TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UM-HSRI-HF-TM-73-5		

4. Title and Subtitle	5. Report Date
The relationship of bicycle maneuverability to handlebar configuration.	June 18, 1973
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Rudolf G. Mortimer, Patricia A. Domas, and Robert E. Dewar	UM-HSRI-HF-TM-73-5
9. Performing Organization Name and Address	10. Work Unit No.
Highway Safety Research Institute University of Michigan Huron Parkway & Baxter Road Ann Arbor, Michigan 48105	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The growing use of bicycles by all age groups coupled with their involvement in numerous accidents has increased the impact of bicycles as a highway safety problem. Since the handling characteristics of bicycles can affect their safety, the present experiment evaluated the maneuverability of three basic handlebar configuations: racing (drop), standard, and high rise.

The performance observed on the bicycles with high rise and standard handlebar configurations indicated they were not significantly different from each other. On the circle, figure 8, and slalom tasks, performance with both the high rise and standard handlebars was significantly better than the race. The high rise showed a slight performance edge on tasks requiring the greatest amount of maneuvering, while the standard handlebars offered more control at slower speeds, and on tasks requiring stability in tracking.

17. Key Words	18. Distribution Statement
BICYCLES BICYCLE HANDLING HANDLEBARS	UNLIMITED

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	29	

Form DOT F 1700.7 (8-69)

REPORT UM-HSRI-HF-TM-73-5

THE RELATIONSHIP OF BICYCLE MANEUVERABILITY TO HANDLEBAR CONFIGURATION

Rudolf G. Mortimer
Patricia A. Domas
Robert E. Dewar

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48105

June 18, 1973

ABSTRACT

The growing use of bicycles by all age groups coupled with their involvement in numerous accidents has increased the impact of bicycles as a highway safety problem. Since the handling characteristics of bicycles can affect their safety, the present experiment evaluated the maneuverability of three basic handlebar configurations: racing (drop), standard, and high rise.

The maneuverability of each bicycle was measured as Ss performed six tasks: circle, lane change, figure 8, straight lane tracking, cornering, and slalom. Subjects were matched by riding experience and grouped by their familiarity with either the race or standard bicycle. Analysis of variance showed that no bicycle versus bicycle-familiarity effects were significant in any of the analyses.

The performance observed on the bicycles with high rise and standard handlebar configurations indicated they were not significantly different from each other. On the circle, figure 8, and slalom tasks, performance with both the high rise and standard handlebars was significantly better than the race. The high rise showed a slight performance edge on tasks requiring the greatest amount of maneuvering, while the standard handlebars offered more control at slower speeds, and on tasks requiring stability in tracking.

Since the high rise handlebar configuration allowed good maneuvering performance it should be considered an acceptable design. Standard handlebars offer a good compromise between the characteristics of the racing and high rise types, and provided stable, low speed tracking which is important for safe riding on streets in the mix of other traffic.

TABLE OF CONTENTS

ACKNOWLEDGEMENT

Dr. Robert E. Dewar was Visiting Scientist at HSRI during the academic year 1971-72, from the University of Calgary, Alberta.

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

A recent survey has indicated that cycling displayed the greatest growth over all outdoor sports since 1965 (U.S. Department of the Interior, 1967). This increased use of bicycles by all age groups can be expected to affect the impact of bicycles as a highway safety problem. Bicycles have been involved in numerous accidents resulting in serious injuries and fatalities. The U.S. Department of Health, Education, and Welfare (1972) estimated that 1,000,000 injuries involved bicycle riders in 1969, of which 39,000 were related to collisions with motor vehicles (Accident Facts, 1970). In 1971 there were 850 deaths as a result of motor vehicle-bicycle collisions (Accident Facts, 1972). As the impact of the bicycle has increased, bicycle-related deaths and injuries have grown in number consistently through the years.

In a special study of bicycle safety, the National Transportation Safety Board (1972) recognized that specific design features have greater accident-injury potential. A tradeoff exists between maneuverability and stability, where greater maneuverability leads to decreased stability and possibly to riskier rider behavior. The introduction of the "high rise" bicycle configuration (characterized by high handlebars, banana seat, smaller wheels, shorter wheelbase) has attracted attention to bicycle design features and their inherent safety aspects. The NTSB states that, although the issue has been insufficiently studied, there is reason to believe that the newer high rise bicycle may be a more hazardous overall design than the conventional style. This attitude, coupled with an increasing number of bicycle-related accidents, has prompted investigations of the characteristics of all bicycle types.

In an attempt to relate the occurrence of accidents to specific characteristics of bicycle usage, Campbell, Foley and

Pascarella (1971) studied bicycle accidents among youths in Raleigh, N.C. Unique to this experiment, Campbell et al. employed "cyclometers" to measure the exposure of riders in terms of actual miles ridden. A survey of bicycle riding and accidents was maintained on a sample of 500 youths and supplemented by city-wide hospital and police reports. The experimental design allowed estimation of accident rates by bicycle type, rider sex and age, corrected for exposure in terms of mileage. The data indicated that rider involvement in a minor accident would occur on an average of once in two years, and a serious accident requiring medical attention once in 25 years. The contention that any particular bicycle type, including the high rise, is associated with a higher accident rate, was not supported, nor was type of bike significantly associated with injury severity or body area injured.

A study conducted at the Cornell Aeronautical Laboratory by Rice and Roland (1970) considered bicycles from a human engineering point-of-view and identified several factors involved in the maneuverability of some common bicycle designs. This study evaluated the performance and handling qualities of conventional and high rise bicycles. Approaching the question experimentally, the authors obtained quantitative measurements of handling qualities as several riders performed a series of maneuvers: braking, steady-state cornering, hands-off path following, and serpentine tracking. In the tests which were performed, the conventional bicycle was just as maneuverable at moderate speeds (10-15 mph) as the high rise bicycle. Although they did not conclude that all maneuvers could be performed equally well with either design, they did suggest that the high rise bicycle outperforms the conventional bike only in acrobatics and in situations where its shorter overall length is essential to success. As a first step towards the development of performance standards and consumer information, the authors recommended further experimental work and accident causation studies linking design characteristics and safety.

