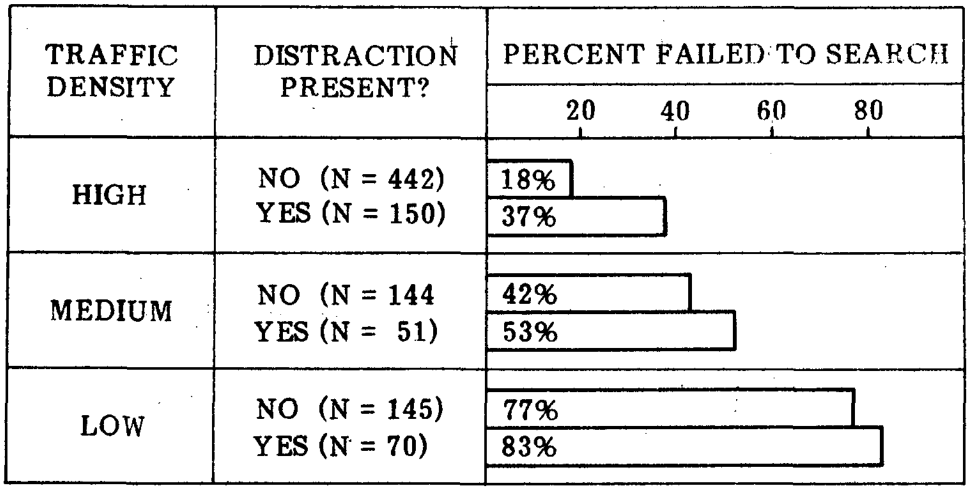


Figure 8. Percent of bicyclists who failed to search as a function of presence/absence of a distraction.

Table 8

TYPES OF DISTRACTIONS

TYPE OF DISTRACTION	TRAFFIC DENSITY			
	HIGH	MEDIUM	LOW	COMBINED
INTERACTING WITH ANOTHER PERSON	12.1%	14.2%	33.3%	59.6%
VEHICLES/PEDESTRIANS CONSIDERED THREAT	24.2%	—	0.7%	24.9%
CARRYING OBJECT IN HANDS	1.4%	8.5%	1.4%	11.3%
ENGAGED IN GAME OR PLAY ACTIVITY	—	—	2.8%	2.8%
ABNORMAL STREET SURFACE CONDITION	1.4%	—	—	1.4%

distractions were a vehicle or a pedestrian the bicyclist considered a threat; and as would be expected, almost all the distractions of this type occurred at a high-density location. Slightly over 11% of the distractions were an object the bicyclist was carrying in his hands. Surprisingly, it was found that less than 3% of the distractions were games or play activity that the bicyclist was engaged in. The small incidence of this type of distraction is probably due to the fact that most bicyclists were commuting at the time they were observed rather than merely playing in the neighborhood. Only 1.4% of the distractions were abnormal street surface conditions. Obviously, the relative frequency of this type distraction could be much higher in geographical areas where bad weather contributes to the deterioration of the street surface and to the accumulation of debris along the edge of the roadway.

Characteristics of Rearward Searches

Although the main purpose of this study was to compile data on the incidence of search failures, the field investigators also recorded data on the behavior of bicyclists who performed a rearward search. The characteristics of bicyclists' search behavior are described below in terms of the incidence of multiple searches, the degree of head/torso rotation associated with a rearward search, and the duration of the rearward searches.

Incidence of multiple searches. Figure 9 shows the relative frequency with which bicyclists searched behind two or more times in preparing to make a left-hand turn. As would be expected, the incidence of multiple searches was found to be highly related to the level of traffic density at the observation sites. At high-density sites, about 37% of all bicyclists searched two or more times before turning; only 15% of the bicyclists performed a multiple search at medium-density locations; and fewer than 2% of the bicyclists performed a multiple search at low-density locations.

Multiple searches to the rear may serve two different functions. One function is to increase the likelihood of perceiving an overtaking motor vehicle. A second function is to provide more information about a motor vehicle that is known to be present. So, after determining that a motor vehicle is present, the bicyclist may search again to obtain more information about the motor vehicle's proximity

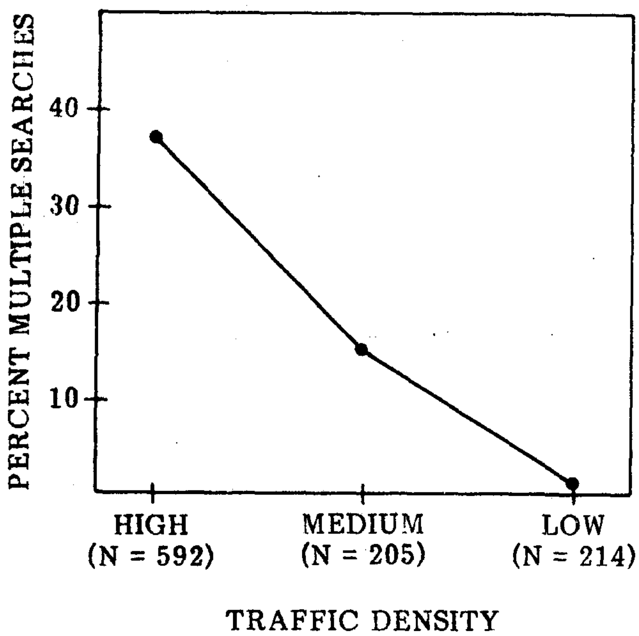


Figure 9. Percent bicyclists who searched behind two or more times in preparing to turn left.

and approach velocity than can be obtained from a single rapid search. If the only purpose of a rearward search was to increase the likelihood of perceiving an overtaking motor vehicle, the incidence of multiple searches would be independent of the presence or absence of an overtaking motor vehicle. Conversely, if the only purpose of a rearward search was to assess the proximity and approach velocity of the motor vehicle, multiple searches would occur only when an overtaking motor vehicle was present.

The findings shown in Figure 10 indicate that bicyclists use multiple searches for both purposes, but more often for judging proximity and closing velocity than for ensuring the detection of a nearby motor vehicle. For example, examine the incidence of multiple searches for the elementary school bicyclists. When an overtaking motor vehicle was present, 55% of the bicyclists who searched did so two or more times. In other terms, 45% of the elementary school bicyclists considered a single search adequate while the remaining 55% considered it necessary to search more than once. When no vehicle was present, only 17% of the elementary school bicyclists considered it necessary to search behind more than once. For all four age groups, the incidence of multiple search was significantly greater ($p<.01$) when a motor vehicle was present than when a motor vehicle was not present.

The incidence of multiple search was less for adult bicyclists regardless of whether an overtaking motor vehicle was present. Adults apparently are more capable than younger bicyclists of obtaining the information they need from a single rearward search.

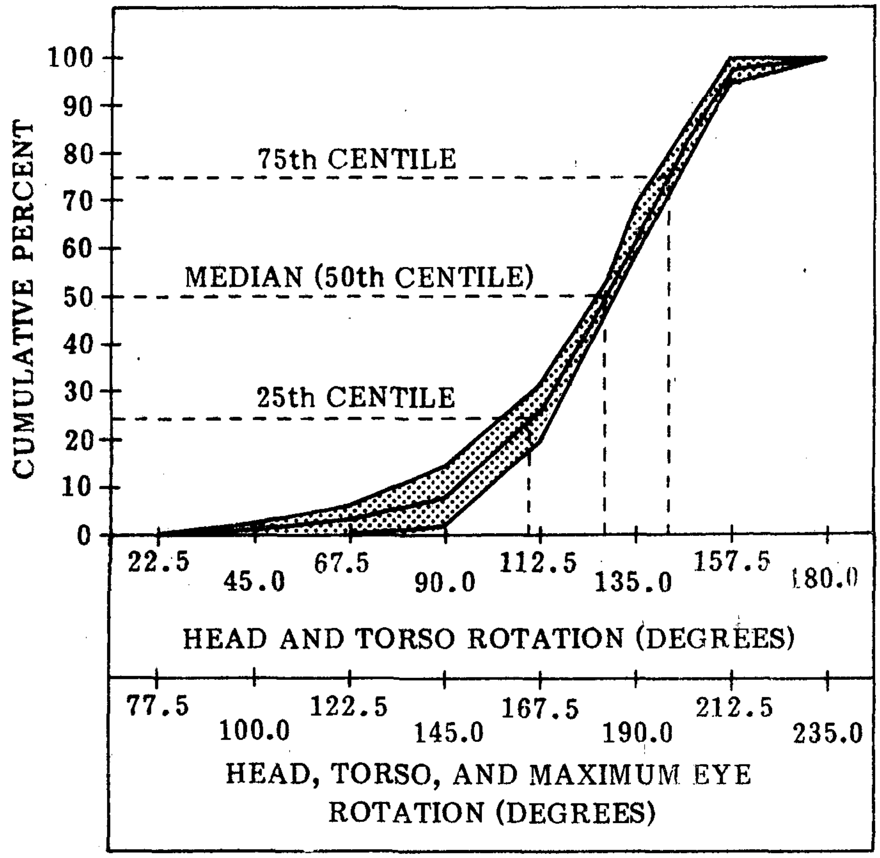
BICYCLISTS' AGE	PRESENCE/ABSENCE OF OVERTAKING MOTOR VEHICLE		NUMBER OF SCANS	
			ONE	TWO OR MORE
ELEMENTARY	PRESENT	(N=64)	45%	55%
	NOT PRESENT	(N=36)	83%	17%
JUNIOR HIGH	PRESENT	(N=155)	46%	54%
	NOT PRESENT	(N=61)	75%	25%
HIGH SCHOOL	PRESENT	(N=133)	55%	45%
	NOT PRESENT	(N=29)	76%	24%
ADULT	PRESENT	(N=115)	68%	32%
	NOT PRESENT	(N=116)	89%	11%

Figure 10. Relative frequency of multiple searches as a function of the presence or absence of an overtaking motor vehicle.

These findings indicate that only a single, rapid search to the rear is usually adequate to detect the presence of a nearby overtaking motor vheicle. These findings correspond closely with the accident data that show few instances in which a Type 18 accident occurred because the bicyclist searched behind too briefly to have detected the presence of an overtaking motor vehicle. Therefore, although bicyclists probably should be instructed to search to the rear more than once at some locations, it seems certain that the incidence of Type 18 accidents would be reduced considerably if bicyclists were induced to search behind at least once, no matter how briefly.

Magnitude of rearward search. The field investigator's judgment of the magnitude of a rearward search was enhanced through the use of a printed circular template with lines radiating from its center at 22.5° intervals. With this aid, the field investigator's task was to match the maximum rotation of the bicyclist's head with the appropriate radial on the template. The degree of head/torso rotation was rounded to the nearest radial, so the rounding error could be as great as 11.25° for any one observation.

Cumulative distributions were generated and plotted for each age group and traffic-density level. The 12 cumulative distribution curves were highly similar and all of them fell within the gray band shown in Figure 11. Thus, the curve



NOTE: The cumulative distributions for all age groups and traffic locations were located within the shaded area shown above.

Figure 11. Cumulative distribution for the magnitude of head and torso rotation during rearward search.

formed by the dark line in the center of the gray band is representative for bicyclists of all ages and for all traffic-density locations.

It should be noted that there are two scales along the abscissa in Figure 11. The upper scale is the degree of rotation that was achieved by rotating both the head and torso. The values in the lower scale are exactly 55° larger than the corresponding values in the upper scale. The value of 55° represents the maximum rotation of the eyes that can be achieved when the head is held in a constant position. Thus, the values in the lower scale show the farthest points to the rear that could be observed with central vision if the bicyclist had rotated his eyes as far as possible in the duration of the head and torso rotation.

Anthropometric data show that the maximum rotation of the head and torso that is possible with the hips kept perpendicular to the line of travel is about 105°. Examination of Figure 11 shows that over 80% of the bicyclists achieved a head/torso rotation greater than 105°. Therefore, it can be concluded that about 82% of the bicyclists rotate their hips when they search behind. The median (50th centile) bicyclist achieved a head rotation of about 117°. If the median bicyclist also rotated his eyes to the maximum, he could have viewed objects with central vision that were located up to 172° from the longitudinal axis of his bicycle. To put this value in context, consider that an angle of 177° is formed by the longitudinal axis of the bicycle and a line from the bicyclist's head to a motor vehicle located two hundred feet behind and 200 feet to the left of the bicyclist. This means that the magnitude of the head/torso rotation for slightly over one-half the searches was too small to enable the bicyclist to view with central vision a motor vehicle located 200 feet to the rear.

Although visual acuity is dramatically reduced when the image falls on the retina at a location 10 degrees or more from the fovea, little acuity is required to detect the presence of a nearby object as large as a motor vehicle.[7] Based upon impressions gained from simple self tests, it seems probable that most bicyclists could reliably detect the presence of a motor vehicle whose image is located at a point on the retina as great as 30° from the fovea. If this impression is correct, a head/torso rotation of 95° plus an eye rotation of 55° (150° total) would be adequate to detect the presence of an overtaking motor vehicle. It can be seen in Figure 11 that more than 90% of the head/torso/eye rotations in the sample exceeded this postulated minimum value of 150 degrees.

Duration of rearward search. The field investigator carefully noted the duration of each rearward search and then classified each search into one of three categories: no pause or a barely discernible pause, a clearly discernible pause, or a pause of more than one second. The searches in these three categories will be referred to hereafter as "short duration" searches, "moderate duration" searches, and "long duration" searches, respectively.

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[7] The visual angle subtended by a motor vehicle located 200 feet away is about 1.4 degrees.

An analysis showed that search duration was independent of traffic density at the observation sites but varied systematically as a function of bicyclist's age. Figure 12 shows that the percentage of long duration searches increases with age and that the relative frequency of long duration searches for the youngest group of bicyclists is about three times as great as that for the adult group. The relative frequency of short duration searches increases with age through high school and decreases dramatically for adult bicyclists.

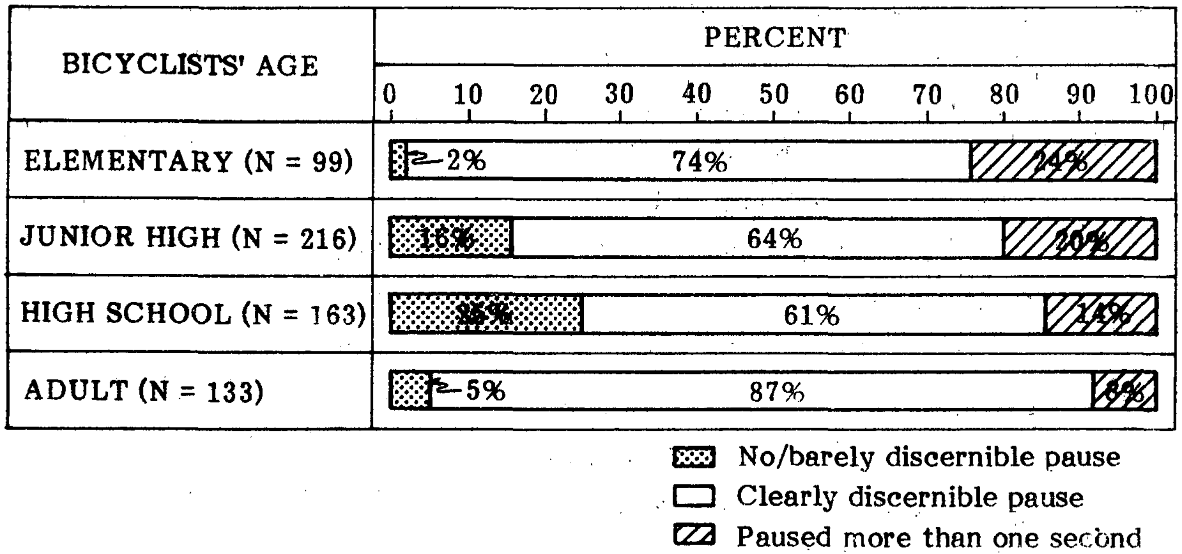

Figure 12. Duration of rearward search as a function of bicyclists' age.

The decrease in long duration searches probably reflects an increase in bicyclists' information processing skills and vehicle handling skills. That is, as bicyclists become older, there is a decrease in the amount of time they need to perform an effective rearward search. The increase in the number of short duration searches is probably the result of a decrease in the perceived risk associated with short duration searches and the perceived risk associated with left-hand turns in general. If this increase in the relative frequency of short duration searches reflected an increase in proficiency, short duration searches would have been at least as frequent for adults as for juveniles.

DISCUSSION

The most important finding of the field-observation study is that a failure to search behind before initiating a left-hand turn is **not** an uncommon event for bicyclists in the Santa Barbara area. To the contrary, a dangerously large number of search failures were noted for bicyclists of every age and for the full range of traffic locations where observations were made. Although these findings cannot automatically be generalized to other bicycling populations in other geographical areas, the authors believe that Santa Barbara bicyclists do not differ in any important way from bicyclists elsewhere and that the high incidence of search failures is not unique to Santa Barbara bicyclists, to the Santa Barbara traffic environment, or to any other behavioral or environmental artifact. Support for this contention is provided in a study of more than 1,000 driving errors committed by bicyclists in Calgory and Edmonton, Canada (Dewar, 1978). Failure to search behind before turning or changing lanes was found to be among the most frequently occurring errors committed by Canadian bicyclists.

Another interesting finding of the present study is that the overrepresentation of juvenile bicyclists between nine and 14 years of age in Type 18 accidents cannot be accounted for by a higher incidence of search failures among this age group. Although the incidence of search failures **was** found to be related to age (or estimated age), this relationship was not nearly strong enough to account for the overrepresentation of 9-14 year-old bicyclists in Type 18 accidents. Based upon these findings, it seems probable that the high incidence of Type 18 accidents among 9-14 year-old bicyclists is due, in part, to the amount or type of exposure for this age group. This finding tends to discredit the view that juvenile bicyclists are "risk takers" who are more willing to expose themselves to serious injury than adult bicyclists.

