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ABSTRACT

This paper reports on a Santa Barbara, California study, to determine the need for establishing a minimum age for bicyclists using the public roadways, examining the proposition that children below a certain age are developmentally unable to perform safely in traffic. Data on the disproportionate incidence of accident involvement among young cyclists include statistics on fatalities, injuries and cyclist behavior. A general description of the cognitive development process in children is presented, with specific discussion of the development of concepts of speed, time and distance, and the concept of rules. Results of a survey of 1,373 parents of 2,764 children, aged 5 to 13, in which parents selected an average minimum age of about 11 years, indicate good-to-enthusiastic parent support of the minimum age idea. The report concludes: (1) that the cognitive deficiencies associated with the incompletely developed child justify a minimum age of 13 years or older for cyclists using public roadways and (2) that registration of bicycle operators using public roadways is the best way to enforce this minimum age requirement. An introductory statement by the project director suggests a minimum age requirement of 9 years and presents additional opinions on licensing and bicycle safety education. (BF)

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I wish to express my gratitude to Mr. C. L. Lefler, City Transportation Engineer, City of Santa Barbara, for his support and understanding throughout. Special thanks are extended to Professor Stina Sandels, formerly associated with the Institute for Child Development Research at the University of Stockholm, for her interest in this study, her kindness in providing and recommending source materials, and her generosity in answering questions and offering suggestions. I wish also to acknowledge the generous help of Eric C. Claxton, O.St.J., B.Sc, C.Eng., F.I.C.E of Stevenage, England, who is associated with the British Cycling Bureau; the International Federation of Pedestrians, the Hague, Netherlands; the International Drivers' Behavior Research Association, Courbevoie, France; and Dr. Kenneth Cross, Anacapa Sciences, Santa Barbara.

The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the City of Santa Barbara, the State of California, or the National Highway Traffic Safety Administration.

FOREWORD

In June, 1973, we completed an extensive analysis of bicycle-motor vehicle accidents in Santa Barbara, California.[4] Principal purpose of the analysis was the development of programs of study and implementation aimed at substantially reducing the number of such accidents.

A major finding of that analysis was the disproportionate number of accidents in which children were the victims. Accounting for only about 8 percent of the observed bicycle traffic, cyclists in the under-13 age group were victims in about 30 percent of the accidents.

Because of that finding we strongly recommended an additional research effort. Its purpose would be to test the hypothesis that a minimum age be established for cyclists using public roadways. It was assumed that below some minimum age children were incapable of performing in traffic with an acceptable degree of safety. Further, their incapacity was hypothesized to result from a deficiency in cognitive development and was not, therefore, amenable to change through intensified or expanded programs of safety education.

The present study derives from that recommendation which was subsequently accepted and supported by the Office of Traffic Safety, State of California, and by the City of Santa Barbara.

ABSTRACT

An analysis of cognitive development as it relates to the child cyclist's capacity for comprehending the traffic environment is reported. Information bearing on the role of cognitive development emphasizes experimentally derived data that seem to show children as severely limited in terms of their capacity to understand truly the traffic environment, its rules, and hazards. Statistical data are included that demonstrate a disproportionate risk of accident involvement attending the younger cyclists. It is concluded that the cognitive deficiencies associated with the incompletely developed child are serious enough to justify a minimum age of 13 years for cyclists using public roadways, and note is made that excellent authority exists for an even higher age. Imposition of a minimum age requirement is seen as the most effective way of immediately and significantly reducing the number of young cyclists killed and injured. Results of a survey of 1,373 parents of 2,764 children, ages 5 to 13, in which the parents selected an average minimum age of about 11 years are also reported; the results are interpreted as a measure of good to enthusiastic parental support of the minimum age idea.

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YOUTHFUL ROAD USERS: THE RECORD

1. INTRODUCTION. Whatever their age, whatever their use of the roadways, the young throughout the world have compiled a remarkably poor record of traffic safety.

The young pedestrian, the young cyclist, the young moped operator, the young car driver--all have demonstrated a singular inability to participate safely in the modern traffic environment. Viewed in this context, the young bicyclist is at one point along a problem continuum ranging from the child pedestrian at one extreme to the teenage driver on the other.

Although the reasons for their poor performance may in some instances be known only in a fragmentary fashion, it is nevertheless possible to state in a general way that along that continuum the reasons gradually shade from inability and developmental immaturity in the very young into inexperience and willingness (and even overt desire) to take risks at about the age of adolescence through the teen years.