Rice and Roland (1970) evaluated the handling qualities of two classes of bicycles: conventional (or standard), and high rise. In the experiment presented here, we addressed the question of the performance characteristics of specific features of bicycle designs. Using a sample of riders and a variety of riding tests, we evaluated the maneuverability of bicycles having three basic handlebar configurations: racing (drop), standard, and high rise (see Figure 1). The tests used in this evaluation included variations of those used by Rice and Roland (1970), and additional tests involving maneuvering that might be required in an emergency. The purpose of the experiment was to compare the handlebar configurations, and their related effects of rider position and center-of-gravity, while all other bicycle design characteristics were held constant. The present study differed from that of Rice and Roland (1970) in that they compared different bicycle models while we compared handlebar configurations only.

Figure 1. Handlebar configurations. Left to right: racing (drop), standard, and high rise.

METHOD

DESIGN

This experiment used a within-subject (S) design, with each S riding all three bicycles. The maneuverability of each bicycle was measured as the Ss performed six different tasks. The tasks were labeled circle, lane change, figure 8, straight lane tracking, cornering, and slalom. The order in which the Ss rode the bicycles was predetermined and counterbalanced across Ss.

Attempts were made to control practice effects resulting from both the tasks and the bicycles. Tasks of a similar nature, for example, circle and figure 8, lane change and straight lane tracking, were separated in the sequence by at least one other task. The Ss performed the tasks in one of two orders: circle first, and then as ordered above, or in the reverse order with the slalom task first. These two blocks of tasks were then presented in one or two ways. First, the S performed all the tasks in the given order on the same bicycle, then proceeded to the second and third bikes and repeated the tasks in the same order. Or, second, the S completed one task at a time, using all three bikes in the predetermined order; and then proceeded to the next task. Both the order of tasks and the presentation order of the block of tasks were counterbalanced across Ss.

SUBJECTS

Eighteen men served as paid Ss. They were employees of the HSRI or students at the University of Michigan. Their ages ranged from 18 to 41, with an average age of 24 years.

Subjects were screened for their bicycle riding experience. Two extremes were avoided: those men who rode every day or more than five miles per week, and those who had not ridden bicycles for several months. On the average, Ss rode once or twice a week. Seven Ss were most familiar with racing handlebars, and two Ss were familiar with two or more bicycle types. The remaining nine Ss predominantly rode bicycles with standard handlebar configurations.

APPARATUS

With the exception of the handlebars, the bicycles were identical (women's model with 26-inch frames). These three experimental bicycles were equipped with 3-speed gear shifts and front and rear hand brakes. During the experiment, however, the Ss were restricted to the use of second gear only. In addition to the experimental bikes, a fourth control bicycle was used for pacing. This bike was equipped with a speedometer, which was accurately calibrated for use in this study.

Supplemental equipment included traffic cones, a stop watch, and an additional timing device, consisting of a step switch and ten counters which allowed multiple times to be recorded consecutively in the lane-change task.

PROCEDURE

Each S was interviewed before the experiment began, and answered questions about his height, weight, and bicycle riding experience. The S was then assigned to an experimental condition determined by three counterbalancing measures: each S was assigned to one of six bicycle orders, one of the two task orders within a block, and one of the two presentation orders of the block of tasks.

Each bicycle was used on all six tasks. The instructions for each task, and the measures taken on each, were as follows:

CIRCLE. The S was instructed to pedal around the circle within its boundaries as fast as possible (see Figure 2). The lane was four feet wide, with inner and outer radii of 9 and 13 feet, respectively. The direction of travel, turning left or right, was at the S's option. However, once the S chose

Figure 2. Subject performing circle task.

the direction, he was limited to it for all three bikes. Whenever the front wheel of the bicycle crossed over the outer or inner boundaries, it was considered an error. The S was instructed to sacrifice accuracy for speed, up to the point that errors cost him additional time.

The S practiced three times around the circle and then rested. One experimental trial consisted of a complete revolution around the circle. Before the experimental trials began, the S was given one to two revolutions to attain speed. Time was measured on five consecutive trials.

FIGURE EIGHT. The lane on each loop of the figure 8 was three feet wide, with an inner radius of six feet (see Figure 3). The instructions for the figure 8 were similar to those for the circle. However, the direction of travel was specified for all Ss. Time was recorded for four consecutive trials.

LANE CHANGE. This task required the S to steer his bicycle in a lane eight inches wide as he was paced at 12 mph. On a given signal the S crossed over to the second lane as quickly as possible (Figure 4). After crossing, the S was to steer in the second lane and remain in it until the end. One experimental trial consisted of one lane change with only one crossover signal given during the 100-foot run.

The S practiced one lane change, traveling right to left. Measures of time were recorded on four trials, two right to left, and two left to right. The measures taken were initiation time, crossover time, and stabilization time. Initiation time began with the experimenter's (E) signal and ended when the S reacted by leaving the first lane. Crossover time began at this point and ended when the front wheel of the bicycle crossed the inner boundary of the second lane. Stabilization time began at this point and was measured until the S stayed within the second lane to its end. If

Figure 3. Figure 8 task.