It has been hypothesized that bicyclists' inclination to search behind before turning is influenced by the relative ease with which a rearward search can be accomplished. However, the incidence of search failure was found to be independent of any variable considered to be an indicator of the ease or difficulty of performing a rearward search, such as bicycle type, position of the hands on the handlebars, and the inclination of the bicyclist's torso. Consequently, if bicyclists' propensity to search behind is influenced by the ease or difficulty of performing the search, the effect is so small that it is completely obscured by other, more important factors.

It was of considerable interest to find that the incidence of search failure was less when an overtaking motor vehicle was within one-half block of the bicyclist than when no overtaking motor vehicle was nearby. The most plausible explanation of this finding is that bicyclists are using auditory cues to determine whether or not a rearward search is necessary. Although not particularly surprising, this finding supports Cross and Fisher's (1977) hypothesis that substantial numbers of bicyclists place undue trust in auditory cues to signal the presence of overtaking motor vehicles.

A search failure was found to be significantly more frequent when a bicyclist was riding with a companion and when the field investigator judged that some type of distractor was present at the time the bicyclist was preparing to turn left. While these data do not establish a causal relationship between search failures and distractors, the fact that a strong concurrent correlation exists between the two is highly suggestive and clearly warrants a more detailed study of the effect of distractors on search failures.

There is no evidence that Type 18 accidents are often the result of bicyclists performing an **ineffective** rearward search. More specifically, there were only a very small number of Type 18 accidents in which the bicyclist searched to the rear and failed to observe the overtaking motor vehicle or misjudged the closing velocity of the overtaking motor vehicle. Thus, it must be concluded that the type of rearward search performed by bicyclists is adequate for the task. It was therefore surprising to find that the data on the characteristics of rearward searches indicate that most bicyclists search behind only once, and that these rearward searches are brief (less than one second) and often made with peripheral rather than with central vision. Hence, although it may appear that many of the bicyclists' rearward searches were ineffective, the accident data provide no evidence to support this view. Thus, it appears that inducing bicyclists to search is a more important objective of Type 18 countermeasures than inducing them to perform a more thorough search.

SECTION IV

CONTROL-STABILITY EXPERIMENT

The first countermeasure that comes to mind for Problem Type 18 is to teach or otherwise induce bicyclists to search behind before initiating a left-hand turn. However, field observations and pilot research conducted by members of the project staff have shown that a rearward search is nearly always followed immediately by a momentary decrease in the stability of the bicycle-bicyclist unit. The most important manifestation of the reduced stability is a consistent increase in the lateral deviation from the bicyclist's desired path. These findings suggest that merely inducing bicyclists to search behind before turning may be counterproductive. That is, the act of searching behind may cause some bicyclists to lose control of their bicycle and to either fall or swerve left into the path of an overtaking motor vehicle.

The primary objectives of the research reported in this section were to measure systematically the magnitude of the inadvertent lateral deviations that accompany a rearward search and to determine the relationship between these lateral deviations and the bicyclist's age and riding experience. Other objectives, of more academic interest, include the following:

- To obtain bicyclists' subjective ratings of bicycle stability during both search and no-search trials and to determine the relationship between rated stability and measured stability.
- To determine the effect of bicycle speed on stability following a rearward search.
- To determine the relationship between bicycle type and lateral stability following a rearward search.
- To determine the magnitude of head/torso rotation and the search duration during a rearward search.

METHOD

In order to make the descriptions of equipment and materials more meaningful, the description of methodology will commence with a brief description of the bicyclist's task and the performance measures recorded for each trial.

Overview

The bicyclist's task in this experiment was to ride as close as possible to a narrow path before, during, and after a purposeful rearward search. The bicyclists who served as subjects were instructed to search to the rear as necessary to read a numeral on a stimulus card that was located about 160^{o} to the left-rear of the bicyclist. Each of the 100 bicyclists performed a total of ten trials--five at a slow speed (about 5 MPH) and five at a fast speed (about 10 MPH). The first trial in each set of five was a control trial in which the bicyclist was not required to search behind. All subjects rode a familiar bicycle, usually their own.

On each trial, members of the research team recorded: the track of the bicycle through the entire length of the test trap, the magnitude of the maximum rotation of the head and torso during the rearward search, the time taken to ride through the test trap, and a rating by the bicyclist of his stability during the trial. Video recordings of the bicyclist riding through the test trap were made for trials 2, 3, 7, and 8. A subsequent study of the video recordings provided a precise measure of the duration of the bicyclist's rearward search.

Subjects

The 100 bicyclists who served as subjects in this experiment were residents of Santa Barbara, California, or its suburbs. All bicyclists were paid volunteers who responded either to printed solicitations posted in local public schools or to signs posted near the test site. Volunteers were accepted sequentially, without regard to age or sex, until 20 bicyclists had been run for each of the following groups:

- First through third grade
- Fourth through sixth grade
- Seventh through ninth grade
- Tenth through twelfth grade
- University students and other adults

The age of the subjects varied from six to 58 years. The mean age and the standard deviation of the mean for each of the five groups are shown in Table 9. Also shown in Table 9 is the number of males and females in each group. Because of the difficulty of soliciting subjects, no attempt was made to obtain equal

Table 9

AGE AND SEX DISTRIBUTIONS OF SUBJECTS

		BICYCLISTS' GRADE LEVEL				
		1st-3rd	4th-6th	7th-9th	10th-12th	Adult
BICYCLISTS' AGE (IN YEARS)	MEAN	7.3*	10.5	12.7	15.2	22.8
	STANDARD DEVIATION	.8*	1	.8	1.1	8.8
BICYCLISTS' SEX	MALE	15	17	19	18	14
	FEMALE	5	3	1	2	6

*Mean and standard deviation in years.

numbers of males and females for each group. The overrepresentation of males in the subject population (87%) is similar to the overrepresentation of males in the field observation study (73%) and in the Type 18 accident sample (73%) investigated by Cross and Fisher (1977).

Table 10 shows the type of bicycle ridden by the subjects in each group. An attempt was made to sample the full range of bicycle types for each age group, so the distribution of bicycle types shown in Table 10 cannot be considered representative of the general bicycling population. It should be noted that most of the bicycles classified as "highrise" were the model of highrise bicycle referred to as a "motocross" bicycle. The motocross bicycle has a frame configuration similar to the conventional highrise bicycle but has a shock-absorbing front fork, knobby tires, and a more ruggedly constructed frame. Although the motocross bicycle is designed to be ridden on dirt paths, it is often used for stunting on paved surfaces as well. The use of the motocross bicycle accounts for the large number of older bicyclists (10th grade and above) who rode highrise bicycles when they participated in the experiment.

Table 10

TYPE OF BICYCLE RIDDEN BY SUBJECTS IN EACH GROUP

BICYCLE TYPE	BICYCLISTS' GRADE LEVEL				
	1st-3rd	4th-6th	7th-9th	10th-12th	Adult
HIGHRISE	18	14	7	10	4
MIDDLE-WEIGHT	2	3	4	3	2
LIGHT-WEIGHT	0	3	9	7	14

Equipment and Materials

The equipment and materials used during this study are illustrated in Figure 13 and are described in the following paragraphs. A test trap, consisting of a 48-foot long by 8-foot wide grid, was constructed by placing strips of white adhesive tape on a large flat asphalt surface. Pilot tests showed that a test trap 48 feet long enabled bicyclists to fully recover from the imbalance created by a rearward search prior to exiting the test trap. The grid lines forming the test trap were spaced at intervals of two feet along both the lateral and the longitudinal dimensions. A strip of gray tape 2.5 inches wide served as the command path for the bicyclists as they approached the test trap and rode through it. The strip of gray tape commenced at a point 75 feet from the start of the test trap, continued through the full length of the test trap, and terminated at a point 10 feet beyond the end of the test trap.

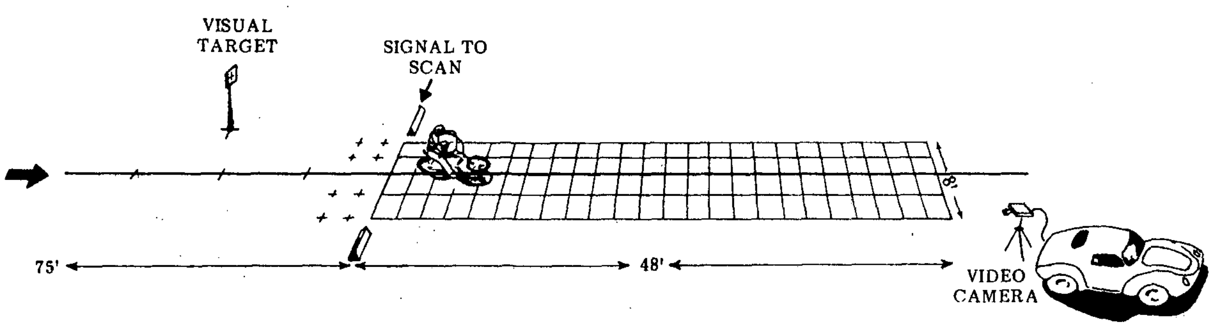

Figure 13. Illustration of the layout of the test trap.

Short strips of red tape and blue tape were placed along the command path at intervals of 7.5 feet and 15 feet, respectively. The purpose of the strips of colored tape was to help the bicyclists achieve and maintain the proper speeds. The red strips were positioned such that a bicycle traveling at a speed of 5 MPH would cross a red strip once each second; similarly, the blue strips were positioned such that a bicycle traveling at 10 MPH would cross a blue strip once each second.

A stand, designed to hold a stimulus card about four feet above the ground, was positioned at a point eight feet from the entrance to the trap and five feet to the left of the command path. This position was selected because it required the bicyclist to rotate his head and torso by about the same amount as would be required to see an overtaking motor vehicle. Pilot tests showed that at the time the bicyclist searched behind, the average angle between the command path and the stimulus-card stand was 162°. The stimulus cards were 14 inches high and 11 inches wide. Each stimulus card had a single black numeral printed on a white background; the numerals used on the five stimulus cards were 2, 3, 4, 6, and 7. The numerals were 11 inches high and about seven inches wide. This study is based on the assumption that searching behind to read a single numeral is at about the same level of information-processing difficulty as searching behind to determine the presence or absence of a nearby overtaking motor vehicle.

A Sanyo VC-3300X video recording camera, equipped with a zoom lens, was positioned 20 feet past the end of the trap. This camera was connected to a Sanyo VTR-1200 helical scan video recorder. Also connected to the video recorder was (a) a Vicon Industries, Inc., V240 series date/time display generator, and (b) a JVC Industries, Inc., 3420M 12-inch diagonal black-and-white monitor. The date/time display generator was used to display the date and the elapsed time, in one-tenths of a second, on the monitor and the video recording. The display of elapsed time along with the capability to play the video recordings at a very slow speed made it possible to measure precisely the onset-termination times of events. The main purpose of this equipment was to provide an efficient way of obtaining precise measurements of the duration of the bicyclist's search. The video camera was positioned such that the entire test trap was simultaneously visible on the monitor. So, there was no need to track bicyclists with the camera as they rode through the test trap.

A device for making a semi-permanent record of the bicycle track was constructed from a plastic one-quart water bottle and a length of flexible plastic tubing. The plastic tubing was inserted into a hole cut in the bottle and was sealed so that the entire contents of the bottle would drain through the tubing. The water bottle and tube were taped onto the left side of the front fork in such a way that the water from the tube drained onto the front tire of the bicycle. The wet tire, in turn, left a distinct track on the dry pavement. Although the wet tire track evaporated within a few minutes, it was clearly visible for the time needed to measure and record the bicycle's track on the data sheet.

Other equipment and materials employed during the data-collection phase of this study include:

- A seven-point rating scale used by bicyclists to rate their judgment about the degree of stability during each trial (see Appendix C).
- Data-recording sheets (see Appendix D).
- A measuring tape to measure the lateral deviation of the bicycle track from the command path.
- A stopwatch to measure the time taken to ride through the test trap.
- A whistle to signal the bicyclists to commence their rearward search.
- Bicycle helmets (all subjects were required to wear a helmet during every trial).

Procedure

Bicyclists were tested individually, and all rode their own bicycle or a borrowed bicycle they had ridden frequently before. Each bicyclist was required to complete a total of ten trials. Five trials were performed at a "slow" speed (about 5 MPH), and five were performed at a "fast" speed (about 10 MPH). These speeds were selected because they represent the approximate limits of comfortable riding speeds for the typical, moderately experienced bicyclist. For most bicyclists, 5 MPH is a slow but stable riding speed, and 10 MPH is about as fast as they can ride comfortably for sustained periods.

To counterbalance for learning effects, one-half of the bicyclists in each age group completed the slow trials first, and the other one-half completed the fast trials first. The first trial at each speed (trial one and trial six) was a control trial to measure the bicyclist's ability to remain on the command path when no rearward search was required. On each of the remaining trials, the bicyclist was required to search behind as necessary to read the numeral on the stimulus card. The trials will be referred to as "search" trials and "no-search" trials.

When a bicyclist arrived at the test site, one experimenter taped the water bottle to the bicycle, and the second experimenter gave instructions to the bicyclist. The experimenter explained the general purpose of the experiment, the nature of the bicyclist's task, and the manner in which the bicyclist would use the colored strips to ride at the desired speed. The bicyclist was then instructed to practice riding at the desired speeds. When necessary, the experimenter instructed the bicyclist to ride faster or slower until the desired speed was achieved and maintained. On all trials, the bicyclist was instructed to ride as close as possible to the command path throughout its length. On trials one and six, the bicyclist was instructed to ride the length of the command path without searching. On the remaining trials, the bicyclist was instructed to search behind as soon as possible after hearing a whistle and to search behind only as long as was required to positively identify the numeral on the stimulus card. The experimenter blew the whistle at the moment the front wheel of the bicycle crossed into the test trap.

During each trial, an experimenter used a stopwatch to measure the amount of time taken for the bicyclist to ride through the test trap. This experimenter was also responsible for judging and recording the magnitude of the bicyclist's head and torso rotation during the search. The video tape system was used to record trials 2, 3, 7, and 8.

Bicyclists were instructed to stop when they reached the end of the command path and to (a) report the numeral that was on the stimulus card and (b) provide a rating of the degree of stability during that trial (on a seven-point rating scale). While one experimenter was obtaining the bicyclist's stability rating, the other experimenter measured and recorded the direction and magnitude of the deviation of the bicycle track from the command path at each of the 25 grid lines (two-foot intervals) within the test trap.

After completing all 10 trials, subjects were questioned about their bicycling experience. Subjects were paid $3.00 for participating in the study. The entire procedure required approximately 25 minutes per subject. Complete experimenters' and subjects' instructions can be found in Appendix E.

Data Analysis

The subject's task in this experiment is a classical continuous-tracking task, but proficiency at this task is defined differently than for many tracking tasks reported in the literature. In the present task, a deviation from the command path has little practical significance unless it is large enough to expose the bicyclist to overtaking traffic on the left or to cause the bicyclist to collide with the curb, shoulder, or other fixed object on the right. Consequently, task proficiency is not necessarily reflected by conventional indices, such as mean square error, route mean square error, number of control reversals, time-on-target, and so on. If the value of a "critical deviation" from the command path could be defined, a meaningful index of proficiency would be the total time during a trial that the bicyclist's deviation from the command path was greater than the "critical deviation." This performance measure was judged unsuitable because it is not possible to define a deviation that is critically large for all or even most traffic contexts.

A performance measure judged to be more suitable is the magnitude of the largest deviation from the command path that occurred during a given trial. This performance measure, referred to hereafter as "maximum error," is illustrated in Figure 14. It can be seen in Figure 14 that the maximum errors for Tracks A and B are one unit and 2.3 units, respectively. If maximum error must be at least two units in order for a bicyclist to be exposed to hazards, the error in Track A is of little or no consequence even though the track is displaced from the command path throughout most of the trial. Conversely, the error in Track B is of critical importance even though the bicyclist deviated from the command path by more than two units only briefly, and then quickly returned to the command path and remained on the command path throughout the rest of the trial.

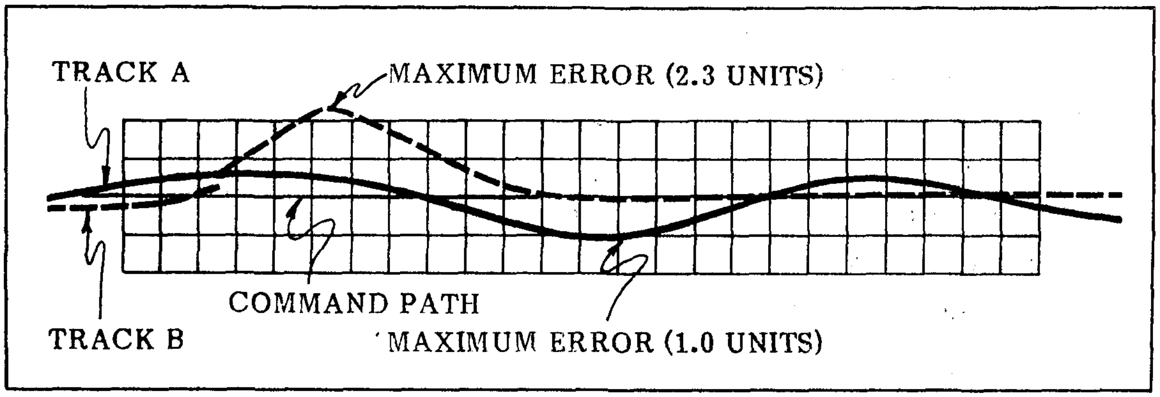

Figure 14. Hypothetical tracks illustrating "maximum error," the main index of task proficiency.