2. THE YOUNG DRIVER. Because at this point we are considering the general traffic record of young road users and because of the broader perspective it affords for later discussion, it is useful to establish in a brief manner the record of teenage drivers.

This because the young driver still bears some of the developmental incompleteness that is known to predominate at the younger ages, together with an added dimension related to his willingness to take risks. And although the young driver's vehicle has an increased potential for violence, the young motorist and young bicyclist share similar responsibilities and shortcomings. They must both function in the same traffic system and must interpret and understand the same rules of the road. They both lack experience and they both have poor traffic records. The fact is, that for some reasons that are probably the same and for others that are undoubtedly different, neither has managed to cope very well in traffic.

There is an additional similarity in that consideration has been given to increasing the minimum age for a driver's license in response to the fact that in the 15 to 24-year age group, traffic accidents lead all other causes of death.[1]

In California, one of every 13 drivers is a teenager, about 900,000 of them in all. The drivers under 20 have the highest accident rates, *about 130 for every 1000 drivers*. As shown in Fig. 1, this rate decreases remarkably with increasing age, particularly at age 20 when it drops to 88 per 1000.

Teenage drivers average twice the number of accidents attributed to adults; and because teenagers drive only about half as many miles their rate of accidents per mile is four times that of adults. Male teenagers have about twice the nurber of accidents