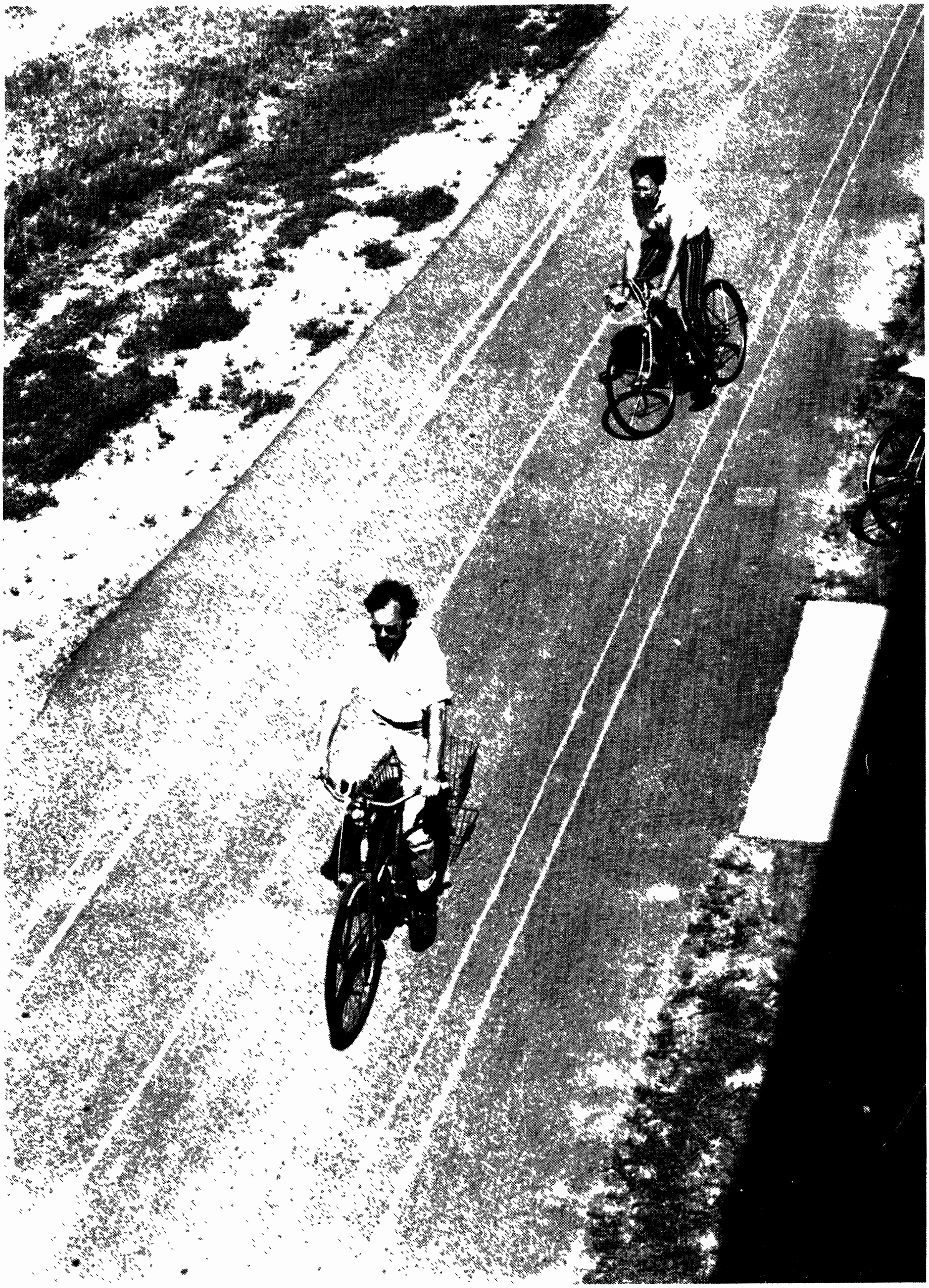

Figure 4. Subject executing lane change with experimenter riding pace bike ahead.

crossed into the second lane and never left it, or remained in it for at least 1.0 second, stabilization time was recorded as zero.

STRAIGHT LANE TRACKING. The straight-lane tracking task required the S to steer his bicycle in an eight-inch wide lane, as in Figure 5. The S was instructed to maintain a straight path down the lane, crossing outside its boundaries as little as possible. One trial involved maneuvering down the 82-foot lane. An error was recorded whenever the front tire of the bicycle crossed outside either of the lane boundaries. Measures of error frequency were taken on two trials at both 3 mph and 12 mph. The S practiced one trial at each speed before beginning the experimental trials with each bicycle.

CORNERING. Ss were paced through a 3-foot lane at 10 mph, and instructed to make a sharp right turn after passing the second pair of traffic cones (Figure 6). The criterion emphasized was to turn with as small a radius as possible. The S was not allowed to use brakes or his feet in the turn, but was told to coast around the corner. The turning radii were marked on the pavement from 2 to 16 feet in six-inch intervals. The performance measure recorded was the furthest line crossed as the Ss made the turn. These distances were recorded for six turning trials.

SLALOM. The slalom task (Figure 7) involved a zig-zag course through nine traffic cones spaced ten feet apart in a lane 3.5 feet wide. The bases of the cones were cut off, making them easy to tip over. The performance criterion that was emphasized to the Ss was to ride through the course without knocking over any of the cones. Whenever the front wheel of the bicycle crossed over the lane boundaries, an error was recorded.

Figure 5. Experimenter pacing subject in straight lane tracking task.