A maximum error value was defined for each trial, so 10 data points were available for each of the 100 subjects. Maximum error was analyzed in three ways. The purpose of one analysis was to determine whether maximum error tended to be larger and/or more frequent on the left than on the right of the command path. To answer this question, maximum errors to the left were assigned a negative value; maximum errors to the right were assigned a positive value; and the error values were summed algebraically across trials and subjects. Since positive and negative errors cancel one another, the sum and mean of "algebraic maximum error" is near zero when response bias is small, and large when response bias is great. It should be kept in mind that algebraic maximum error does not reflect task proficiency.

The purpose of a second type of analysis was to determine whether maximum error for one group or condition was statistically different from maximum error for another group or condition. To test for statistical significance of differences, standard parametric statistical tests were used to analyze "maximum absolute error"--maximum error **without** respect to the direction of the deviation. Both analysis of variance and t-tests were used to test the null hypothesis of no difference between/among means. The means referred to here were derived by summing maximum absolute error values and dividing the total by the number of observations.[8]

[8] The mean of N absolute maximum error values = $\frac{\sum_{i=1}^{N} |e_i|}{N}$

The purpose of a third type of analysis was to assess the practical significance of maximum errors. To accomplish this task, it is necessary to examine the **distributions** of maximum absolute error rather than the **average value** of maximum absolute errors. Information about the distribution of maximum absolute error can be conveyed by presenting standard deviation values and/or by presenting confidence intervals about the mean. However, because of the great importance of extreme values of maximum absolute error, a decision was made to compute centiles and to present the data in the manner shown in Figure 15.

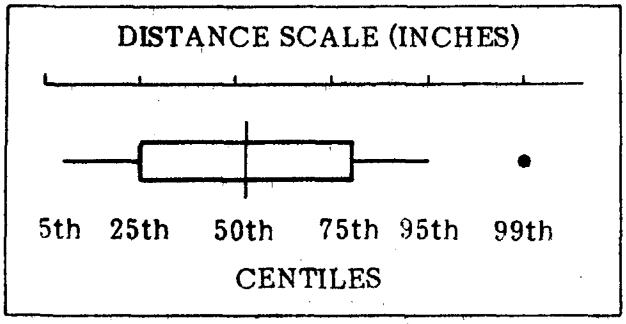

Figure 15. Illustration of method used to portray the distribution of maximum absolute error.

The horizontal bar in Figure 15 represents the interquartile range; the left extreme shows the value of the 25th centile, and the right extreme shows the value of the 75th centile. The vertical line, which passes through the horizontal bar, shows the value of the 50th centile. The termination of the horizontal lines extending from the left and right of the horizontal bar shows the value of the 5th and 95th centiles, respectively. The solid black dot to the right of the 95th centile defines the value of the 99th centile.

In addition to the analysis of maximum error, the stability ratings of the bicyclists and the characteristics of their rearward search were analyzed. The bicyclists' ratings of stability during each trial were analyzed to determine the extent to which the bicyclist's subjective assessment of stability corresponded with the objective measurement of stability, as reflected by maximum absolute error. The relationship between stability ratings and maximum error was examined for each speed and for the search and no-search trials. The analysis of bicyclists' rearward searches consisted of an analysis of both search duration and the magnitude of head rotation during the search.

RESULTS

The results are presented in three major subsections. This first subsection describes response bias in maximum error and the relationship between maximum error and a host of independent variables. The second subsection describes the value and the distribution of bicyclists' stability ratings and the relationshp between stability ratings and various variables. The third subsection describes the characteristics of the bicyclists' rearward searches.

Maximum Absolute Error

This subsection describes the response bias present in the maximum error values, and describes the relationship between maximum absolute error and (a) the presence or absence of a rearward search, (b) bicycle speed (fast or slow), (c) bicyclist's age, (d) bicycle type, and (e) bicycling experience. The relationship between maximum absolute error and the bicyclist's sex is not discussed in detail because bicyclist's sex was found to be confounded with the number of hours per week spent riding a bicycle. So, it is assumed that the finding that maximum absolute error is greater for females than for males merely reflects a difference in the riding experience of the two groups.

Maximum error is not presented by trial because an analysis showed that there was not a statistically significant improvement in performance over the four trials at either the fast speed ($F = 1.70$, $p>.05$) or the slow speed ($F = .41$, $p>.05$).

Response bias. It has been hypothesized that rotating the head and torso to search to the left-rear would cause the bicyclist to consistently veer to the left during and immediately after a rearward search. To determine the validity of this hypothesis, maximum errors were summed algebraically over trials and subjects, and the algebraic sum was divided by the number of observations in the sample.

It was found that the algebraic mean of the maximum errors was +.6 inches for both the fast trials and the slow trials. This means that there was no important bias to either the right or to the left of the command path. Although there were a few subjects who consistently deviated to one side of the command path during most of their trials, their bias was as likely to be on the right as on the left. In light of these findings, it can be concluded that maximum error is distributed symmetrically around the command path.

These findings fail to support the hypothesis that searching to the left rear causes bicyclists to veer to the left more often than to the right.

Rearward search. As expected, maximum absolute error was significantly greater for the search trials than for the no-search trials; mean error[9] was 7.5 inches for the search trials (N = 800) and 3.9 inches for the no-search trials (N = 200). Although the difference between means is not large (d = 3.6 inches), it was found to be statistically significant (F = 94.0, $p<.001$).

The error distributions for the search and the no-search trials are shown graphically in Figure 16. It is clear from Figure 16 that a rearward search affects extreme errors far more than average errors. For instance, it can be seen that the two medians differ by slightly less than three inches, whereas the two 99th centile values differ by more than 10 inches.

This finding is an extremely important one because it is the relatively infrequent but large lateral deviations that are of primary interest in this study. This finding indicates that a rearward search typically has little effect on the magnitude of lateral deviation. However, on the few trials when error is atypically large for one reason or another, it is considerably larger when a rearward search is

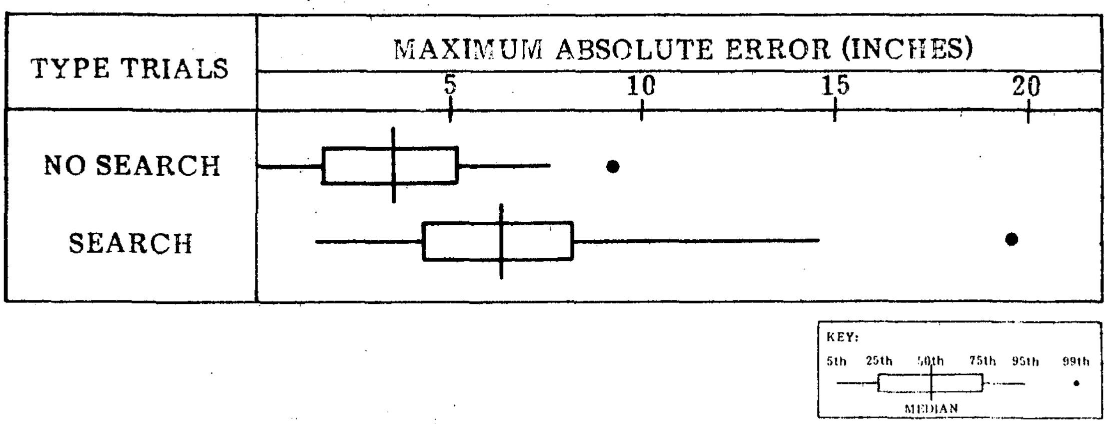

Figure 16. Effect of rearward searches on the distribution of maximum absolute error.

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[9] The abbreviated term "mean error" is used throughout this section to refer to the mean of the maximum absolute error values.

performed than when not performed. This means that if a critical lateral deviation is smaller than about 20 inches, a rearward search increases the likelihood that a critical lateral deviation will occur.

Bicycle speed. Earlier, it was explained that the command speed was 5 MPH for the "slow" trials and 10 MPH for the "fast" trials. The time it took the bicyclist to ride the length of the test trap was measured for each trial and was used to determine the correspondence between the nominal and the actual speeds. Figure 17 shows the mean speeds and the 95% confidence intervals[10] for both the slow trials and the fast trials. The mean speeds were found to be 5.7 MPH for the slow trials and 9.2 MPH for the fast trials. Although the confidence intervals for the two speeds overlap, this overlap is not great; and the difference between the two means is highly significant (F = 2229, p<.001).

Figure 18 shows mean error as a function of bicycle speed for both the search and the no-search trials. It can be seen that the mean error is greater for the slow trials than for the fast; moreover, the effect of speed is seen to be greater for the no-search trials than for the search trials. Although the magnitude of the differences between means is not large, an analysis of variance showed that both the main effects of speed and the speed-by-search interaction are statistically significant. The F-ratio for the main effect of speed is 10.5 (p < .01); the F-ratio for the speed-by-search interaction is 42.6 (p<.001).

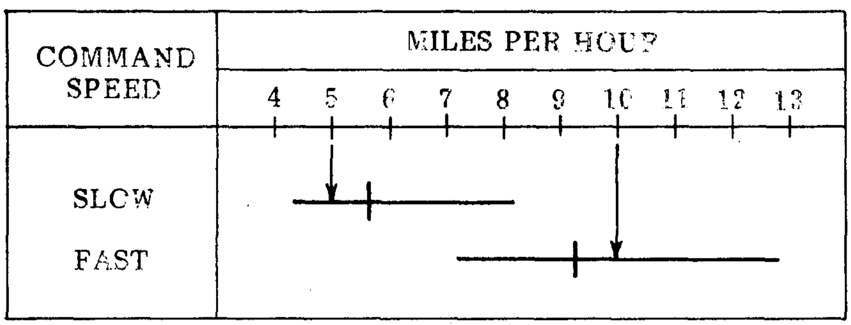


Figure 17. Means and 95% confidence intervals for bicyclists' speed during slow and fast trials.

[10]Confidence intervals for the time-in-trap were computed, and the time values (in feet per second) were then converted to MPH. This is why the confidence intervals in Figure 19 are not symmetrical about the means.

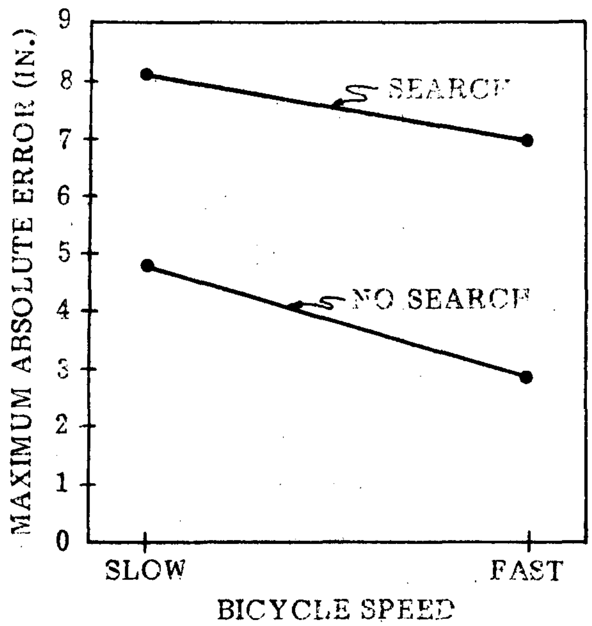


Figure 18. Mean error as a function of bicyclists' speed for search and no-search trials.

The effect of bicycle speed on the distribution of maximum absolute error is shown in Figure 19. It can be seen that the inverse relationship between maximum absolute error and bicycle speed is present for all the centiles portrayed except the 99th centile. Thus, except for the 99th centile, the likelihood of large error is greater for the slow trials than for the fast. So, as was true for the effect of search, the effect of bicycle speed (within the limits of speed examined in this study) is to expand the error distribution by increasing the magnitude of the largest errors. It is probable that the lack of an inverse relationship between bicycle speed and error for the 99th centile is due to the small number of cases on which the 99th centiles are based.

These findings indicate that it may be counterproductive to instruct bicyclists to slow their bicycle considerably before attempting to search behind. However, before such a recommendation is made, a follow-on study should be performed to define the relationship between speed and lateral error over a larger range of speeds.

Bicyclist's age level. The results of an analysis of variance showed that there is a statistically significant relationship between bicyclist's age level and mean error for both the search and the no-search trials. The results of this analysis also showed that there is a statistically significant three-way interaction among age level, bicycle speed, and presence/absence of a rearward search ($F = 12.3$, $p < .0001$). Thus, the relationship between age level and mean error is not a simple one.

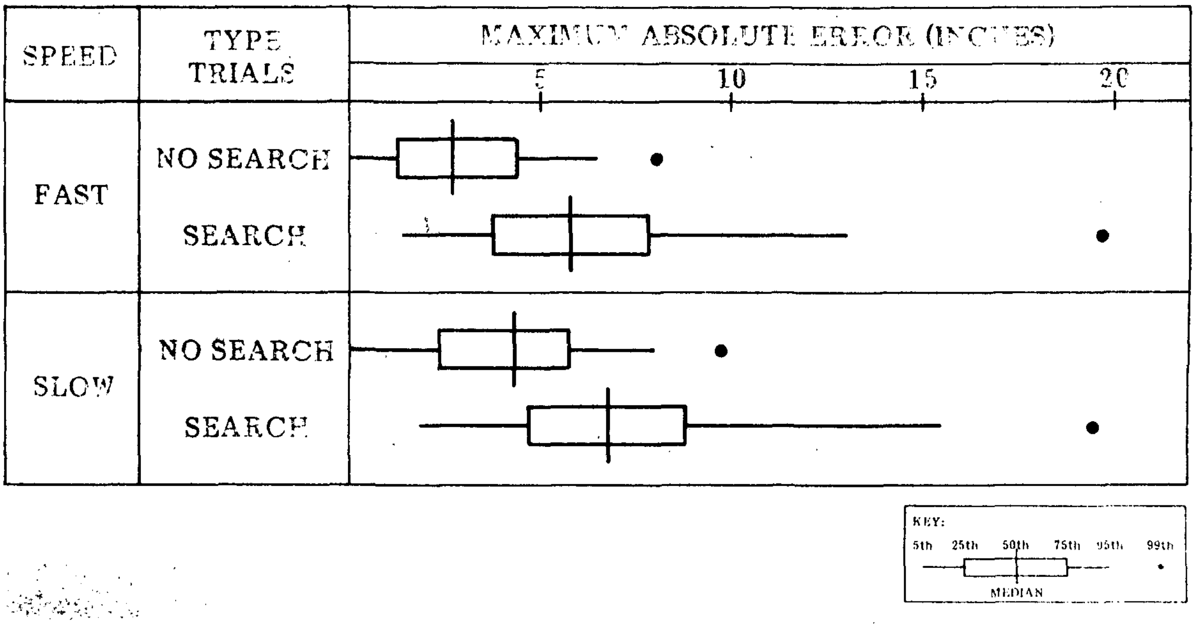
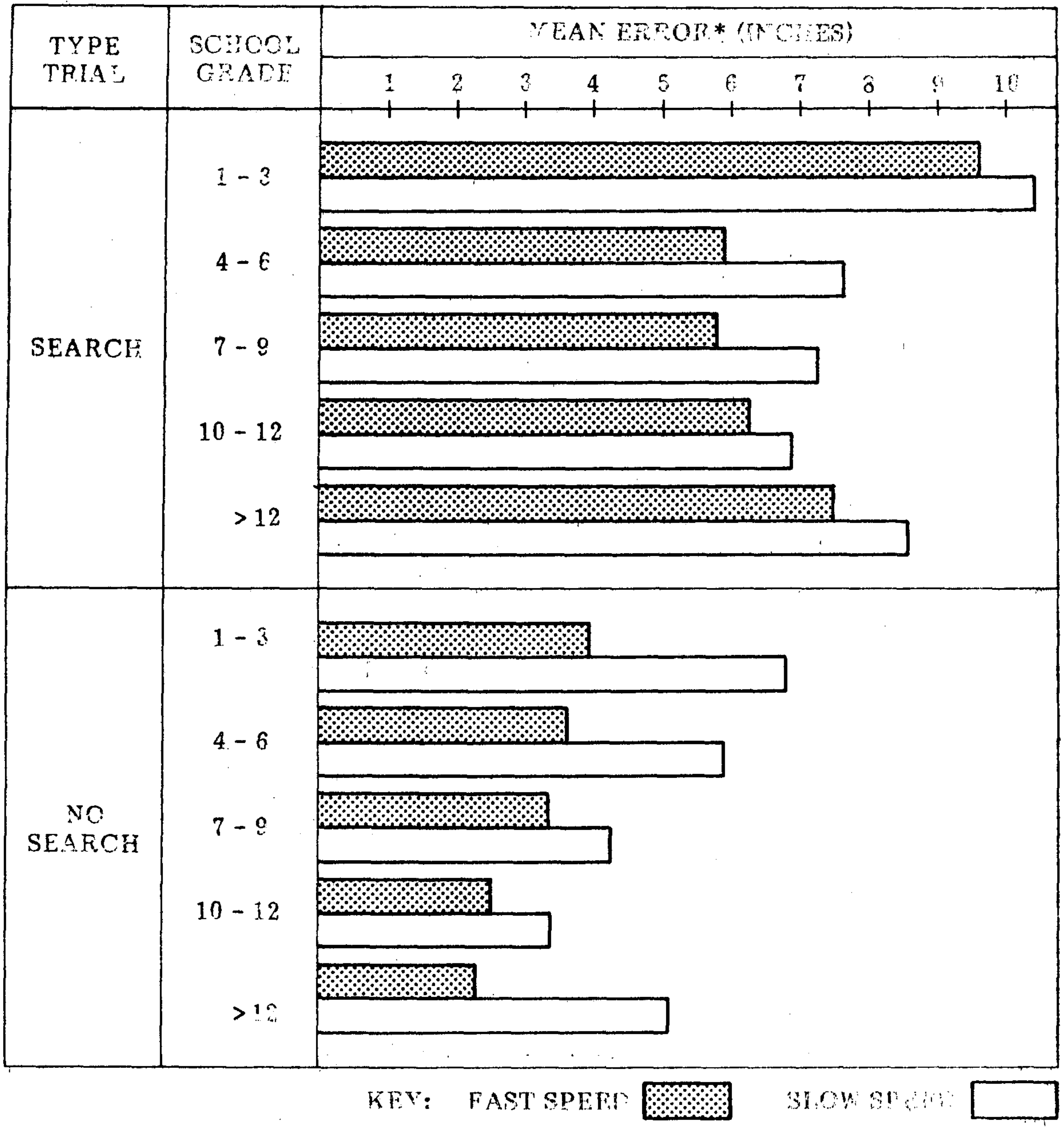


Figure 19. Effect of bicycle speed on the distribution of maximum absolute error, shown for both search and no-search trials.