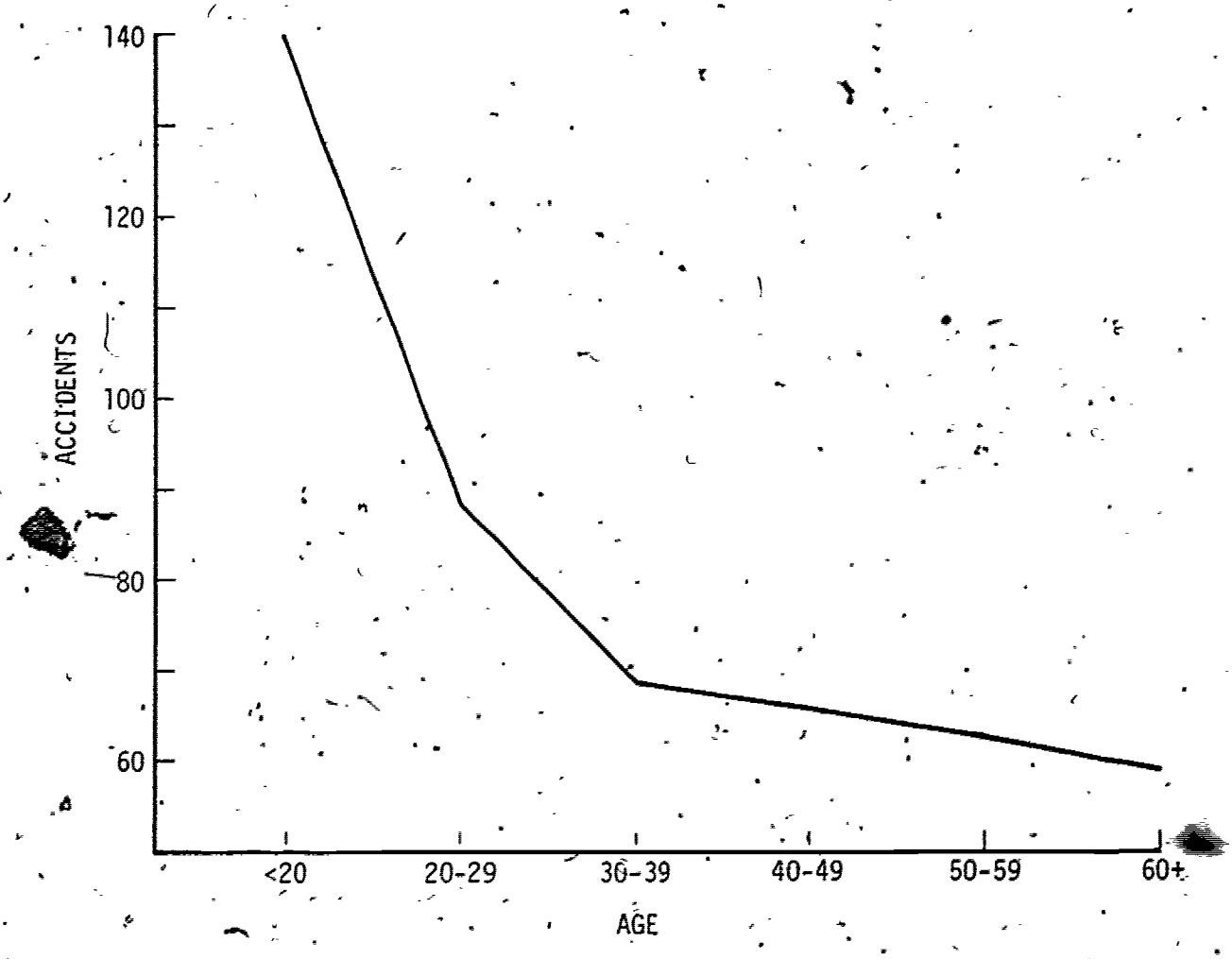


Figure 1. Average annual accidents per 1000 drivers, California (Ref. 1).

females do, but drive twice as many miles. The high teenage accident rate is not caused by a few very poor drivers: only 15 percent of the males and 44 percent of the females get through the first 4 years of driving with neither accidents nor convictions. (Conviction rates, compared with adults, are even higher than the accident rates.) And although the teenage driver learns a good deal during the first 4 years of driving, evidence shows little improvement in accident rates until age 20. That is, the high rate is not the result of an excessively high rate in the first year of driving followed by a significant decrease immediately thereafter.

Some national figures[2]: In 1966, 5.2 percent of about 96 million driver licenses were held by drivers under 20 years of age; they accounted for almost 10 percent of the accidents. Noting that the high accident rate among young drivers is an international phenomenon, one source[3] reports that *even when motorists are matched according to driving experience and driving habits the high rate among the younger drivers persists.*

In short: When his senses, coordination, and general physical abilities are at their keenest, our young driver is at his worst.

3. THE YOUNG BICYCLIST. An analysis of bicycle-motor vehicle accidents in Santa Barbara, California[4] disclosed that children in the under-13 age group accounted for about 30 percent of the accident victims. The same analysis included a study of the traffic

behavior of 500 cyclists; results of this latter study, in which observed cyclists were categorized in age groups, made it possible to estimate that as observed on Santa Barbara streets the under-13 age group made up only about 8 percent of the bicycle traffic. In any case, it is abundantly clear that the under-13 age group is involved in a significantly disproportionate number of bicycle accidents. The comparison of total injuries and total accidents, by age group, is shown in Fig. 2.

Regarding these statistics and others to follow, it would be well to note that Ref. 4, as well as other source materials, show that younger children do not ride bicycles nearly as extensively as might be thought. For one thing, children do not use bicycles for transportation to and from school to any great extent. A careful survey of the number of elementary school children who rode bicycles to school showed by actual count a total of 375 bicycles for a student population of 4,905; that is, about 7-1/2 percent of the children rode bicycles.

That bicycle usage in general and among the young in particular is not as great as sometimes assumed is borne out by figures for Stevenage, England, which has a highly developed system of special bikeways, complete with underpasses at all intersections and separated in all respects from roadways.[5] Usage rates there for elementary school children are about the same as we reported for Santa Barbara and the overall bicycle usage rate is also quite low.