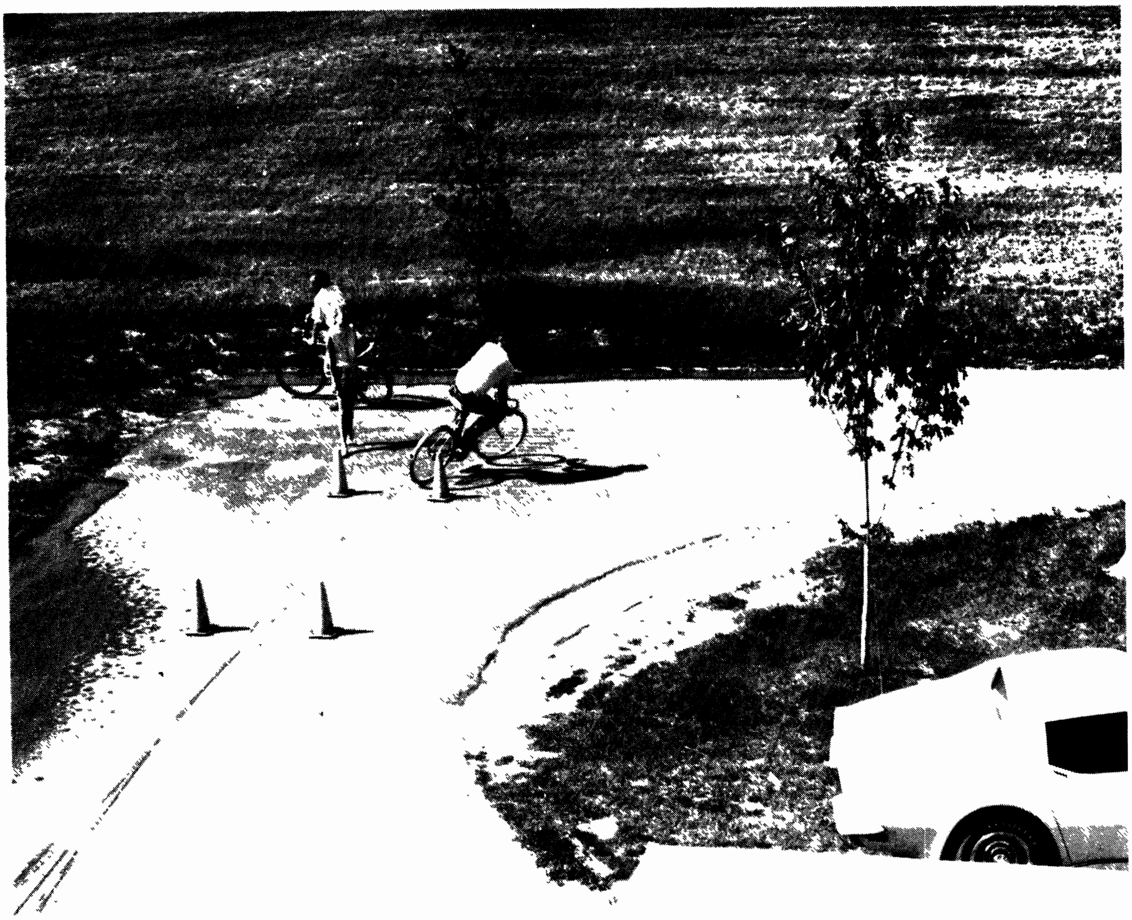

Figure 6. Cornering task.

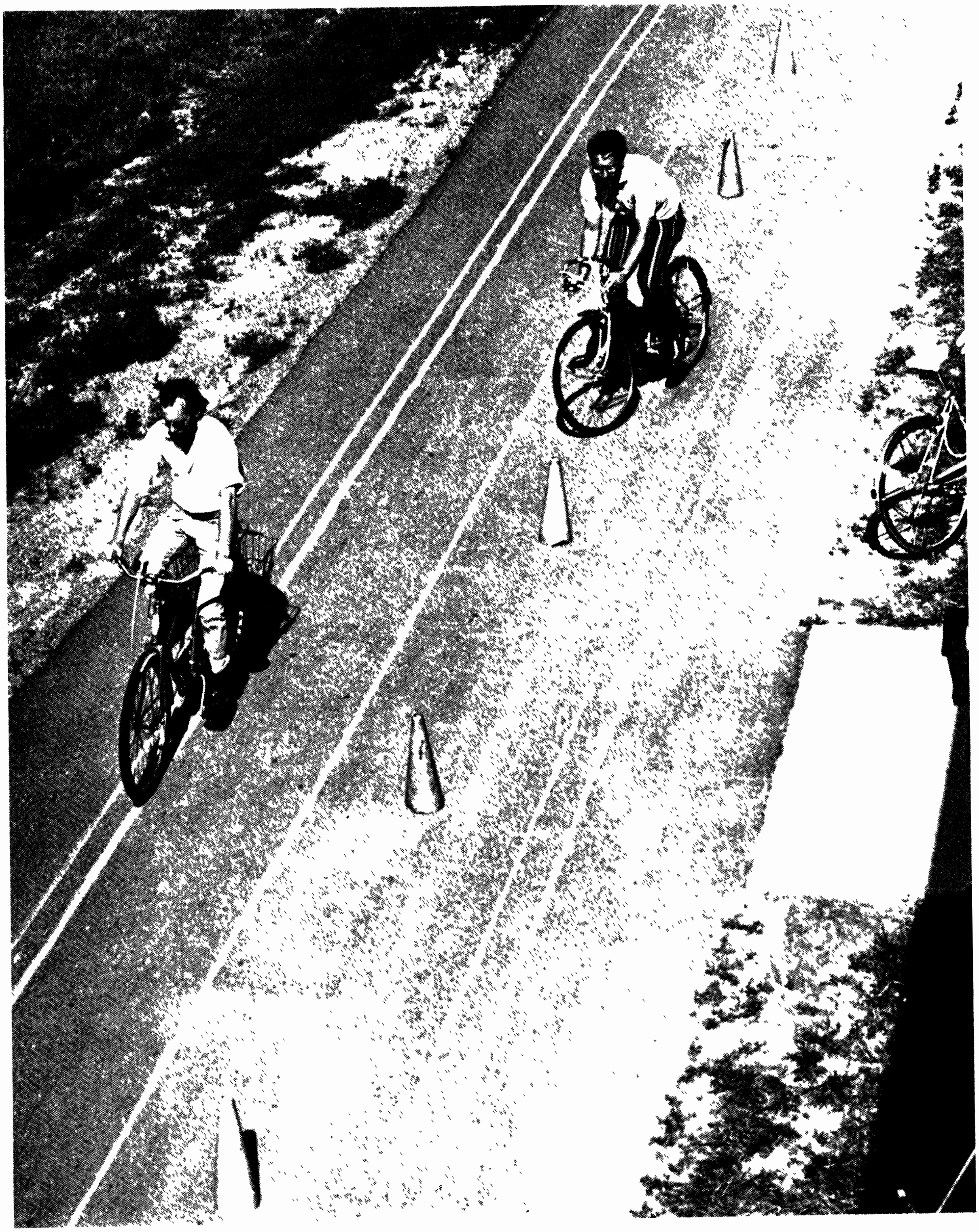

Figure 7. Slalom.