As a first step in comprehending the nature of the relationship between bicyclist age level and mean error, examine the upper portion of Figure 20 which shows the data for the search trials. It can be seen that error tends to be greater for the youngest (grade 1-3) and the oldest (grade >12) age groups and roughly equivalent for the three intermediate age groups. This trend is more clearly shown in the slow-speed than the fast-speed trials. The results of an analysis of the significance of difference among means (Tukey method as defined in Glass and Stanley, 1970) revealed the following:

- On the fast trials, mean error for the youngest bicyclists (grades 1-3) was significantly greater than that for the remaining four age groups.
- On the fast trials, mean error for the oldest bicyclists (grade > 12) was significantly greater than that for the three intermediate age groups (grades 4-6, 7-9, and 10-12).
- On the fast trials, mean error for the three intermediate age groups did not differ significantly.
- On the slow trials, the mean error for the youngest group was significantly greater than that for the remaining four age groups, but there were no significant differences among the four older age groups.



*Mean error is absolute maximum error averaged over subjects and trials.

Figure 20. Mean error as a function of age level, bicycle speed, and presence or absence of search.

Next examine the data for the no-search trials, which are shown in the lower portion of Figure 20. It can be seen that when a rearward search is not performed mean error tends to decrease with the age of the bicyclist. The only exception to this trend is that the mean error for the oldest groups' slow-speed trials is greater than that for two of the four younger age groups.

Figure 21 shows the distributions of maximum absolute error for each of the five age groups. Separate distributions are shown for the search and the no-search trials, but the fast-speed and slow-speed trials have been combined. The medians shown in Figure 21 reflect the same trends as the mean error shown in Figure 20. That is, for search trials, the errors for the youngest and the oldest age groups are larger than the errors for the three intermediate age groups. However, this same trend is **not** shown for the 75th centiles, the 95th centiles, or the 99th centiles. It can be seen that the relationship between age and maximum absolute error tends to wash out when the extreme errors are considered. In fact, it can be seen that the magnitude of the 95th and 99th centile errors for the youngest age group is less than the error for three of the four remaining age groups.

This is an important finding because it suggests that attempts to decrease the incidence or magnitude of extreme errors must be directed at all age groups rather than at just the youngest and the oldest groups, as was suggested by the analysis of mean error (Figure 20). This is another case in which the trends reflected by measures of central tendency (means and medians) are altogether different from those reflected by the error distributions.

Bicycle type. It has been suggested that bicycle stability and responsiveness vary considerably from one bicycle type to another. Thus, it seems reasonable to hypothesize that maximum absolute error is greater for some bicycle types than others. In order to control for the age effect, it was possible to compare only the bicycle types that were common to the same age group. To accomplish this comparison, bicyclists in grades 7-12 were pooled together, and 16 riders of highrise bicycles and 17 riders of lightweight bicycles were selected from the bicyclist pool. As before, the mean absolute maximum error during the search trials served as the measure of performance. A t-test, adjusted for unequal

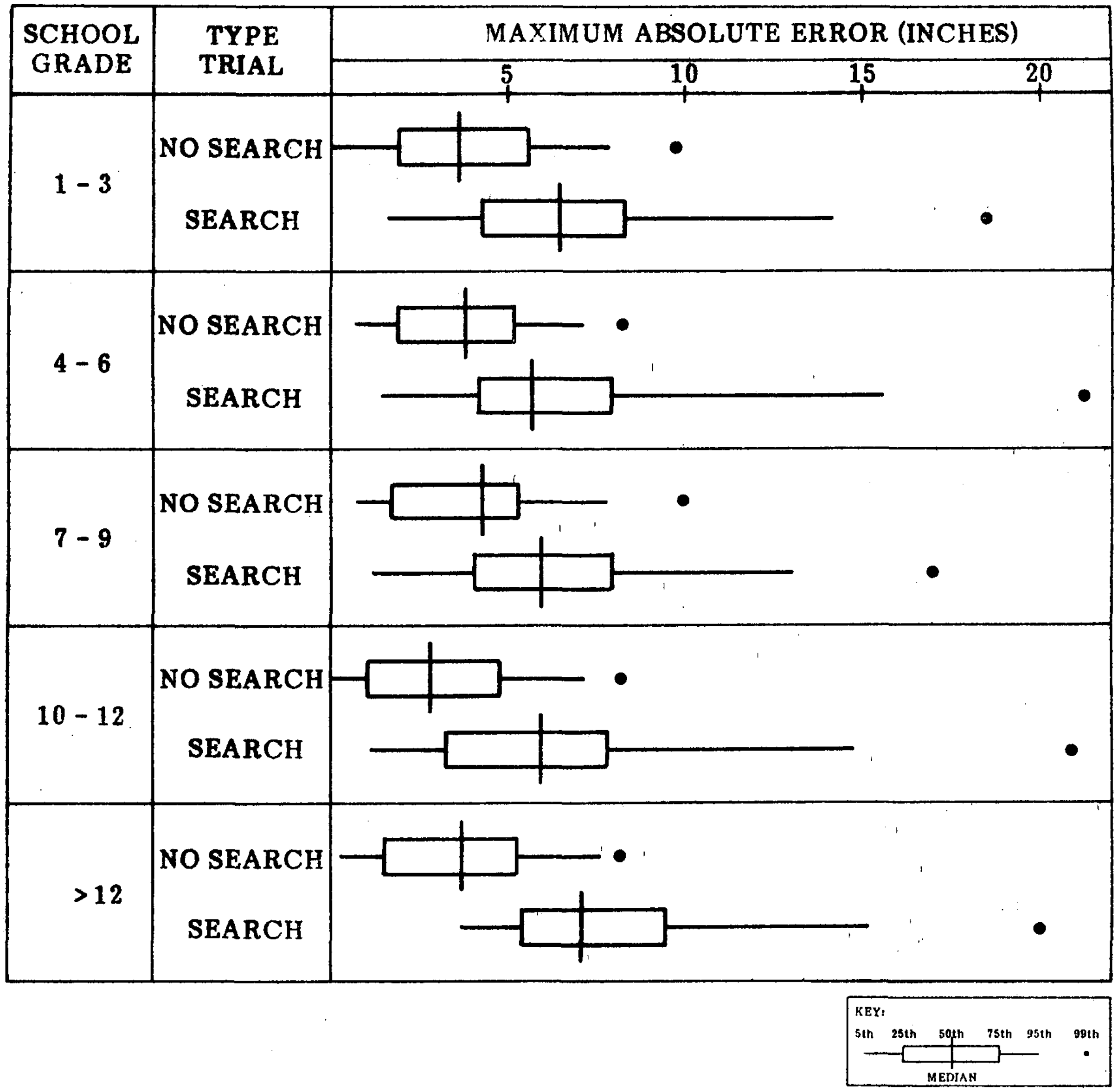


Figure 21. Effect of age and rearward search on the distribution of maximum absolute error. The fast- and slow-speed trials are combined.

numbers of observations, indicated that bicycle type did **not** significantly affect performance on the fast trials, the slow trials, or the fast and slow trials combined. In short, the results of this study provided no support whatever for the hypothesis that there is a relationship between bicycle type and lateral deviation during and after a rearward search.

Bicyclists' riding experience. Two indices of riding experience were obtained from each of the 100 subjects who participated in the experiment. One index was the number of years the bicyclist had been riding regularly. This index is highly correlated, but not perfectly, with bicyclists' age. The second index is the number of hours spent riding a bicycle during an average week. This index is definitely not highly correlated with bicyclists' age.

Pearson Product Moment correlation coefficients were computed to assess the strength of the relationship between each index of riding speed and mean error (maximum absolute error averaged over all search trials). The correlation between mean error and years riding experience proved to be non-significant for both the fast-speed trials ($r = -.18$, $p > .05$) and the slow-speed trials ($r = -.19$, $p > .05$). However, both of these correlation coefficients missed the value required for statistical significance at the .05 level by a only small margin. It is likely that a larger sample would have resulted in a statistically significant but small correlation between mean error and number of years riding regularly.

The correlation between mean error and hours ridden during an average week proved to be statistically significant for both the fast-speed trials ($r = -.25$, $p < .05$) and the slow-speed trials ($r = -.24$, $p < .05$). As would be expected, the correlation coefficients are negative, indicating that error tends to decrease as the number of hours spent riding per week increases. These findings suggest that maintaining lateral control of a bicycle during and after a rearward search is a skill that deteriorates without regular practice.

Stability Ratings

One possible reason for the bicyclists' reluctance to search behind is their fear of falling or swerving when searching. If fear is indeed a widespread contributor to search failures, a bicyclist's rating of his stability should be considerably lower when a search is performed than when no search is performed. To determine the validity of this hypothesis, bicyclists who served as subjects in this experiment were required to rate their stability on both the search and the no-search trials. At the termination of each trial, bicyclists were asked to rate on a seven-point scale their degree of stability during the trial just completed. The phrases anchoring the extremes of the scale were "fell off bicycle" (rating of 1) and "perfectly stable" (rating of 7). The phrase anchoring the midpoint of the scale was "moderately stable" (rating of 4).

Figure 22 shows the mean and the standard deviation of the stability ratings for the search and the no-search trials at both the fast speed and the slow speed. The vertical line marks the value of the mean; the lengths of the lines extending from both sides of the symbol define the value of one standard deviation about the mean.

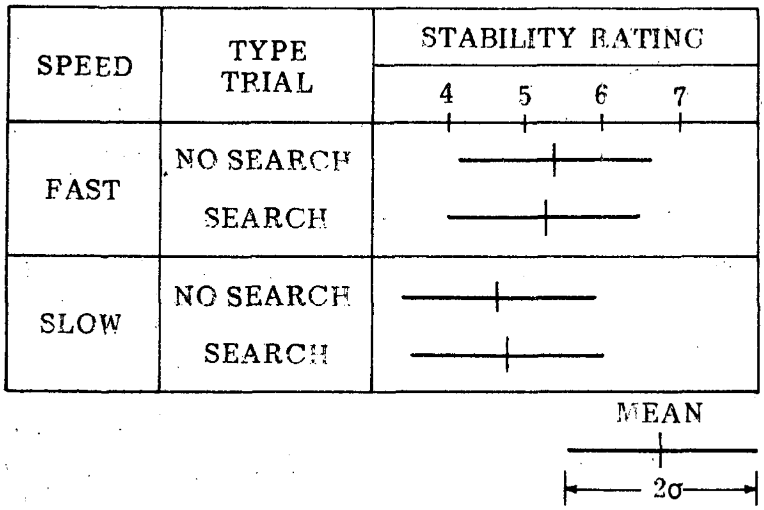
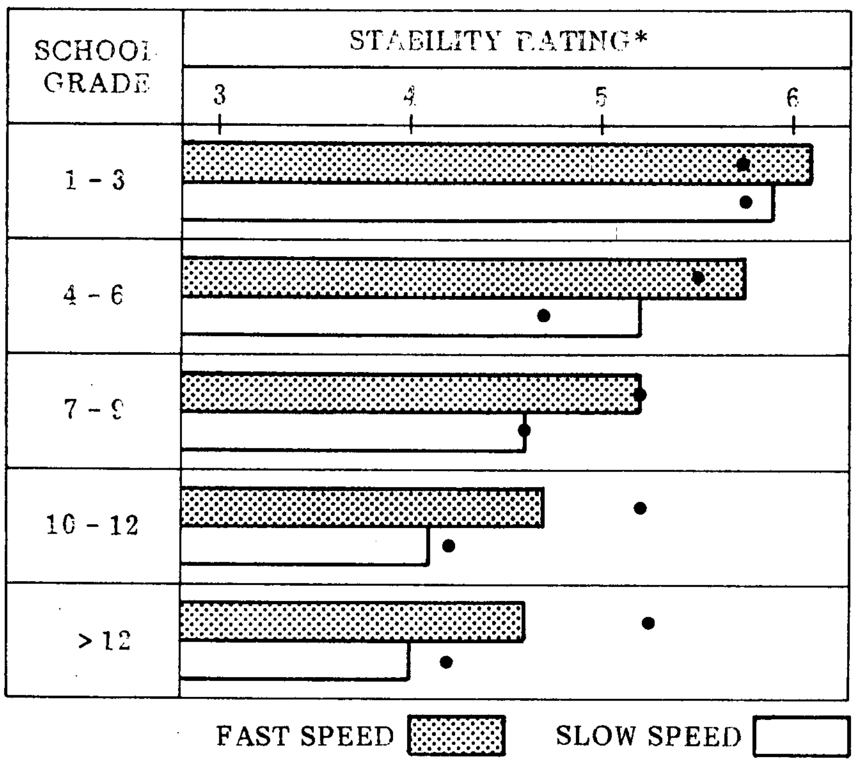


Figure 22. Means and standard deviations of bicyclists' stability ratings.

It is clear from Figure 22 that, on the average, a search had little impact on a bicyclist's stability rating on either the fast-speed or the slow-speed trials. In fact, on the slow-speed trials, bicyclists judged their stability to be higher during the search trials than during the no-search trials. The values of the standard deviation are nearly the same for the four conditions; the values range from 1.17 to 1.41, a difference of only .24 units on the seven-point rating scale. So, when ratings are averaged over subjects and trials, the distributions for the four conditions shown in Figure 22 are very nearly the same. The data in Figure 22 provide no support for the hypothesis that bicyclists feel considerably less stable during and immediately after a rearward search.

An analysis was performed to determine if the trends present in Figure 22 are the same for all age groups. Figure 23 shows the mean stability ratings for each age group. The shaded and unshaded bars indicate the average stability ratings for the **search** trials. The solid black dots indicate the average stability ratings for the no-search trials. It can be seen that all age groups felt less stable during the slow-speed trials, whether or not they searched behind during the trial. However, a more important finding is that the age groups differed on the absolute values of their ratings and on the relative ratings of stability during search and no-search trials. The bicyclists in the three youngest groups rated their stability equal to or higher for the search trials than for the no-search trials. The bicyclists in the two oldest groups rated their stability lower for the search trials than for the no-search trials; however, at the slow speed the stability ratings were very nearly the same for the search and the no-search trials.



*The bars indicate the average stability ratings for the search trials; the solid black dot indicates the average stability ratings for the no-search trials.

Figure 23. Mean stability rating by bicyclists' speed and age level.

Although young-adult and adult bicyclists indicated that a rearward search made them feel somewhat less stable than when no search was performed, the difference doesn't seem large enough to account for the widespread failure to search—as shown by the results of the field-observation study. Consequently, a fear of falling or swerving is likely to be only one of the factors contributing to bicyclists' reluctance to search behind.

Characteristics of Rearward searches

Two characteristics of rearward searches were examined during this study: the magnitude of the head/torso rotation and the duration of the rearward search. The magnitude of the head/torso rotation was judged by an experimenter during every trial. To make this judgment, the experimenter used the same template that was used to judge the head/torso rotation in the field observation study. To determine the duration of rearward searches, the first two search trials at each speed were video taped, and the tapes were subsequently examined to determine the elapsed time between the onset of the rearward search and the return of the head to the forward position. The video tapes, with the superimposed readout from the date/time display generator, made it possible to measure search duration to an accuracy of 1/10 of a second.

The rearward searches performed by the subjects in this experiment were remarkably uniform in both their magnitude and duration. Consider first the magnitude of the head/torso rotation associated with the rearward search. It was found that the mean head/torso rotation for the five age groups varied from 140° to 149°—a difference of only nine degrees. Similarly, the standard deviation of the means for the five age groups varied only from 9° to 15°. When averaged over all age groups, the mean head/torso rotation was 144°; and the lower and upper limits of the 95% confidence interval about the mean were 119° and 169°, respectively.

It will be recalled that the median head/torso rotation for rearward searches observed in the field study was 126°, so it is safe to conclude that the magnitude of the head/torso rotation of the bicyclists who participated in this experiment was equal to or larger than the magnitude of the head/torso rotations that occur when bicyclists on typical roadways are searching behind for overtaking motor vehicles.

It will also be recalled that rotation of the eyes add another 55° to the maximum head/torso rotation. This means that the average subject in this experiment rotated his head and torso enough to enable him to view, with central vision, objects located directly behind. The stimulus card was about 160° to the subject's left rear, so an average of only 18° of eye rotation was required to enable the subject to view the card with central vision. These findings leave little doubt that the search task performed by the subjects was not significantly more or less difficult than the task of bicyclists on the street who must search behind for overtaking motor vehicles.

Next, consider the duration of the rearward searches. The data obtained from the video recordings showed that search duration for the entire sample of observations varied only from .5 second to 1.1 seconds; the mean of the 400 observations was .74 second and the standard deviation was .17 second. The duration of the searches exhibited by the bicyclists who served as subjects were nearly as short as is physically possible, and yet the durations were long enough to enable subjects to recognize the numeral printed on the stimulus card with near 100% accuracy.

Although the search durations were found to be very brief, there is no reason to believe that they were considerably more brief than the duration of the rearward searches observed in the field study. The results of the field study showed that the duration of 16% of the rearward searches were estimated to exceed one second. By comparison, over 9% of the searches in the experimental study exceeded one second. In light of these findings, it is concluded that the search duration of the bicyclists in the sample was comparable to the duration of rearward searches performed in a typical traffic environment. Therefore, there is no reason to believe that the lateral error is unrepresentatively large or small because search durations in the experimental study were atypical.