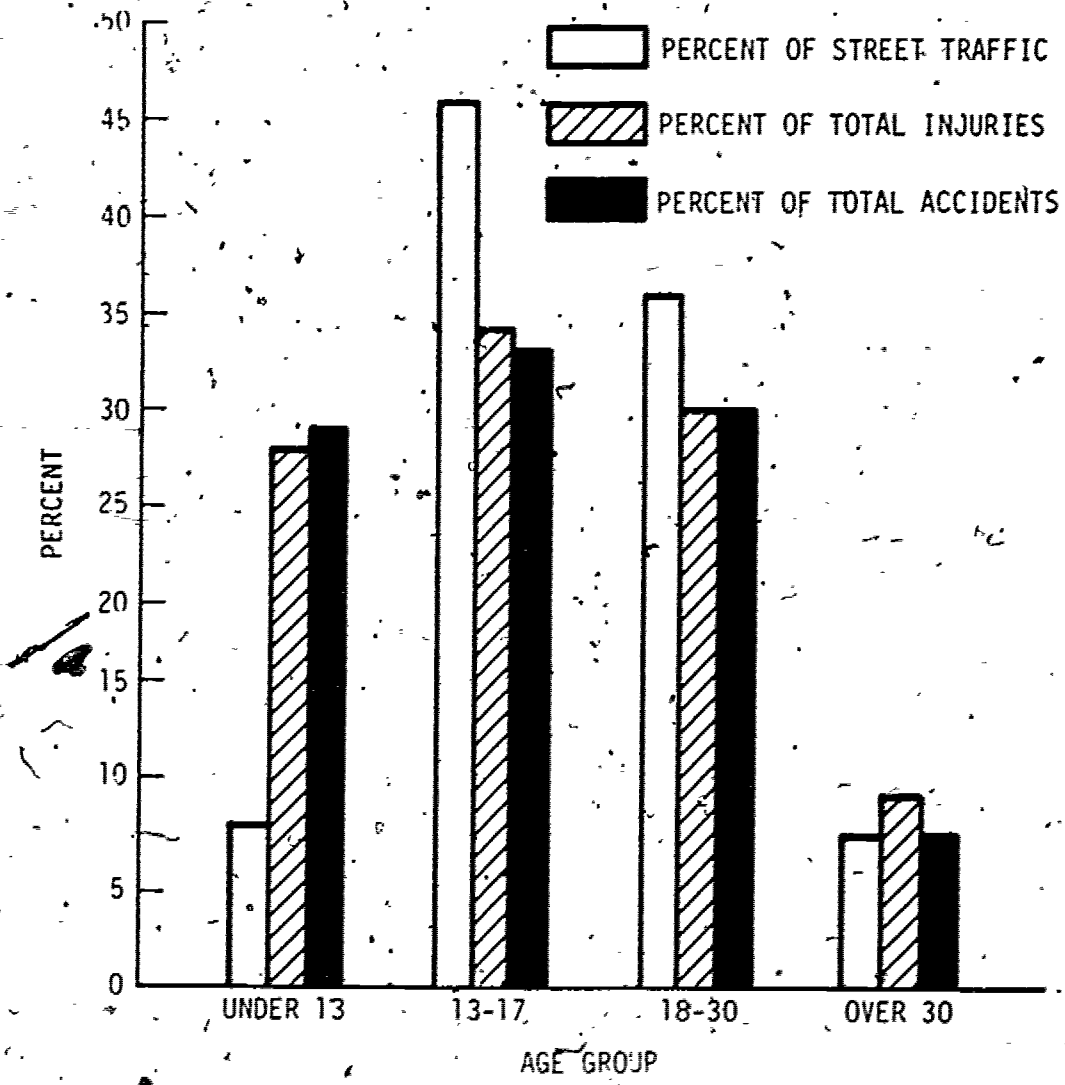


Figure 2. Comparison of total injuries and total accidents, by age group: Santa Barbara, Calif., 1970 through 1972.

In fact a decline in bicycle usage seems to be associated with increased availability of cars throughout Europe. Another researcher also reports that purposeful transportation is not the major activity of children who instead use their bicycles for play.[6] The significance of these data lies in their support of the assumption that the accident rate among children is probably much greater than usually indicated because of the apparent low usage rate (at least when considered in terms of miles traveled).

Of 477 bicycle-motor vehicle accidents analyzed in the work reported in Ref. 4, 247 involved bicyclists age 15 and under. The accident involvement by age is shown in Fig. 3. The number of accidents involving the very young—ages 4 through 9—is surprisingly high considering evidence that suggests a low exposure rate for the younger ages. As shown in Fig. 3, the 12-year-olds led all others with 44 involvements.

A cumulative total of accidents by age based on the same 247 Santa Barbara accidents is shown in Fig. 4. In the age range 4 through 15 years, the group 4 through 9 accounts for about 25 percent of all these accidents; 50 percent of the total is reached before age 12. Undoubtedly, the increased involvement with increased age reflects a greater exposure for the older children.