The S was paced through the course at four speeds: 5, 8, 10, and 12 mph, in that order. The S was allowed to ride slower than the pace bike if necessary, but never faster. The S was allowed one practice trial at 5 mph. Each S then had two trials at each speed to make a successful run through the course. If he failed on both trials at 8, 10, or 12 mph he did not try again at any other speed on that bike. The performance measure recorded was the maximum speed through the course without knocking over any cones.

BICYCLE FAMILIARITY EFFECTS. Each of the Ss was most familiar with one of the three bicycle handlebar configurations. In order to assess any bicycle versus familiarity interactions, a subset of 12 Ss was divided into two groups. These Ss were grouped by their familiarity with either the race or standard bicycle. Six Ss were familiar with the race bicycle and were matched by riding experience to six Ss familiar with the standard.

RATINGS OF MANEUVERABILITY AND TASK DIFFICULTY. In addition to recording the performance measures described, Ss were asked (at the end of the experiment) to rate each bicycle for its maneuverability on each task, as soon as the task was completed, with a bike. A five-point scale was used with the following assignments: 1=very easy, 2=easy, 3=neutral, 4=hard, and 5=very hard. Using the same scale Ss were also asked to rate the overall difficulty of each task independently of the bicycles they had ridden when it had been completed with all bikes.

RESULTS

The analysis of variance (ANOVA) was used as the primary means of data analysis. Ten performance measures were subjected to an ANOVA: circle time; figure eight time; lane change initiation time, crossover time, stabilization time, and total time; straight lane tracking error at 3 and 12 mph; cornering distance; and slalom maximum successful speed. In the analysis of the slalom task, maximum successful speed was defined as the highest actual speed (in feet per second) attained during a run in which no cones were knocked over. The Newman-Keuls method was used to make *post hoc* comparisons among the treatment means.

BICYCLE FAMILIARITY EFFECTS

A subset of 12 *S*s was divided into two groups in order to test bicycle versus familiarity interactions. These *S*s were matched by riding experience and grouped by their familiarity with either the race or standard bicycle. An ANOVA was performed on each of the ten performance measures outlined above.

No bicycle versus familiarity effects were significant in any of the analyses. Main effects due to the familiarity groups are outlined in Table 1 for each of the ten performance measures. Significant differences between the two familiarity groups were found in only two tasks: circle time and cornering distance. That is, on these two tasks, *S*s who were familiar with the race bike performed significantly better on both the race and standard bikes than did those *S*s who were familiar with the standard bicycle. While the significantly better performance of the group familiar with the race bike on two tasks suggests the groups' overall superiority, the differences between the familiarity groups are obviously small.

Since no bicycle versus familiarity interactions were found, the remainder of the analyses presented here concern the entire sample of 18 *S*s.

TABLE 1. Mean Performance by Familiarity With Bicycle Configuration: 6 Ss/Group.

Performance Measure	Bike Familiarity Group		P
	Standard	Race	
Circle Time (sec)	5.34	4.89	.01
Figure 8 Time (sec)	8.54	8.24	NS
Lane change, initiation Time (sec)	.71	.66	NS
Lane change, crossover Time (sec)	1.37	1.37	NS
Lane change, stabilization Time (sec)	.19	.40	NS
Lane change, Total Time (sec)	2.27	2.43	NS
Cornering Distance (ft)	11.81	9.61	.05
Straight Lane Tracking Error - 3 mph (freq.)	1.42	2.19	NS
Straight Lane Tracking Error - 12 mph (freq.)	.55	.44	NS
Slalom Maximum Speed	14.47	14.06	NS

PERFORMANCE DIFFERENCES AMONG HANDLEBAR CONFIGURATIONS

Means and standard deviations of the ten performance measures are displayed in Table 2. The ANOVA's performed indicated significant performance differences between bicycles on three measures: circle time; figure eight time; and slalom maximum successful speed.

The analysis of circle times indicated that both the standard and high rise bikes were significantly faster than the race ($p \leq .01$), but not different from each other. The average lateral acceleration on each bike, high rise, standard, and race, was calculated to be 0.52g, 0.52g, and 0.49g, respectively. This limit was probably affected by pedal clearance while banking the bicycle.

On the figure eight, both standard and high rise bikes were faster than the race ($p \leq .01$), but, again not significantly different from each other. The mean times on each bicycle in these two tasks are displayed in Figure 8. It appears, that, at the speeds encountered in these two tasks (5-10 mph), the high rise bicycle has no distinct performance advantage over the standard configuration. The average limit on lateral acceleration for both was equal.

On all three bicycles in the straight lane task, Ss made significantly more errors at 3 mph than at 12 mph. This emphasizes the decreased stability of the bicycles at slower speeds. The error differences between bikes were not significant at either speed. However, the trend in errors indicated that at slow speed most errors were made on the high rise, and at the higher speed most errors were made on the race bike. At 3 mph the standard bike had the least errors. The results, as displayed in Figure 9, suggest that the conventional bike is more controllable at slower speeds.

The analysis of maximum successful speed on the slalom task

TABLE 2. Means and Standard Deviations of Riding Performance: 18 Subjects.

Performance Measure	Bike					
	High Rise		Standard		Race	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Circle time (sec)	<u>5.116</u>*	0.365	<u>5.108</u>	0.410	5.264	0.452
Figure 8 time (sec)	<u>8.255</u>	0.645	<u>8.366</u>	0.732	8.701	0.673
Lane change initiation time (sec)	0.631	0.138	0.649	0.171	0.652	0.142
Lane change crossover time (sec)	1.408	0.244	1.331	0.261	1.424	0.294
Lane change stabilization time (sec)	0.448	0.523	0.372	0.349	0.506	0.386
Lane change total time (sec)	2.493	0.218	2.350	0.108	2.584	0.181
Cornering distance (ft)	10.425	2.225	10.541	2.196	10.981	2.291
Straight lane tracking 3 mph (error freq.)	2.083	2.033	1.805	1.653	2.000	1.788
Straight lane tracking 12 mph (error freq.)	0.388	0.728	0.472	0.608	0.583	0.806
Slalom maximum successful speed (ft/sec)	<u>14.973</u>	1.817	<u>14.354</u>	2.516	12.519	3.133

*Underline indicates significantly better performance ($p \leq .01$) than those not underlined in same row.