DISCUSSION

Before conducting this experiment, it was feared that the structure and functioning of the human vestibular system would prevent a substantial number of bicyclists from learning to search behind without swerving by a dangerous amount.

The results of this study proved this fear to be unwarranted. Although every subject's performance was adversely affected by a rearward search, the vast majority of the search trials were completed without a dangerously large swerve; and there was no subject who swerved by a dangerous amount on every trial. In light of these findings, it can be confidently concluded that there is no physiological limitation that prevents bicyclists from learning to search behind safely. No data are available to use in estimating the extent to which the magnitude of search-induced swerves can be further reduced through training. However, Burden (1980) reports that the ability of elementary-school students to search behind without swerving increased "substantially" with only a few days of instruction and practice. A similar observation is reported by Forrester (1980). Forrester, who has trained large numbers of juvenile and adult bicyclists, reports that only a few practice sessions are required for novice bicyclists to develop the skill needed to search behind without swerving dangerously.

Given that bicyclists **can** be taught to search behind safely, the next question concerns whether or not further training in rearward search is needed. When considering this question, it must be kept in mind that the magnitude of the swerves in both the search and the no-search trials represents **optimal** rather than **typical** performance. The experimental runs were conducted on a smooth, clean surface in an area free of threats and other distractions found in the traffic environment. Furthermore, the subjects were highly motivated to complete each run with the smallest lateral deviation possible. For this reason, it seems certain that the swerves accompanying a rearward search would be larger in most traffic settings and considerably larger in some. Since no data are available to estimate the extent to which the magnitude of search-induced swerves would be increased by non-optimal conditions, it is necessary to consider the need for training with the data in hand—keeping in mind that conclusions based upon the research findings are highly conservative.

The risk associated with a lateral swerve of a given magnitude depends on the distance between the right edge of the motor vehicle and the left edge of the bicycle at the moment the motor vehicle overtakes and passes the bicyclist. This distance is referred to hereafter as "separation distance." Even a small swerve to the left can be catastrophic if motorists customarily allow for only a small separation distance when overtaking and passing a bicyclist. So, it is necessary to consider the magnitude of the voluntary separation distance in order to assess the risk associated with a search-induced swerve by the bicyclist.

A limited amount of data on the magnitude of voluntary separation distance is reported by Smith (1975). Smith measured separation distance on ten streets in Sacramento, California, and computed the means and standard deviations of the separation distances for each location. As would be expected, the values of both the means and standard deviations were positively related to available travel space.[11] The mean separation distance varied from over ten feet to slightly under seven feet and the standard deviation varied from 11 inches to 27 inches.

In order to estimate the magnitude of the smallest voluntary separation distances, the means and standard deviations reported by Smith were used to compute the value of the fifth centile and the first centile separation distances for each of the ten locations. At the location where voluntary separation distances were smallest, it was found that only five of 100 motorists passed the bicyclist with a separation distance smaller than 47 inches and only one of 100 motorists passed the bicyclist with a separation distance smaller than 31 inches. Clearly, a 95th centile swerve (15 inches) or even a 99th centile swerve (20 inches) would seldom lead to an accident at any one of the ten locations where Smith measured voluntary separation distance. However, it is important to note that these findings can be generalized only to locations where available travel space is at least 13.3 feet--the value of available travel space on the narrowest street investigated by Smith.

Since every community has numerous streets that are considerably more narrow than the streets investigated by Smith, motorists' behavior on the more narrow streets is of critical importance in assessing the risk associated with

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[11] Smith (1975) uses the term "available travel space" to refer to the distance between the centerline of the roadway and the location of a bicyclist who was riding as far to the right as practicable.

search-induced swerves. Unfortunately, the only information available on this important topic was obtained from informal observations by the authors and from discussions with expert bicyclists. The consensus of opinion is that every community has a substantial number of locations where motorists sometimes overtake and pass a bicyclist with a separation distance as small as 12 inches. It appears that the smallest voluntary separation distances occur at locations where the total space available in the motorist's traffic lane is between nine feet and 12 feet. For present purposes, the "motorist's traffic lane" extends from the center of the street to the left edge of the parking lane; or, if there is no parking lane, the traffic lane extends from the center to the right-hand edge of the roadway. On streets with a traffic lane wider than 12 feet, there is sufficient space for motorists to overtake and pass with a large separation distance. On streets with a traffic lane less than nine feet in width, motorists will seldom attempt to overtake and pass a bicyclist unless the opposing traffic lane is free of traffic and can therefore be entered when passing the bicyclist.

As an illustration of the problem, consider the separation distance available on a two-way, two-lane street that is 36 feet wide and has a seven-foot wide parking lane on both sides of the street. On a street of this type, there is 4.5 feet of space between the right side of a moving motor vehicle and the left side of a parked vehicle when the moving motor vehicle is situated as far to the left as is possible without crossing the center of the roadway. If the bicyclist in this situation maintains a 24-inch separation between the right handlebar and the parked motor vehicle, the clearance between the left handlebar and the overtaking motor vehicle is only 12 inches.[12] In this situation, both a 95th centile swerve (15 inches) and a 99th centile swerve (20 inches) would place the bicyclist in the path of the overtaking motor vehicle. An even smaller swerve would lead to an accident if the motorist failed to move as far to the left as possible before passing the bicyclist.

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[12]The clearance values reported here are based on an assumed width of 78 inches for the motor vehicles and 18 inches for the bicycle handlebars.

While no empirical data are available to support the claim that separation distances are dangerously small on a substantial number of streets, the casual observations discussed above appear to be sufficient justification for **not** recommending countermeasures that merely induce bicyclists to perform a rearward search--regardless of the traffic context and the bicyclist's level of skill. Rather, countermeasures aimed at modifying the bicyclist's behavior should accomplish one or more of the following objectives:

- Perform tests to determine the size of search-induced swerves for each bicyclist;
- Identify bicyclists with a skill deficiency, inform them of the deficiency, and provide guidance on ways to acquire adequate skill;
- Teach bicyclists to recognize when the available travel space is or is not large enough to perform a rearward search (without undue risk); and
- Induce bicyclists to (a) perform a rearward search when it is safe to do so, and (b) stop and search or delay the left-hand turn until there is sufficient space to perform a rearward search safely.

The above countermeasures objectives appear achievable, but additional research may be required to: define the criterion for a skill deficiency, determine the most cost-effective way to identify the bicyclists with a skill deficiency, and determine the most cost-effective way for bicyclists to acquire the requisite level of skill in searching behind. Since many cyclists have acquired an adequate level of skill without formal training, it seems likely that nothing more would be required than inducing bicyclists to practice the tasks at a safe location.

Countermeasures aimed at the motorists' behavior should be designed to (a) teach motorists to recognize when the available travel space is dangerously small, and (b) induce motorists to delay overtaking and passing a bicyclist until there is sufficient space to do so safely.

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APPENDIX A

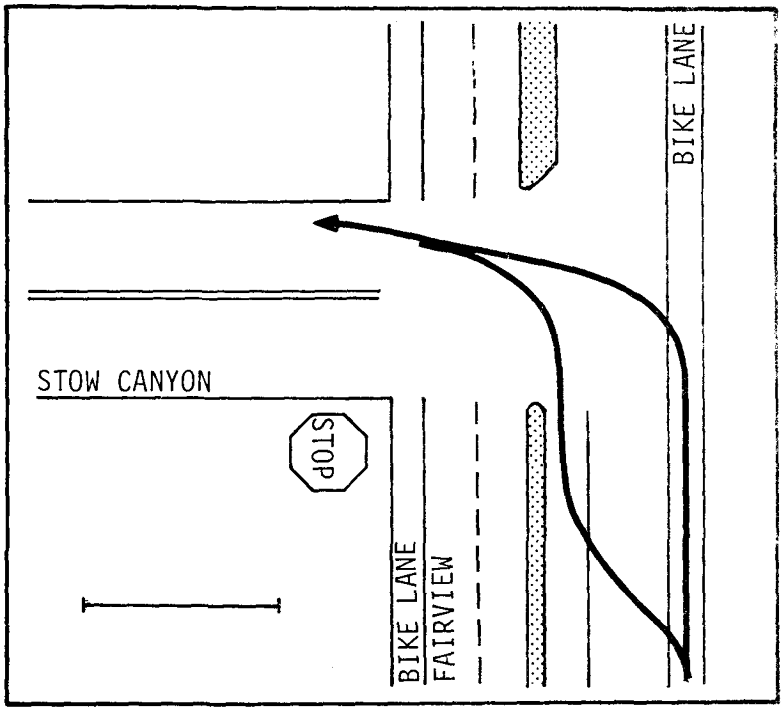
OBSERVATION SITE DESCRIPTIONS

SITE DESCRIPTION

SITE: Fairview onto Stow Canyon Road

TRAFFIC DENSITY: 600 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 98

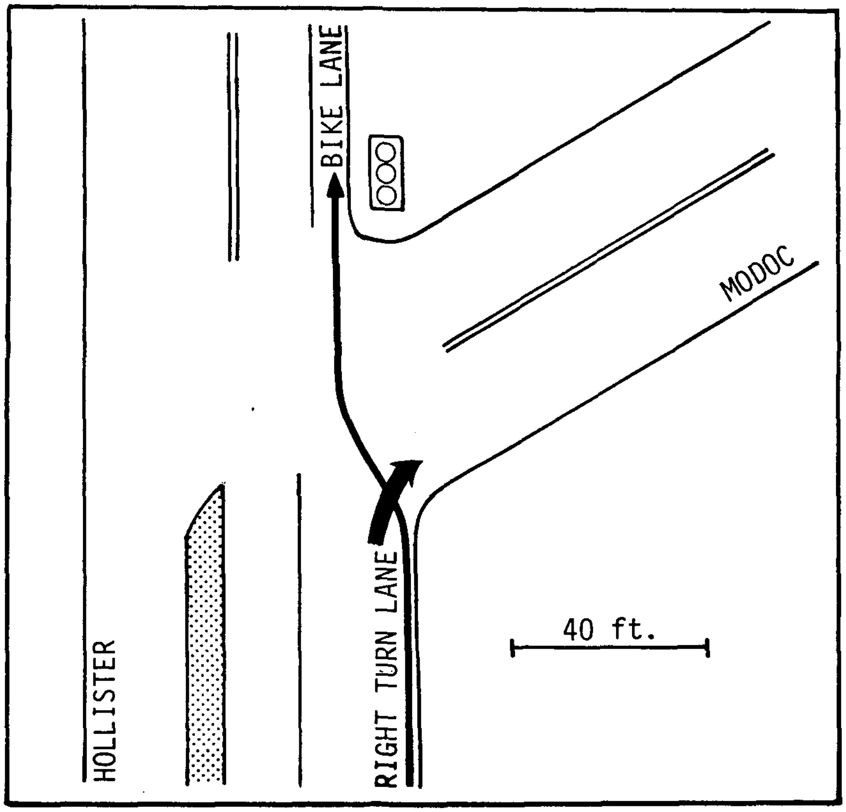


SITE DESCRIPTION

SITE: Hollister at Modoc

TRAFFIC DENSITY: Up to 1,100 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 104

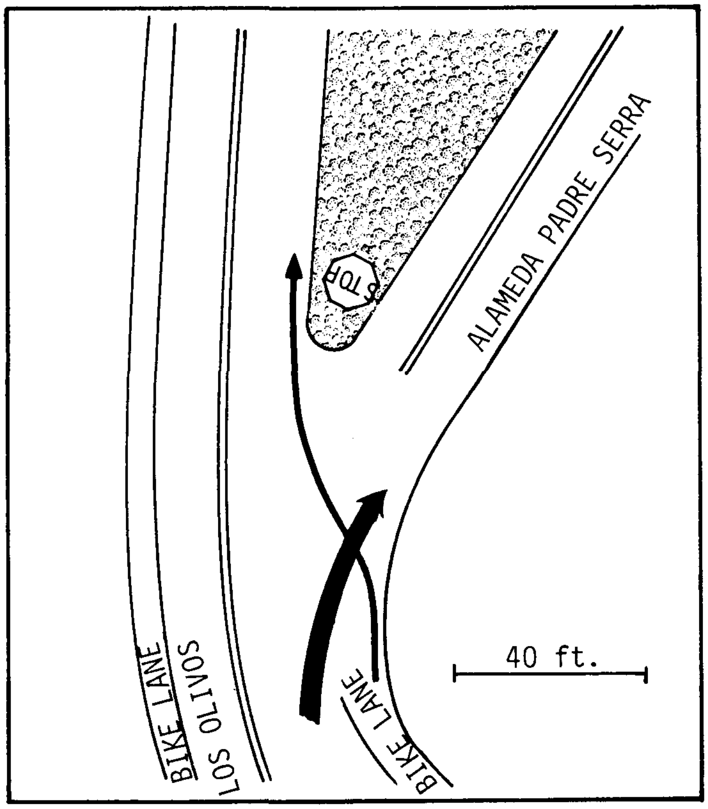


SITE DESCRIPTION

SITE: Los Olivos at Alameda Padre Serra

TRAFFIC DENSITY: 400-500 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 88

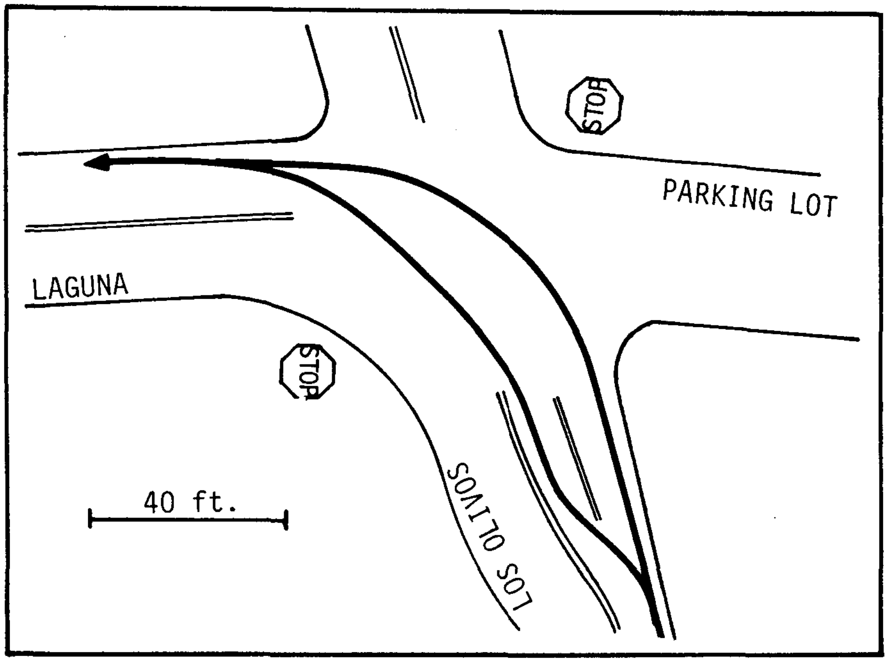


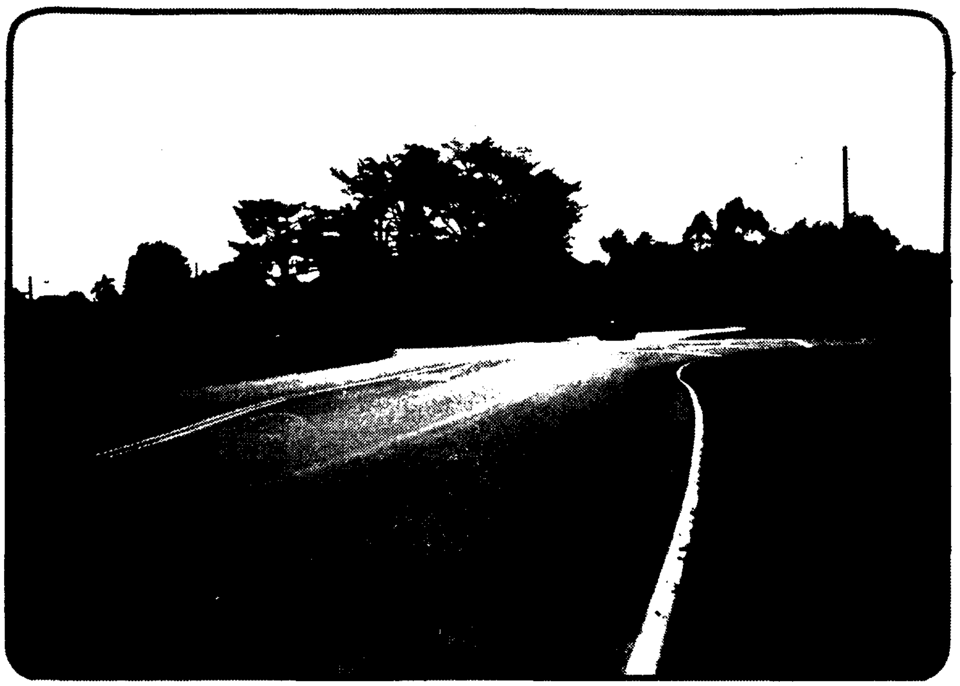
SITE DESCRIPTION

SITE: Los Olivos onto Laguna

TRAFFIC DENSITY: 600-800 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 53