In the work reported in Ref. 4, it was shown that in general the bicyclist was at fault in about 70 percent of the accidents studied. Ordinarily, blame was placed as the result of a violation

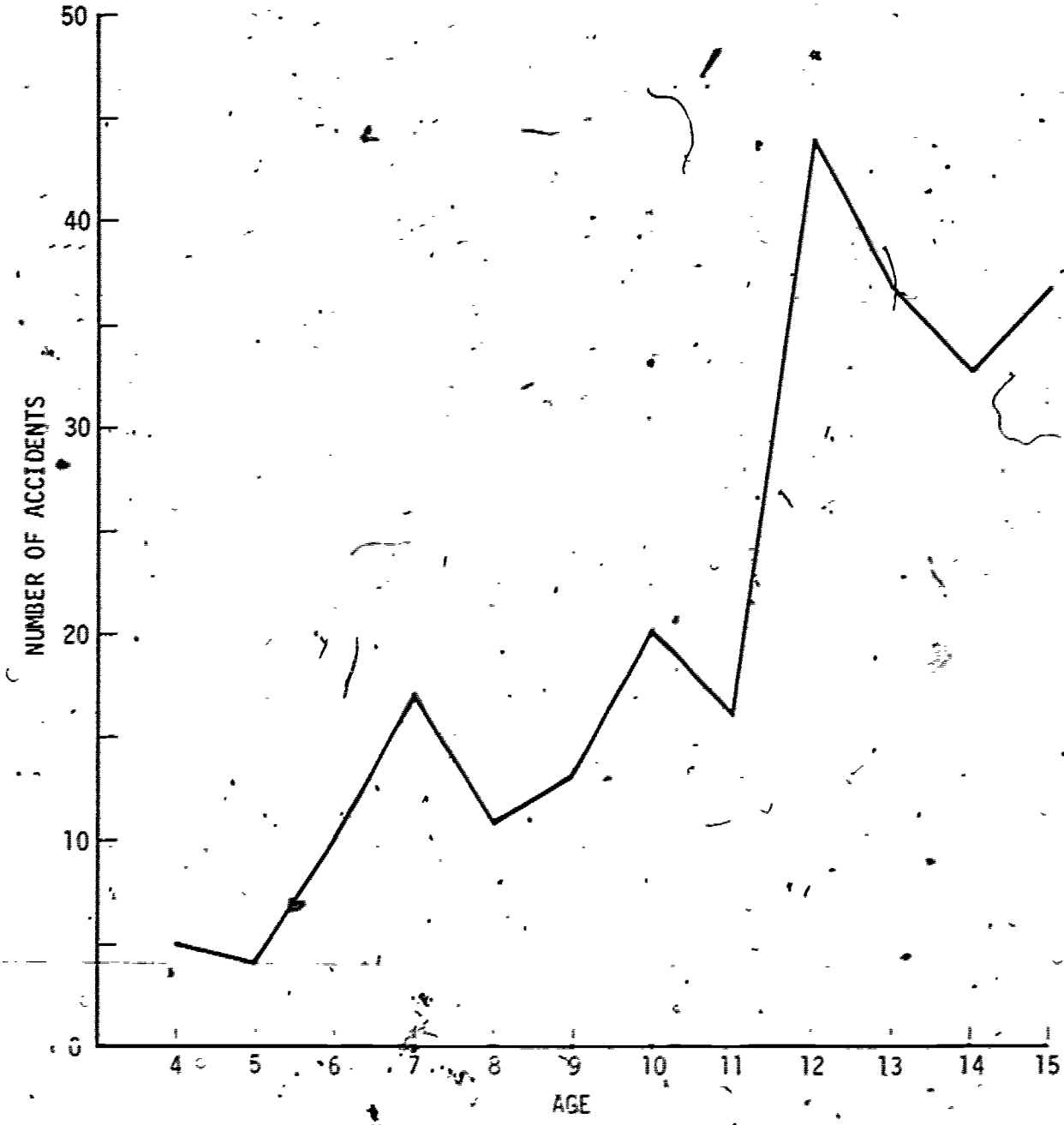


Figure 3. Accident involvement by age, based on 247 Santa Barbara City and County bicycle-motor vehicle accidents (Ref. 4).