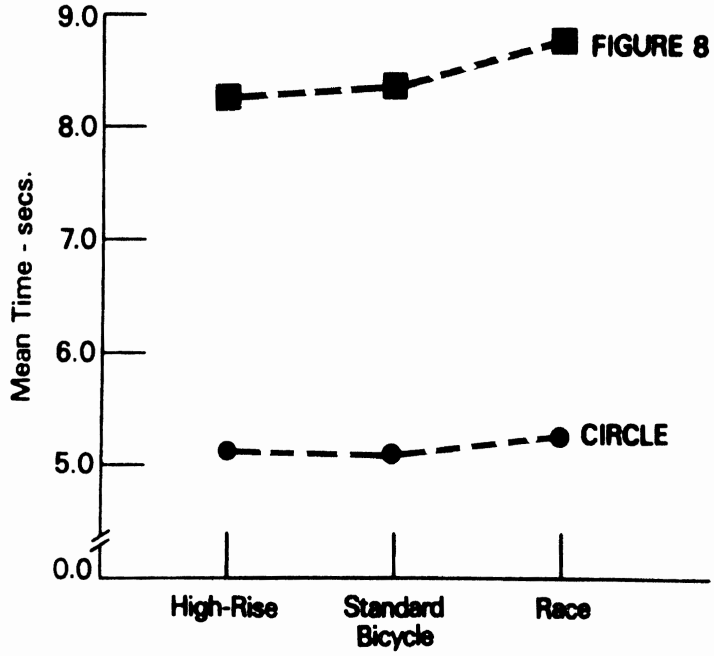

Figure 8. Mean performance times on circle and figure 8 tasks.

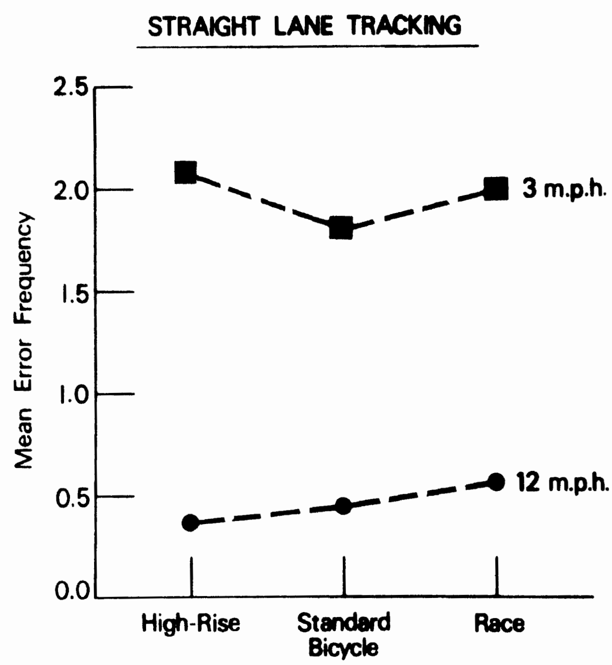

Figure 9. Mean error frequency on straight lane tracking task at slow and fast speeds.

indicated no significant differences between the standard and high rise bicycles. However, in this task these bikes allowed a significantly higher speed to be reached over the course than the race bike. Mean speeds on each bicycle are displayed in Figure 10.

Graphs of mean performance for the lane change and cornering tasks are displayed in Figures 11 and 12, respectively.

Figure 13 shows the mean performance on the race and high rise bicycles relative to the standard on all tasks and performance measures. On all ten measures, the performance of the race bike was relatively worse (i.e., slower or more errors made) than that of the standard. The performance of the high rise was relatively (but not significantly) poorer than that of the standard on the measures of circle time; lane change crossover, stabilization, and total time; and straight lane tracking errors at 3 mph.

SUBJECTIVE RATINGS

The ANOVA of the bicycle maneuverability ratings indicated a bike versus test interaction. Looking at the mean ratings for the bicycles, the high rise was rated as the easiest bike to maneuver on the cornering, figure eight, and serpentine tasks. On the circle, the straight run task at 3 mph, and lane change, the standard bicycle was rated as most maneuverable. The race bike was rated as easiest to handle on the straight lane task at 12 mph. Averaged over all the tests, the high rise and standard bicycle were rated equally maneuverable (2.6) with the race evaluated as slightly more difficult to maneuver (2.8).

Although a *post hoc* comparison failed to indicate that any of the above rating differences between bicycles for a given test were significant, differences existed in tests on a given bike. The straight lane task at 12 mph was considered as the easiest maneuvering task for all three bicycles. Considering only the high

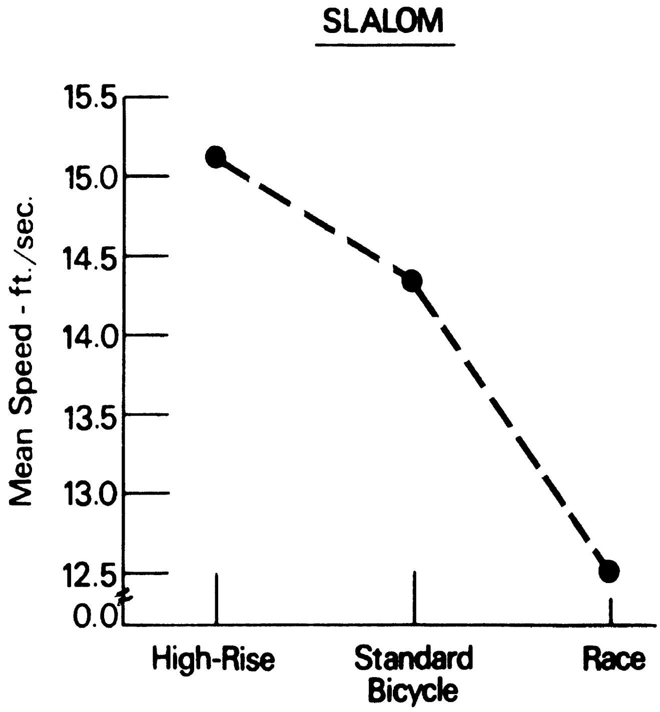

Figure 10. Mean maximum speeds attained on slalom task.