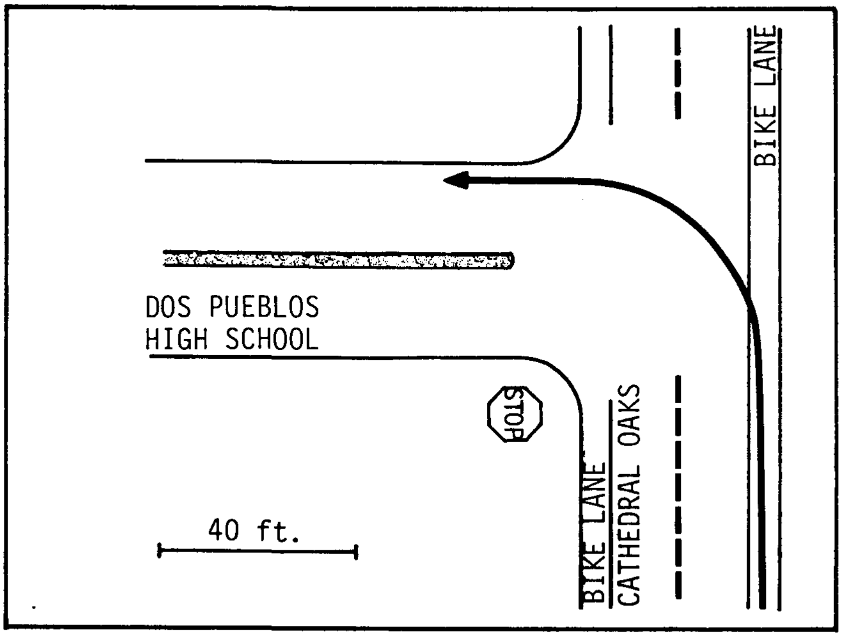


SITE DESCRIPTION

SITE: Cathedral Oaks onto Dos Pueblos High School Parking Lot

TRAFFIC DENSITY: 400 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 155

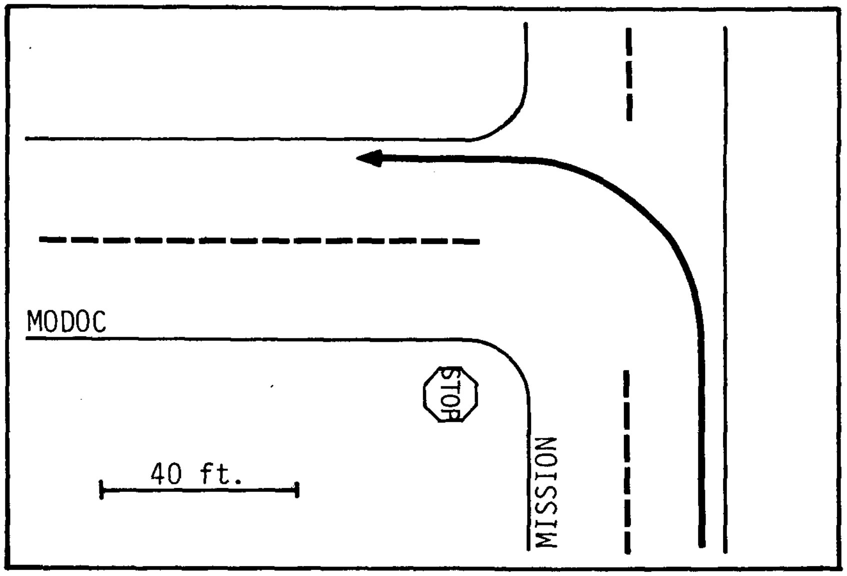


SITE DESCRIPTION

SITE: Mission onto Modoc

TRAFFIC DENSITY: 720 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 19

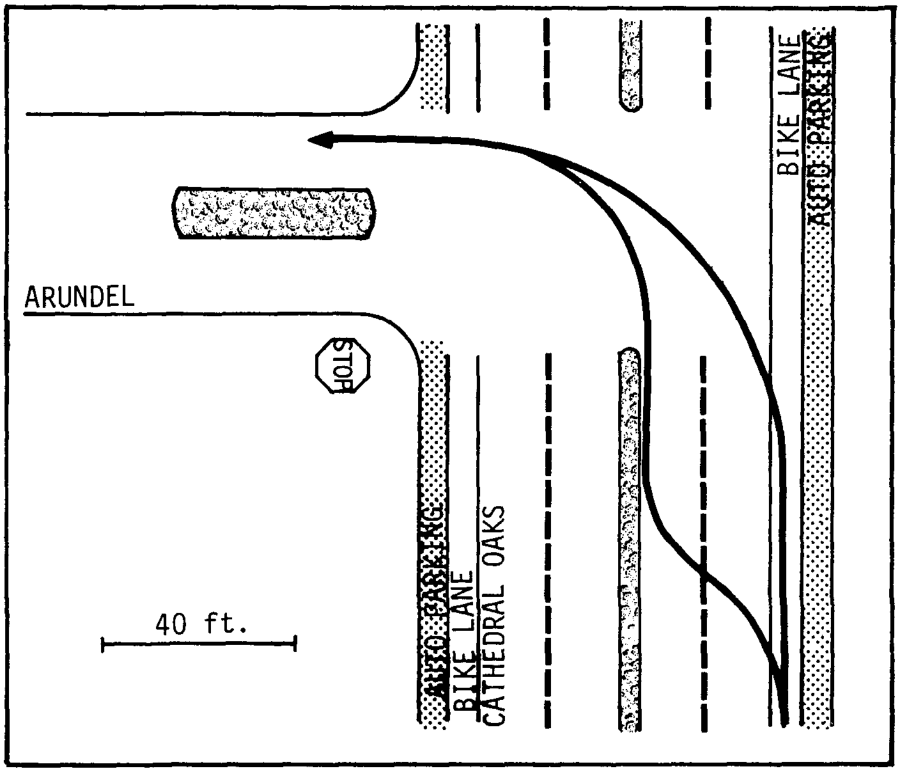


SITE DESCRIPTION

SITE: Cathedral Oaks onto Arundel

TRAFFIC DENSITY: 400 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 5

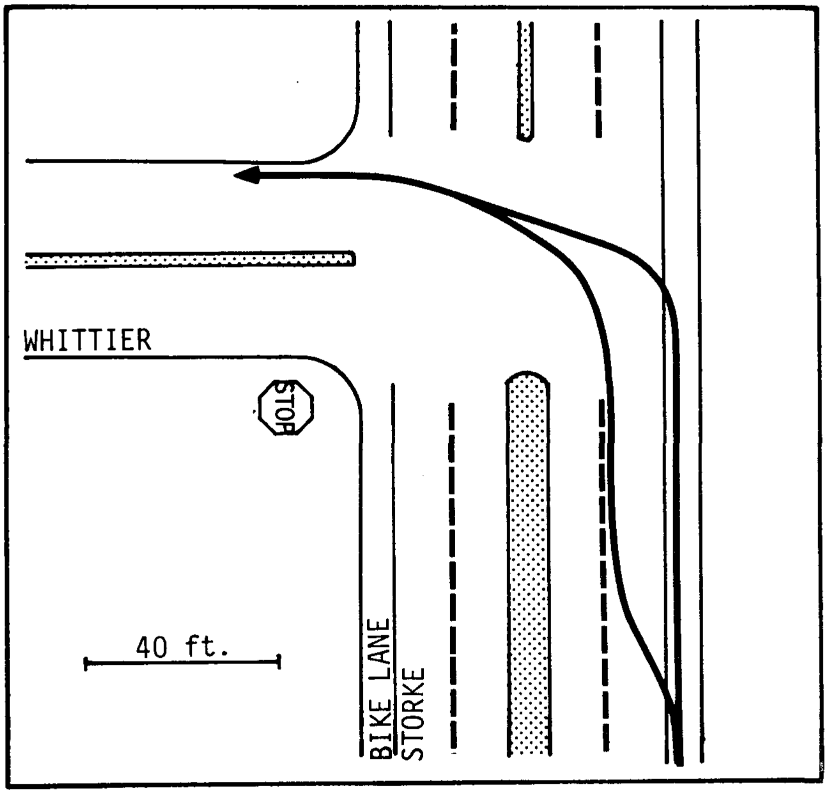


SITE DESCRIPTION

SITE: Storke onto Whittier

TRAFFIC DENSITY: 400-500 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 29

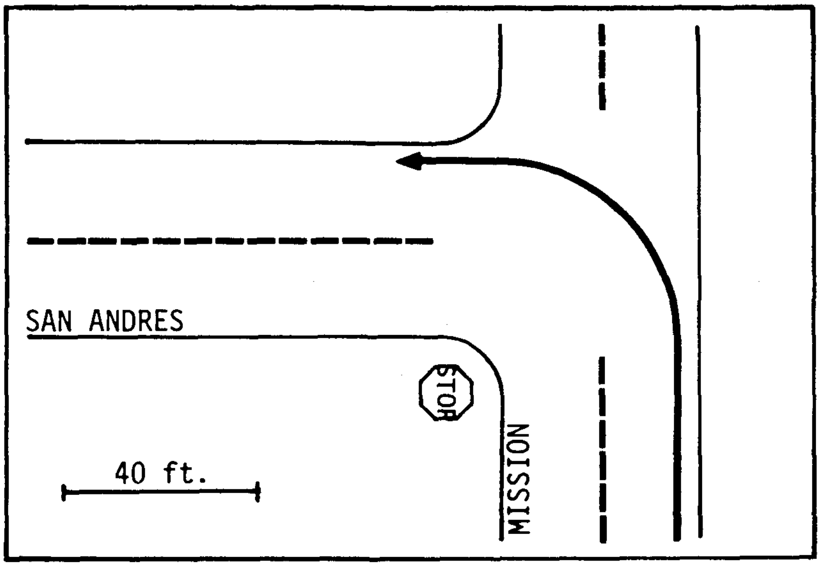


SITE DESCRIPTION

SITE: Mission onto San Andres

TRAFFIC DENSITY: 360 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 25

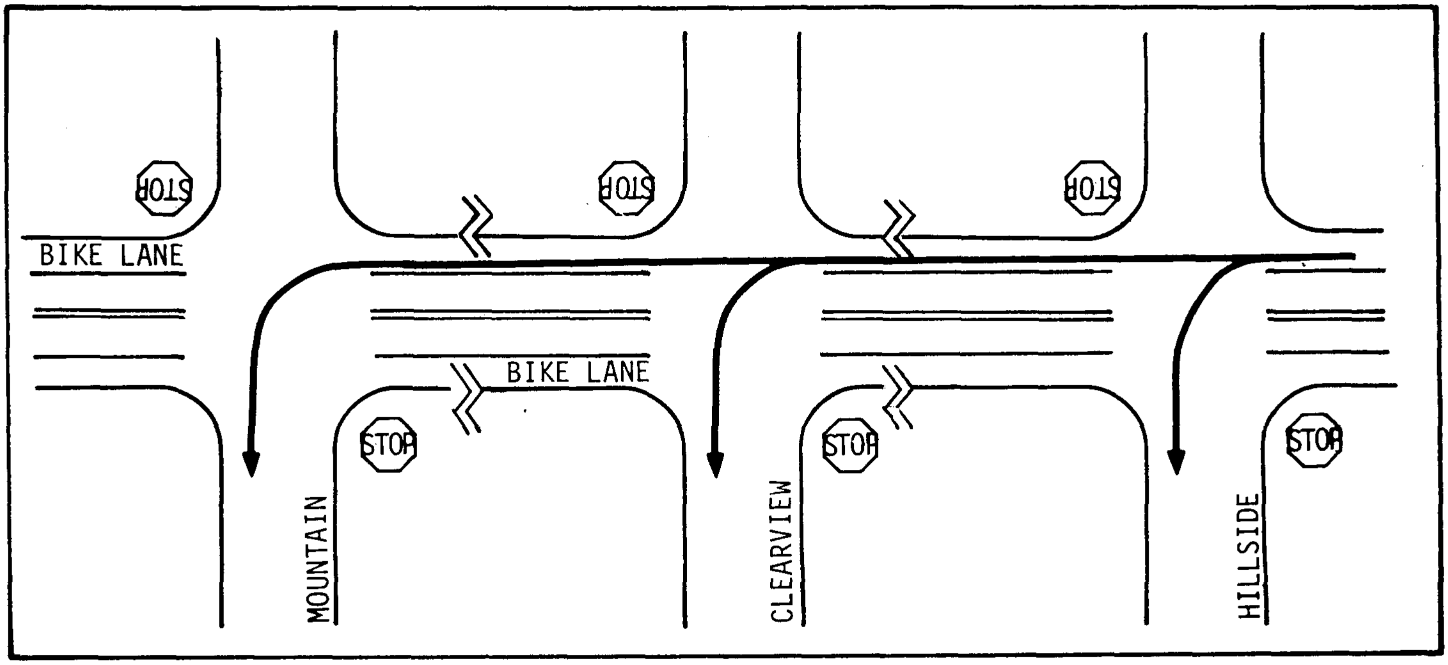


SITE DESCRIPTION

SITE: Valero and Hillside, Clearview, or Mountain

TRAFFIC DENSITY: 300 motor vehicles per hour (high)

NUMBER OF OBSERVATIONS: 16



Valerio and Hillside

Valero and Clearview

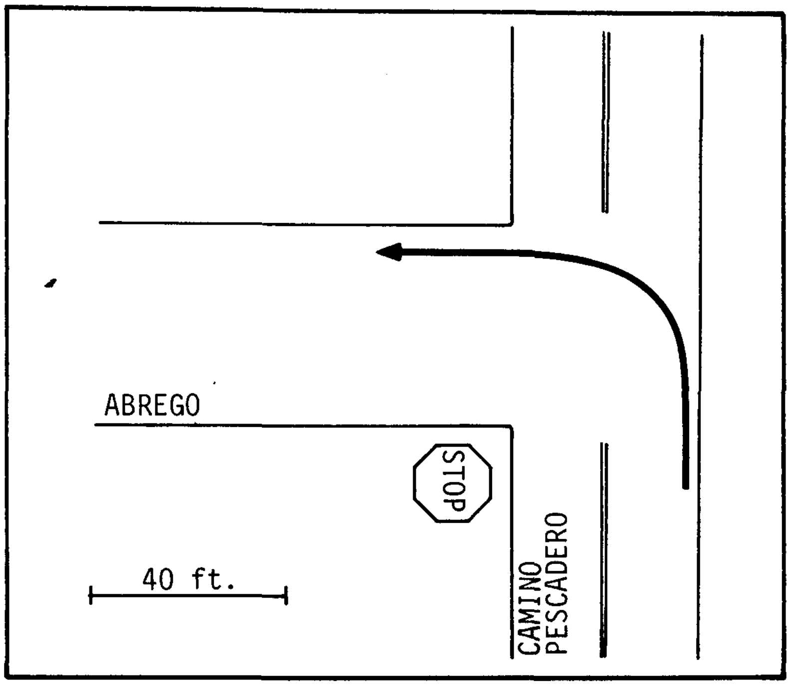
Valero and Mountain

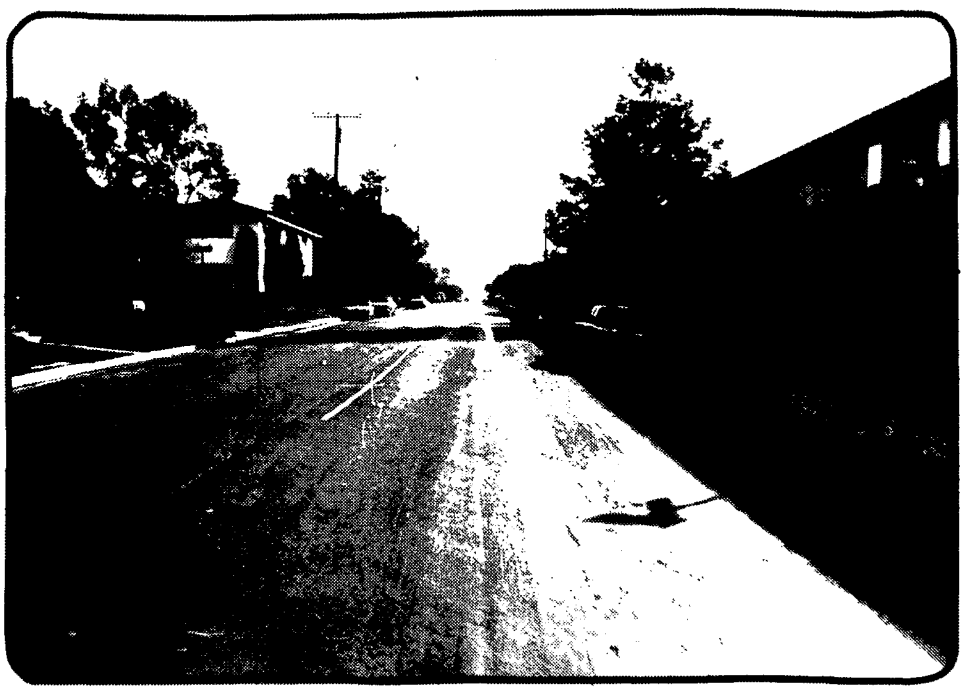
SITE DESCRIPTION

SITE: Camino Pescadero onto Abrego

TRAFFIC DENSITY: 100 motor vehicles per hour (medium)

NUMBER OF OBSERVATIONS: 87



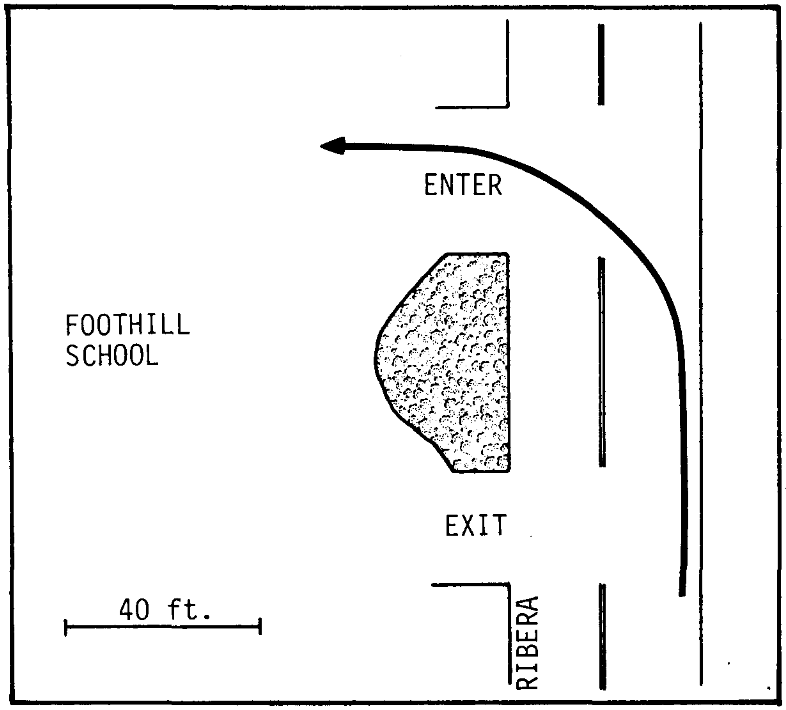


SITE DESCRIPTION

SITE: Ribera at Foothill Elementary School

TRAFFIC DENSITY: 90-100 motor vehicle per hour (medium)