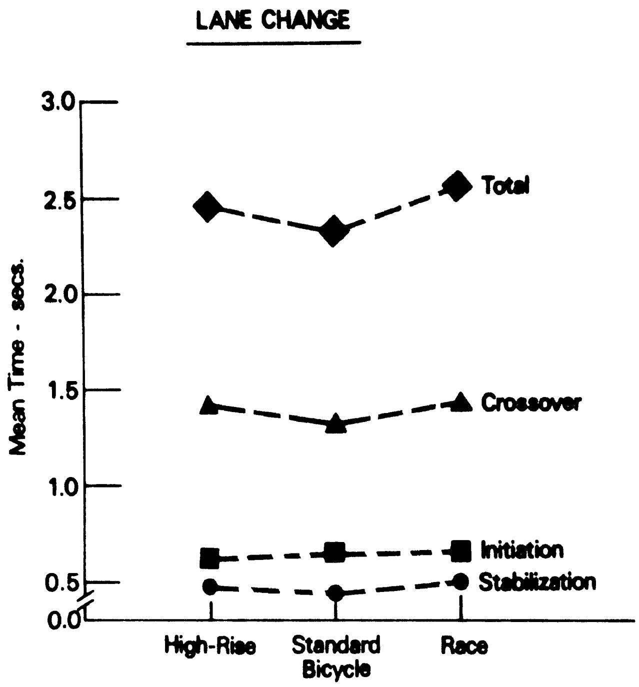

Figure 11. Mean performance times on lane change task.

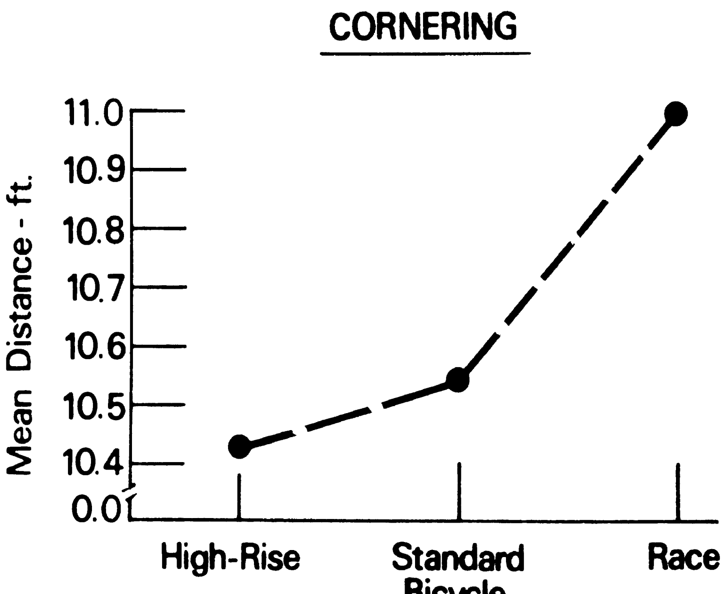

Figure 12. Mean distances on cornering task.