NUMBER OF OBSERVATIONS: 80

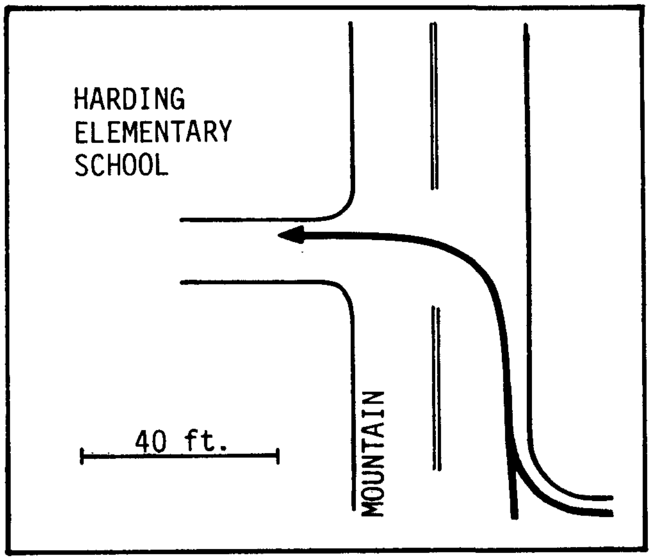


SITE DESCRIPTION

SITE: Mountain into Harding Elementary School

TRAFFIC DENSITY: 100 motor vehicles per hour (medium)

NUMBER OF OBSERVATIONS: 9

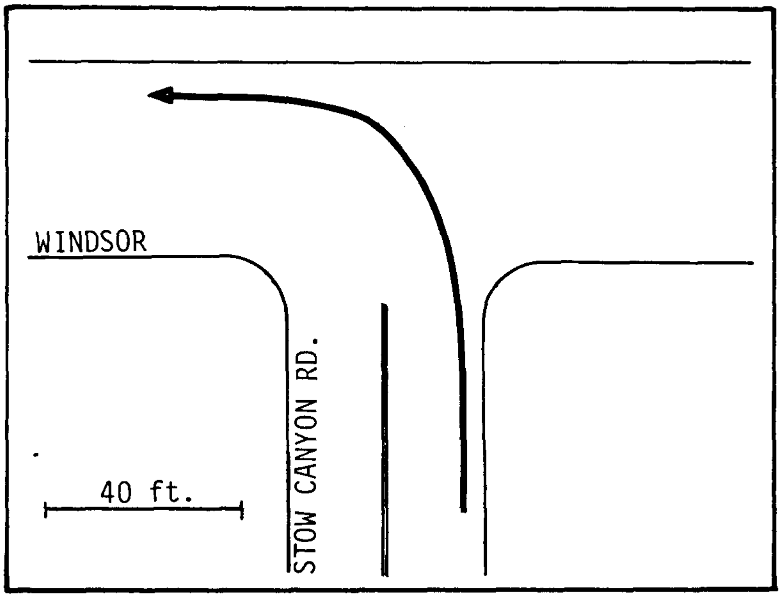


SITE DESCRIPTION

SITE: Stow Canyon onto Windsor

TRAFFIC DENSITY: 70 motor vehicles per hour (medium)

NUMBER OF OBSERVATIONS: 8

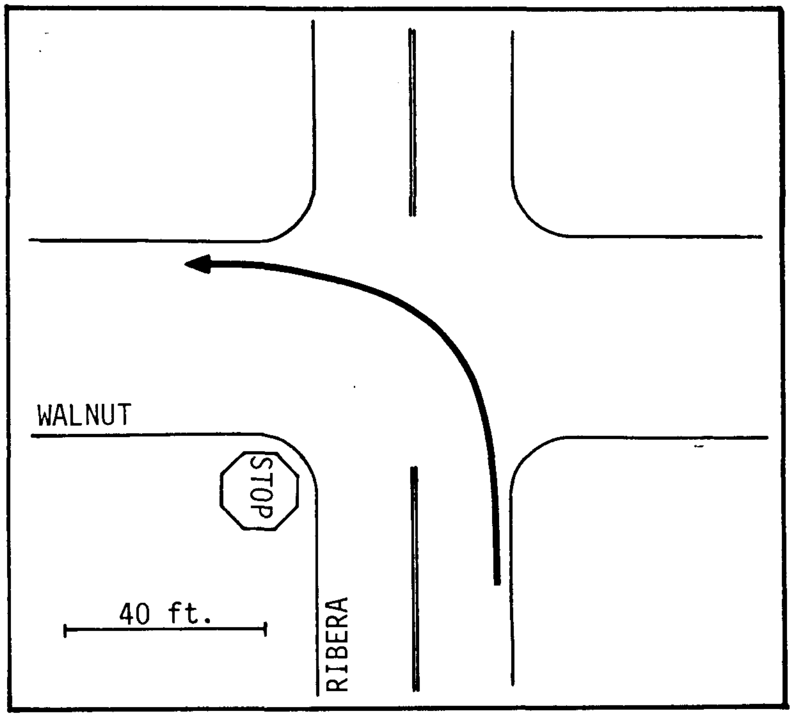


SITE DESCRIPTION

SITE: Ribera onto Walnut

TRAFFIC DENSITY: 70 motor vehicles per hour (medium)

NUMBER OF OBSERVATIONS: 15

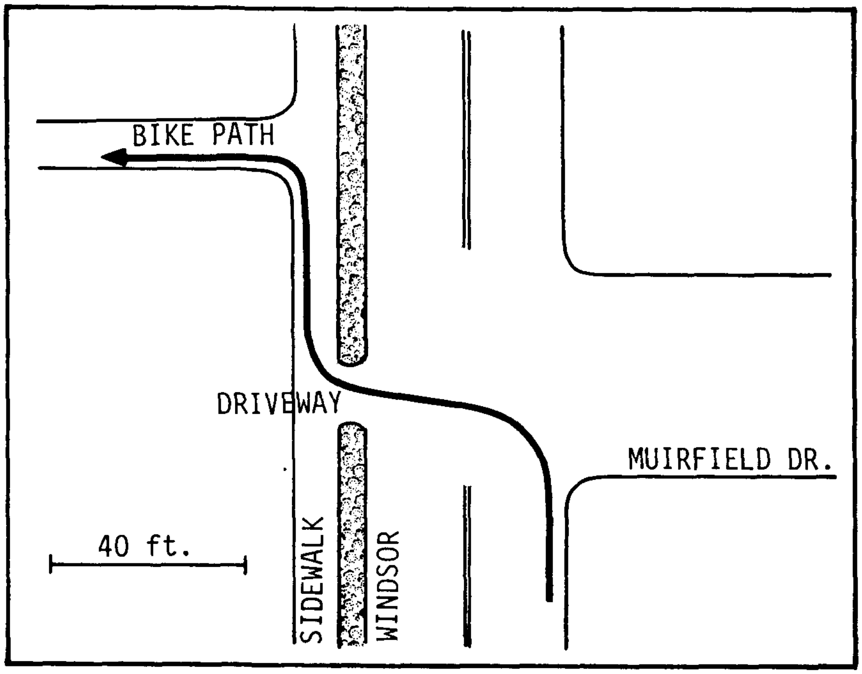


SITE DESCRIPTION

SITE: Windsor onto La Patera Bike Path

TRAFFIC DENSITY: 60 motor vehicles per hour (medium)

NUMBER OF OBSERVATIONS: 6

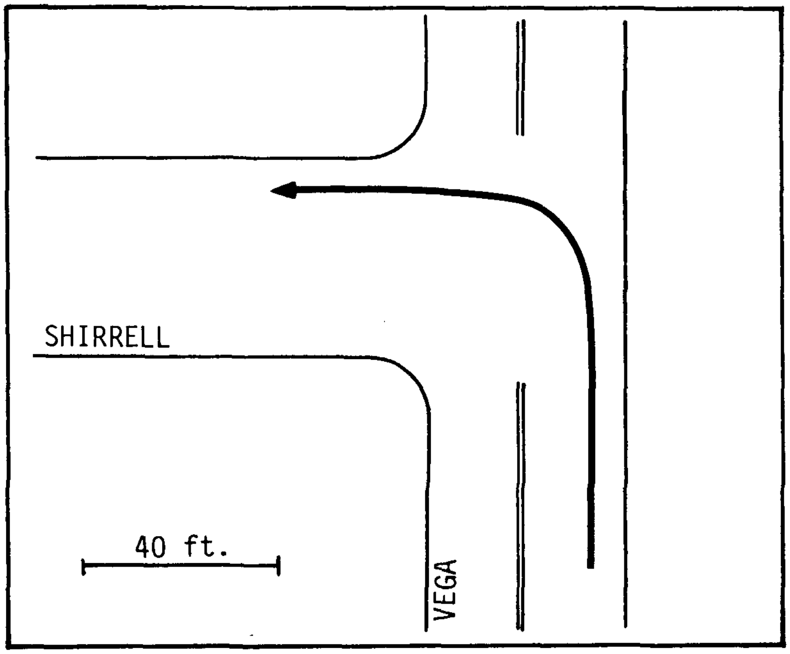


SITE DESCRIPTION

SITE: Vega onto Shirrel

TRAFFIC DENSITY: 30 motor vehicles per hour (low)

NUMBER OF OBSERVATIONS: 70

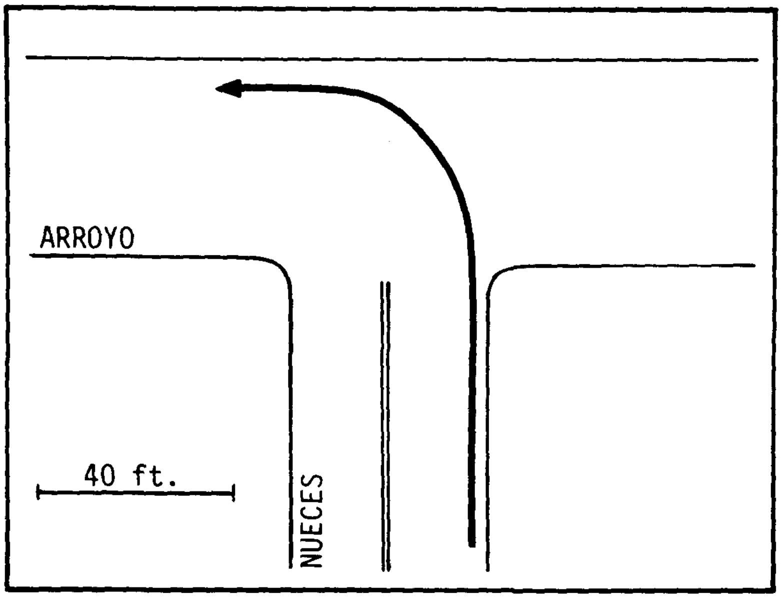


SITE DESCRIPTION

SITE: Nueces onto Arroyo

TRAFFIC DENSITY: 20-30 motor vehicles per hour (low)

NUMBER OF OBSERVATIONS: 145



APPENDIX B

DATA-RECORDING FORMS AND CODING SHEETS USED FOR FIELD-OBSERVATION STUDY

OBSERVER ______________

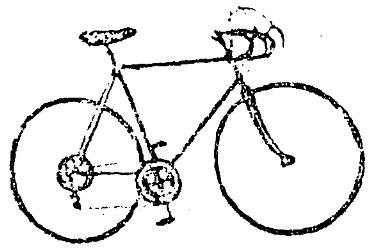
DATA SHEET

LOCATION ______________________________________

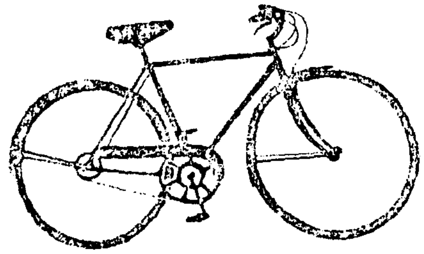
OBSERVATION PERIOD ______________________ DATE ______________
(24-hour clock)

Draw diagram of roadway configuration on reverse. Indicate number of traffic lanes, type of intersection, and bike lane if one present. Also, indicate traffic density (round to nearest 10 vehicles per hour--code 99 if 99 or more).

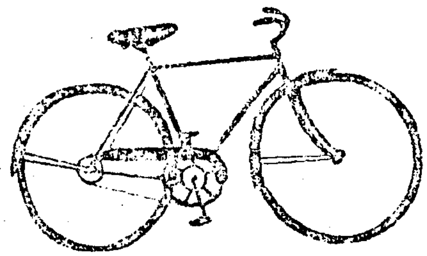
		OBSERVATION NUMBER									
DATA ITEM		1	2	3	4	5	6	7	8	9	10
ESTIMATED AGE											
SEX											
BICYCLE TYPE											
BICYCLE FIT											
BODY POSITION											
POSITION OF HANDS											
PURPOSE OF TURN											
NUMBER OF SCANS											
LONGEST SCAN	DIRECTION										
	MAGNITUDE-HEAD										
	MAGNITUDE-TORSO										
	DURATION										
PROXIMITY OF OVERTAKING MV											
PROXIMITY OF ONCOMING MV											
BIKE POSITION IN ROADWAY											
RIDING COMPANIONS											
POSITION IN GROUP											
DISTRACTIONS											



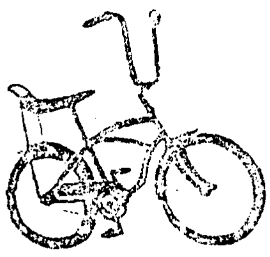
LIGHTWEIGHT



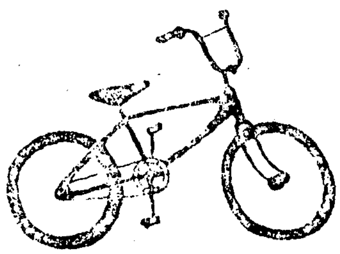
MIDDLEWEIGHT



HEAVYWEIGHT



HIGHRISE



MOTOCROSS

CODING SHEET

ESTIMATED AGE
A = Under 6 years (preschool)
B = 6 to 11 years (elementary school)
C = 12 to 15 years (jr. high school)
D = 16 to 18 years (high school)
E = Over 18 years

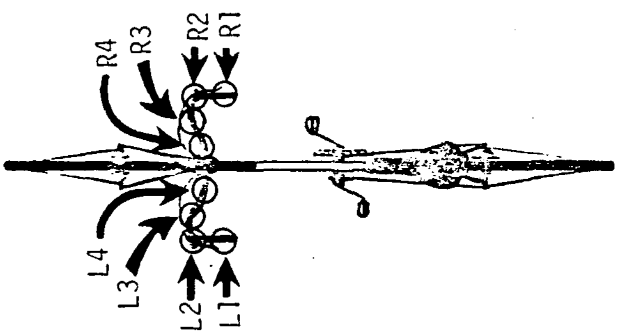
SEX
M = Male
F = Female

BICYCLE TYPE (see reverse for illustrations of types)
L = Lightweight
M = Middleweight
H = Heavyweight (balloon tires)
R = Highrise
C = Motocross
Y = Other (specify)

BICYCLE FIT
A = Adequate fit
L = Bike too large
S = Bike too small

BODY POSITION
A = Upright
B = Inclined forward (moderate)
C = Inclined forward (maximum)

POSITION OF HANDS ON HANDLEBARS
(code four digits, e.g. LOR2)
LO = Left hand not on handlebars
RO = Right hand not on handlebars

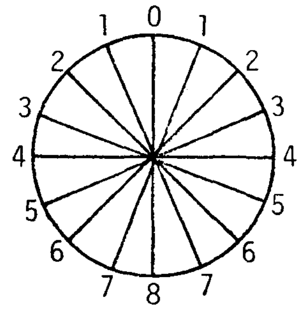


PURPOSE OF TURN
L = Left turn
R = Right turn (one-way street)
ML = Merge left
MR = Merge right (one-way street)

NUMBER OF SCANS--code directly (0 if none)

DIRECTION OF LONGEST SCAN
L = Left
R = Right

MAGNITUDE OF LONGEST SCAN (code for both head and torso)



DURATION OF LONGEST SCAN
A = No pause
B = Barely discernible pause
C = Clearly discernible pause
D = Paused more than one second

PROXIMITY OF OVERTAKING MOTOR VEHICLE
0 = None within 1/2 block
1 = No slowing/braking required
2 = Slowing/slight braking required
3 = Moderate braking required
4 = Hard braking required

PROXIMITY OF ONCOMING MOTOR VEHICLE
0 = None within 1/2 block
1 = No slowing/braking required
2 = Slowing/slight braking required
3 = Moderate braking required
4 = Hard braking required

BIKE POSITION IN ROAD
A = Close as possible to curb/shoulder
B = Close as possible to parked car(s)
C = Close to right of traffic lane
D = Close to center of traffic lane
E = Close to left of traffic lane

NUMBER OF RIDING COMPANIONS (code directly and include bicyclist being observed)

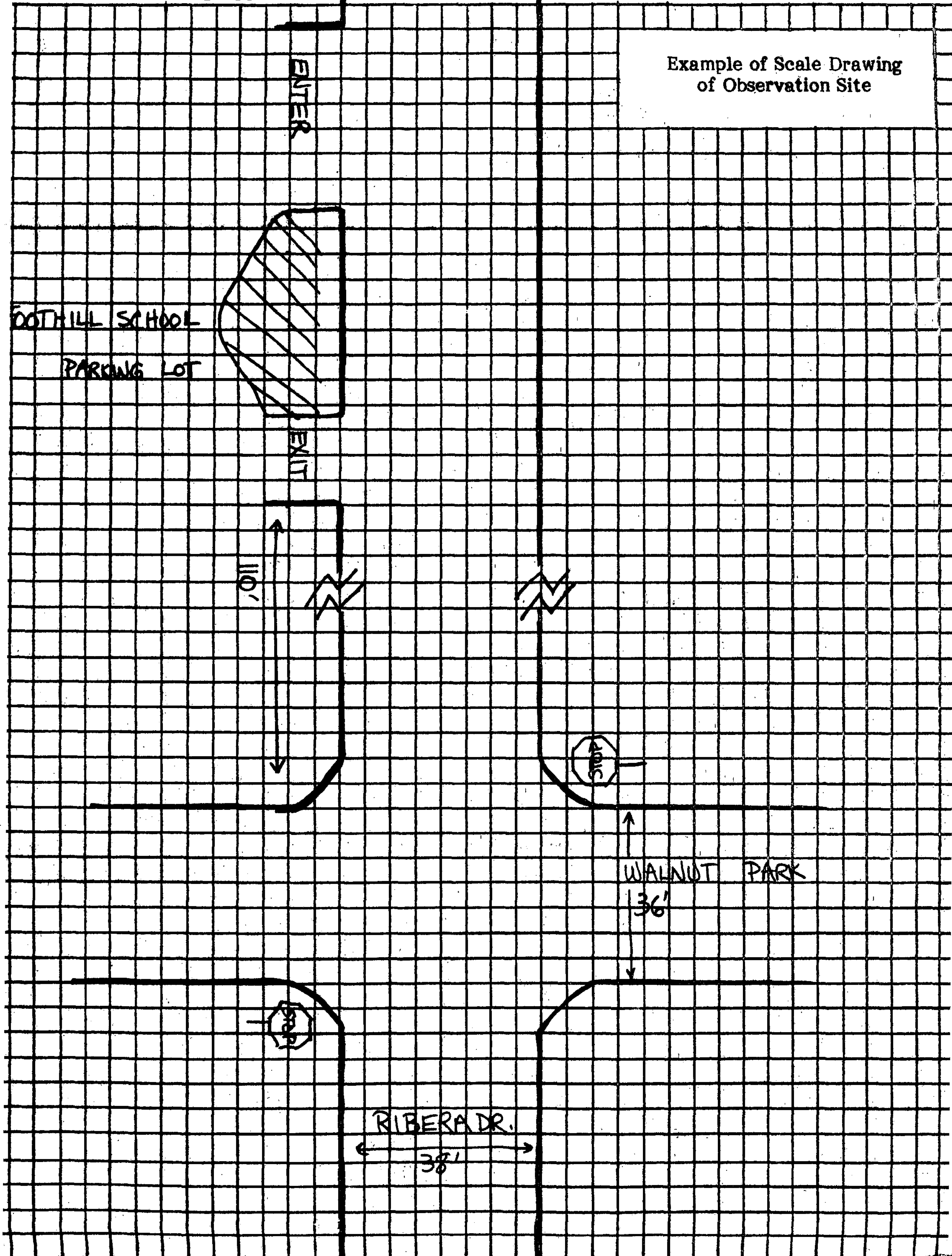
POSITION IN GROUP (Observe lead bicyclist and one other if time permits)
L = Lead bicyclist
T = Trailing bicyclist
Y = Other (specify)

DISTRACTIONS
0 = No apparent distractions
A = Interacting with another person
B = Vehicles/pedestrians possible threat
C = Abnormal street-surface condition
D = Engaged in game or play activity
E = Carrying object in hands
Y = Other (specify)

TRAFFIC DENSITY: [ ][ ] MOTOR VEHICLES PER HOUR

Ribera Dr at Foothill H.S.

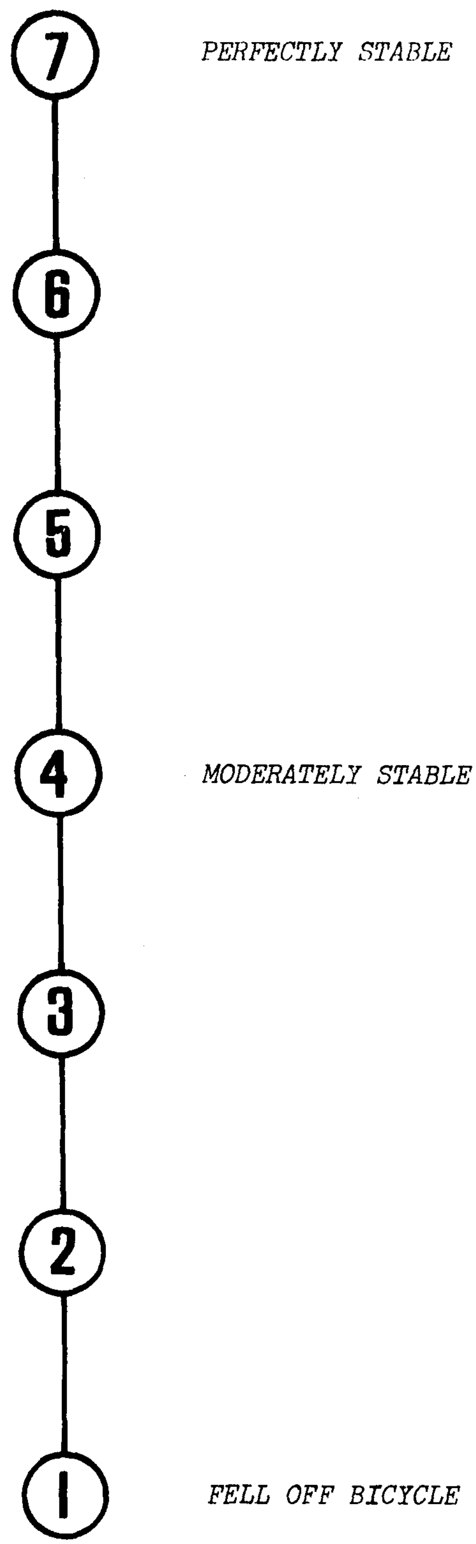
Example of Scale Drawing of Observation Site



SCALE: 1 SQUARE = 5 FEET

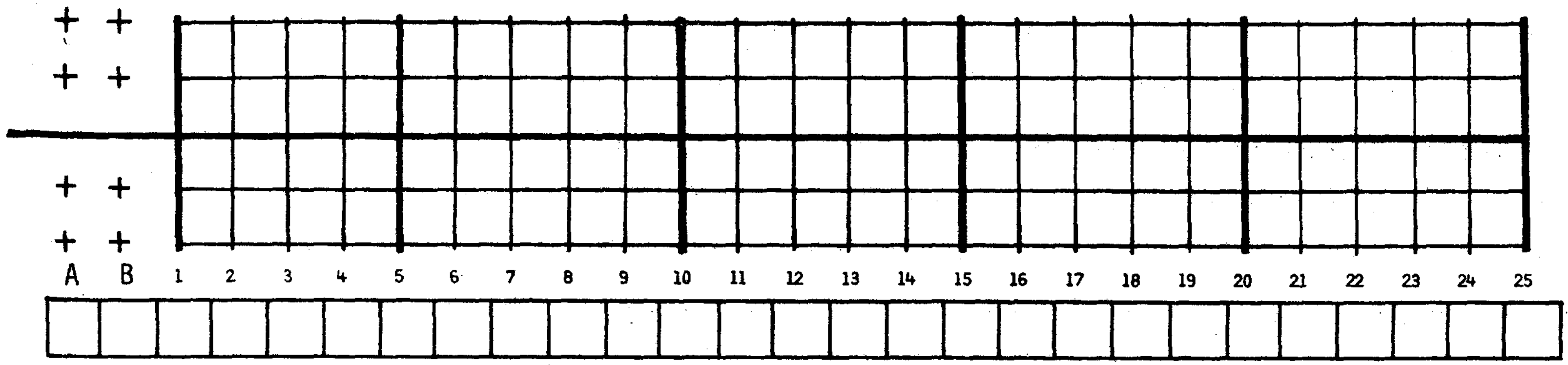
APPENDIX C

STABILITY RATING SCALE


7
PERFECTLY STABLE
6
5
4
MODERATELY STABLE
3
2
1
FELL OFF BICYCLE

APPENDIX D

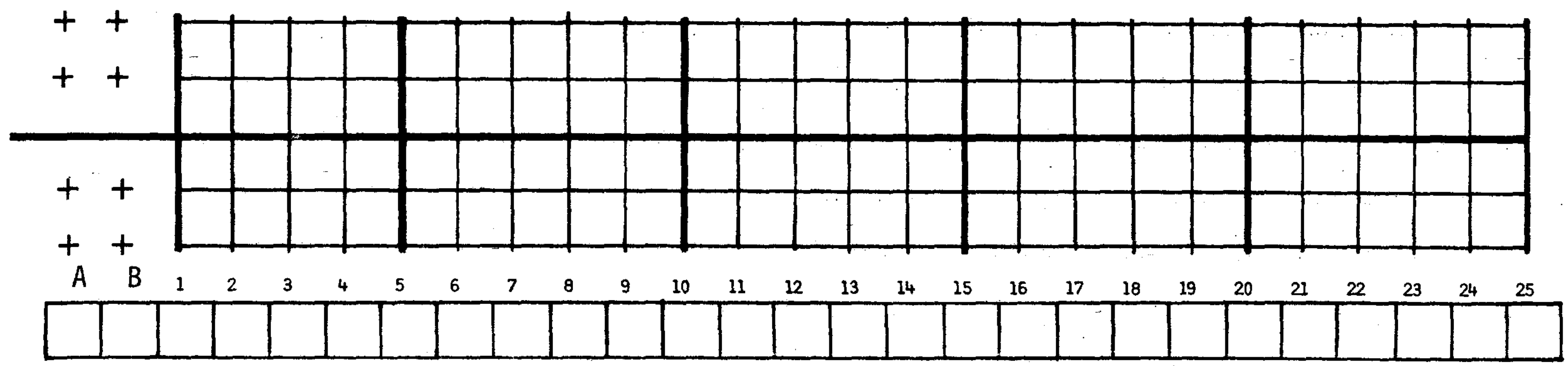
DATA RECORDING FORMS AND CODING SHEETS USED FOR CONTROL STABILITY EXPERIMENT



Subject. . . . .[ ][ ][ ] __________

Run. . . . .[ ] __________
Speed. . . . .[ ] __________
Number of scans. . . . .[ ] __________
Scan magnitude (head). . . .[ ] __________

Scan magnitude (torso) . . . . .[ ] __________
Duration of scan . . . .[ ][ ] __________
Direction of scan. . . . .[ ] __________
Time in trap . . . . . .[ ][ ][ ] __________
Stability rating . . . .[ ] __________



Run. . . . .[ ] __________
Speed. . . . .[ ] __________
Number of scans. . . . .[ ] __________
Scan magnitude (head). . . .[ ] __________
Scan magnitude (torsc) . . .[ ] __________

Duration of scan . . . .[ ][ ] __________
Direction of scan. . . . .[ ] __________
Time in trap . . . . . .[ ][ ][ ] __________
Stability rating . . . .[ ] __________

CODING SHEET

SUBJECT NUMBER (code three numbers)

TIME (code four numbers on 24-hour clock)

DATE (code month and day)

LEVEL

1 = Under 6 years (preschool)
2 = 6 to 11 years (elementary school)
3 = 12 to 15 years (jr. high school)
4 = 16 to 18 years (high school)
5 = Over 18 years

SEX

M = Male
F = Female

BICYCLE TYPE

H = Highrise
M = Standard/Medium Weight
L = Lightweight

BICYCLE FIT

A = Adequate fit
L = Bike too large
S = Bike too small

RIDING EXPERIENCE (number of years riding at least once a month)

WEEKS RIDING (code hours)

RIDE BIKE TO SCHOOL OR JOB

Y = Yes
N = No

MEMBER OF BICYCLE ORGANIZATION?

Y = Yes
N = No

RIDING EXPERIENCE ON THIS BICYCLE (code years and/or months)

MOST OFTEN RIDDEN BICYCLE

Y = Yes
N = No

RUN

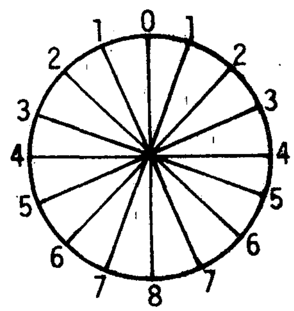
0 = Control (no search)
1 = First search
2 = Second search
3 = Third search
4 = Fourth search

SPEED

S = Slow
F = Fast

NUMBER OF SCANS (code number)

MAGNITUDE OF LONGEST SCAN (code for both head and torso)



DURATION OF SCAN (code seconds and tenths of second)

DIRECTION OF SCAN

L = Left
R = Right

TIME IN TRAP (code seconds and tenths of seconds)

STABILITY RATING (code one of seven digits)

AGE (code years)

SUBJECT DATA

Subject number . . . .[ ][ ][ ]

Time . . . .[ ][ ][ ][ ]

Date . . . . .year[ ][ ] month[ ][ ] day[ ][ ]

Level. . . . .[ ]

Sex . . . .[ ]

Bicycle type . . . .[ ]

Bicycle fit . . . .[ ]

Riding experience . . . . .year[ ][ ]

Typical weeks riding (hours) . . . .[ ][ ]

Ride bicycle to school or job? . . . .[ ]

Belong to bicycle club or related organization . . . .[ ]

Riding experience on this bicycle. . . .years[ ][ ] months[ ][ ]

Is this most often ridden bicycle? . . . .[ ]

Age . . . .[ ][ ]

Trial order: slow [ ] fast [ ]
Tape number: [ ][ ]
Tape counter on first trial: [ ][ ][ ]

APPENDIX E

EXPERIMENTERS' AND SUBJECTS' INSTRUCTIONS
(CONTROL-STABILITY EXPERIMENT)

EXPERIMENTERS' AND SUBJECTS' INSTRUCTIONS

I. EQUIPMENT CHECK

- Recorder on and ready
- Trap clear of debris
- Water bottles full and draining
- All recording forms available
- Helmet strap tight
- Stopwatch and whistle available

II. INTRODUCTION

Hello. We are conducting bicycle-safety research for the Department of Transportation. We are trying to determine how well people can steer their bicycles while they are looking behind to check traffic. We are asking bicyclists to ride down a 100-foot line while they perform a few simple tasks. The entire procedure takes about 25 minutes and we will pay you $3.00 in cash. Would you like to participate?

Walk to the test site, install the draining water bottle, and fit the bicycle helmet to the bicyclist.

III. SLOW RUNS

Experimenter No. 1: *Now I would like you to ride down to the start of the gray line. When he/she raises his/her hand* (point to other experimenter), *ride all the way up the gray line, through the gridded area, and up to the "END" sign on the ground. Do your best to ride as close to the center line as possible--from start to finish. Stop when you reach the end and one of us will ask you a few questions.*

Now, do you see the red lines every few feet along the gray line? I would like you to ride so that you cross one of these red lines about every second. This is a slow but comfortable riding speed.

Remember to ride as close to the center line as possible and ride so that you cross a red line about every second. Now ride down to the start of the line and ride down the line when he/she (Experimenter No. 2) *raises his/her hand.*

Experimenter No. 1 fills water bottle. Experimenter No. 2 checks stopwatch and recording forms.

When the subject has reached the starting position, Experimenter No. 2 raises his/her hand to signal the subject to proceed. When the subject crosses Line #1, Experimenter No. 2 starts the timer and notes the track of the bicycle. Experimenter No. 2 stops the timer when the subject exits the trap and records the time. Experimenter No. 2 then records the marks left by draining water.

When the subject leaves the trap, Experimenter No. 1 asks the subject to rate his/her stability using the stability rating scale:

> *Using this rating scale, I would like you to tell me which number best represents how stable you were while you rode through the gridded area.*

Experimenter No. 1 records this number and explains the next task.

> *We would now like you to ride down the line again. This time, when you cross the large red line at the beginning of the grid, he/she* (Experimenter No. 2) *will blow a whistle. When you hear the whistle, look back at the white sign* (point to sign). *A number, like the number now on the sign, will be hanging there. After you have seen the number, ride down the rest of the line, again staying as close to the line as possible. When you ride over the red line at the end of the grid, shout out the number that you saw on the sign. Stop when you reach the end of the gray line and I will ask you to rate your stability as you did before.*
>
> *Again, stay as close to the line as you can and travel at a slow but comfortable speed--just so you are crossing a red line each second. Remember to look back when he/she blows the whistle. Now ride down to the starting point and begin riding when he/she raises his/her hand.*

Experimenter No. 1 now fills the water bottle and checks and starts the video recorder. Experimenter No. 2 (a) changes the target number after the subject passes by, (b) returns to the starting position, and (c) starts the subject by raising his/her hand. When the subject enters the trap, the whistle is blown and the timer is started by Experimenter No. 2. The timer is stopped when the subject leaves the trap. After turning off the recorder, Experimenter No. 1 records (a) scan magnitude, (b) response accuracy, and (c) the stability rating. Stability ratings on search runs should be recorded as follows:

> *Using this rating scale, I would like you to tell me which number best represents how stable you were while you were looking back at the number.*

The same procedure is repeated for runs 2—slow, 3—slow, and 4—slow.

IV. FAST RUNS

Fast runs (one control and four search runs) are the same as above except for the description of riding speed. Fast runs require that the bicyclist ride at a comfortable but moderately fast rate. The subject should cross a blue line every second.

One-half of the subjects in each age level should perform the slow runs first and the fast runs second. One-half of the subjects should have the opposite arrangement.

After completion of all runs, remove the water bottle, pay the subject (and have receipt signed) and thank the bicyclist for his/her cooperation.