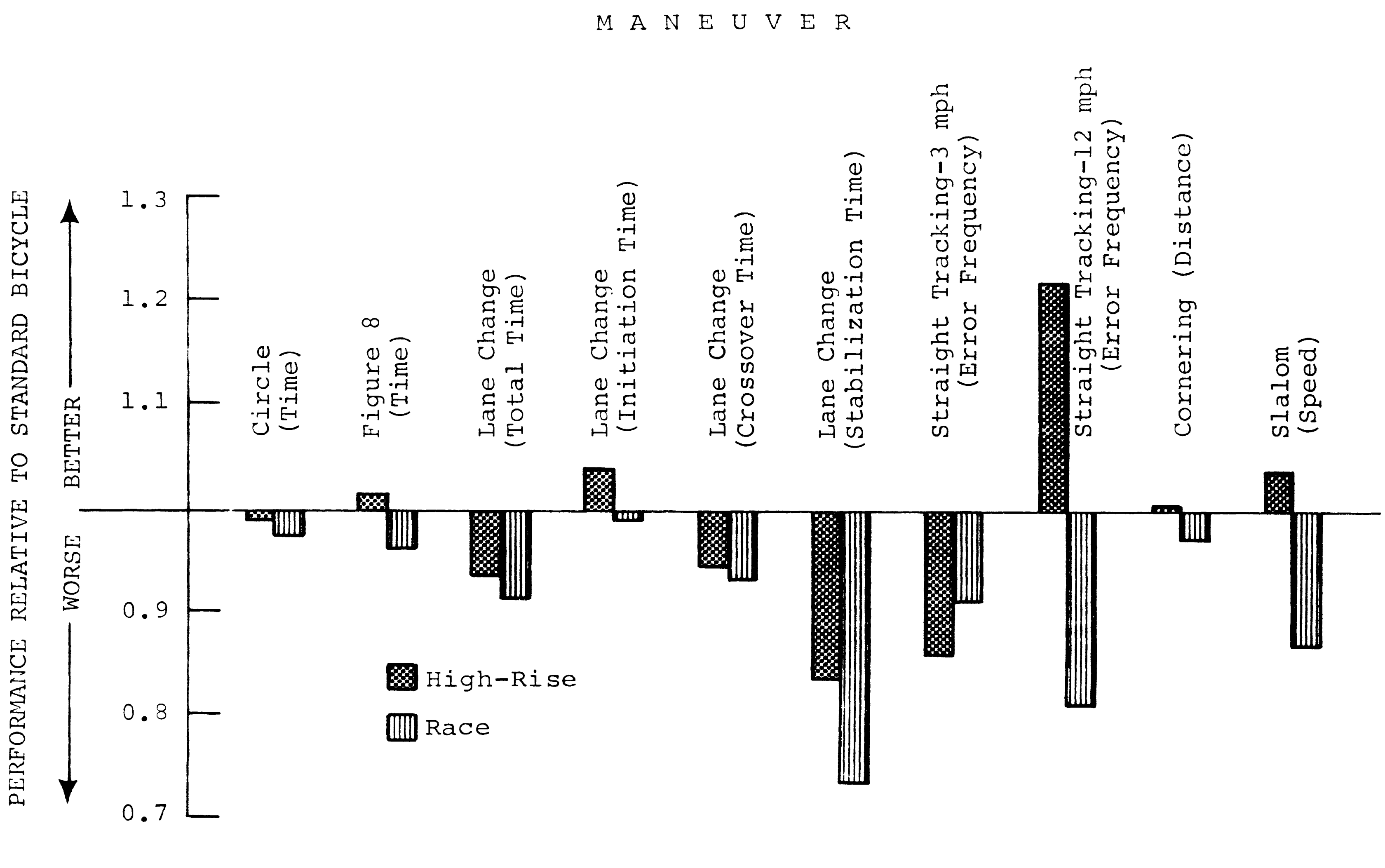

Figure 13. Relative performance (using standard as baseline) on high-rise and race bicycles as a function of ten task and performance measures.

rise bicycle, Ss rated the lane change and straight lane tracking at 3 mph as significantly more difficult. Ss rated the race bike as more difficult to maneuver on every other task as compared to the straight lane at 12 mph. On the standard bicycle, Ss rated the figure eight as the only task significantly more difficult than the circle, lane change, and straight lane at 12 mph. The overall ratings of each task are displayed in Table 3.

Table 4 displays the correlation between performance and rating measures of the bicycle configurations on a given task. With the exception of straight lane tracking at 12 mph, the bicycle that was rated easiest to handle also was the bicycle with the best performance.

TABLE 3. Mean Ratings of Tasks.

Maneuver	Mean Rating	
Tracking - 12 mph	1.9	Easy
Circle	2.4	↓
Lane Change	2.6	
Cornering	2.7	
Slalom	2.8	
Figure 8	3.0	
Tracking - 3 mph	3.1	Difficult

TABLE 4. Comparison by Performance and Rating of Bicycle Easiest to Maneuver in Each Task.

Task	Mean Performance	Mean Rating
Tracking - 12 mph	High Rise	Race
Circle	Standard	Standard
Lane Change	Standard	Standard
Cornering	High Rise	High Rise
Slalom	High Rise	High Rise
Figure 8	High Rise	High Rise
Tracking - 3 mph	Standard	Standard

DISCUSSION

The performance observed on the bicycles with high rise and standard handlebar configurations indicated they were not significantly different from each other. This is not to say that each bicycle is equally maneuverable on all tasks. The high rise exhibited a slight performance edge on the tasks which required the greatest amount of maneuvering; namely, the figure eight, cornering, and serpentine tasks. On the other hand, the results of the straight lane tracking at slow speed suggest that the standard bicycle is more controllable at slower speeds. At the Cornell Aeronautical Laboratory, Rice and Roland (1970) determined that the conventional bicycle was more controllable than the high rise at speeds slower by 2 to 5 mph.

A similar trend is indicated by the subjective ratings. On the average, Ss preferred the high rise on the tasks involving maneuvering. However, the standard bicycle was easier to handle on those tasks where greater stability was more likely to lead to better performance; namely, the circle and lane change tasks, and straight lane tracking at slow speed. Thus, the high rise may excel on tasks involving relatively more maneuvering, while the standard bicycle excels on tasks where greater stability leads to better performance.

The race bicycle appeared to be the least maneuverable of the three. The analysis of Ss' performance grouped by familiarity suggests that Ss who were familiar with the race bike were more skillful on a majority of tests. In order to be handled as easily as the others, the race bicycle probably required a higher level of proficiency. Despite all of its characteristics of stability, the race bike was harder to handle on all tasks for most Ss. Once a higher level of skill was obtained on the race, most Ss could perform as well as or better than they did on the standard bicycle.

The role of bicycle maneuverability in accidents is not known, but it would seem reasonable that a maneuverable and stable bicycle has characteristics that are needed for safe riding on streets in the mix of other traffic. The results of this study show that there is no reason to disallow the high-rise handlebars as has recently been suggested by the U.S. Food and Drug Administration.

REFERENCES

Campbell, B.J., Foley, J.P., and Pascarella, E.A. Bicycle Riding and Accidents Among Youths: A Summary Report. Chapel Hill, N.C.: The University of North Carolina Highway Safety Research Center, 1971.

National Safety Council. Accident Facts, Editions 1970 and 1972.

National Transportation Safety Board. Bicycle Use as a Highway Safety Problem. Washington, D.C.: Bureau of Surface Transportation Safety, Report No. NTSB-HSS-72-1, 1972.

Rice, R.S. and Roland, R.D. An Evaluation of the Performance and Handling Qualities of Bicycles. Buffalo, N.Y.: Cornell Aeronautical Laboratory, Inc., Report CAL No. VJ-2888-K, 1970.

U.S. Department of Health, Education and Welfare. Staff Analysis of Bicycle Accidents and Injuries. Bethesda, Maryland: Bureau of Product Safety, Report No. PB-207-665, 1972.

U.S. Department of the Interior. Outdoor Recreation Trends. Washington, D.C.: Bureau of Outdoor Recreation, 1967.