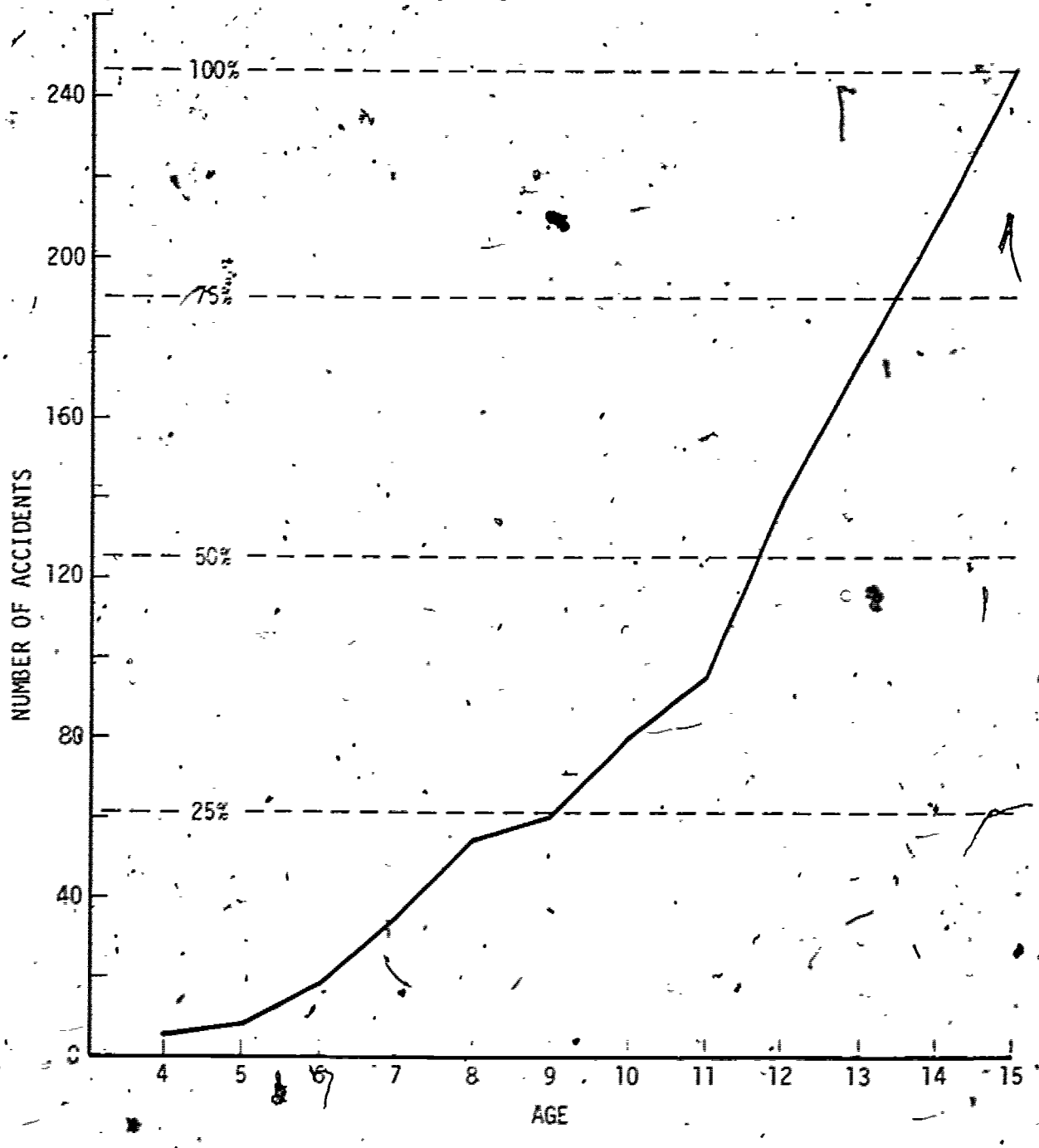


Figure 4. Cumulative total: accident involvement by age based on 247 Santa Barbara City and County bicycle-motor vehicle accidents (Ref. 4).

of a basic traffic law which figured directly and causally in the accident. For the group 15 and under, the bicyclist was considered at fault in a high of 100 percent of the cases to a low of 36 percent at age 14. Seven of the remaining 10 ages are seen to be at fault in at least 60 percent of the accidents. This distribution is shown in Fig. 5.

In summary:

1. Children 15 and under were involved in 51 percent of the 477 accidents reported.
2. Of the 247 accidents in which they were victims, those 15 and under were at fault in 61 percent of the cases.
3. Ages 12 and below accounted for 140 accidents or 57 percent of the total; they were at fault in 68 percent of the cases.
4. Ages 13 through 15 were involved in 107 accidents, 43 percent of the total; they were at fault in 47 percent of the cases.

Some accident data for the State of California are shown in Table 1 where injuries and fatalities are tabulated by age groups for the years of 1971 and 1972. In both years the disproportionate involvement of the younger cyclists is clearly seen. Fatalities among bicyclists for the years 1971 and 1972 are plotted in Figs. 6 and 7; as shown, the 10 through 14 age group incurred the most fatal injuries during those years. According to figures recently

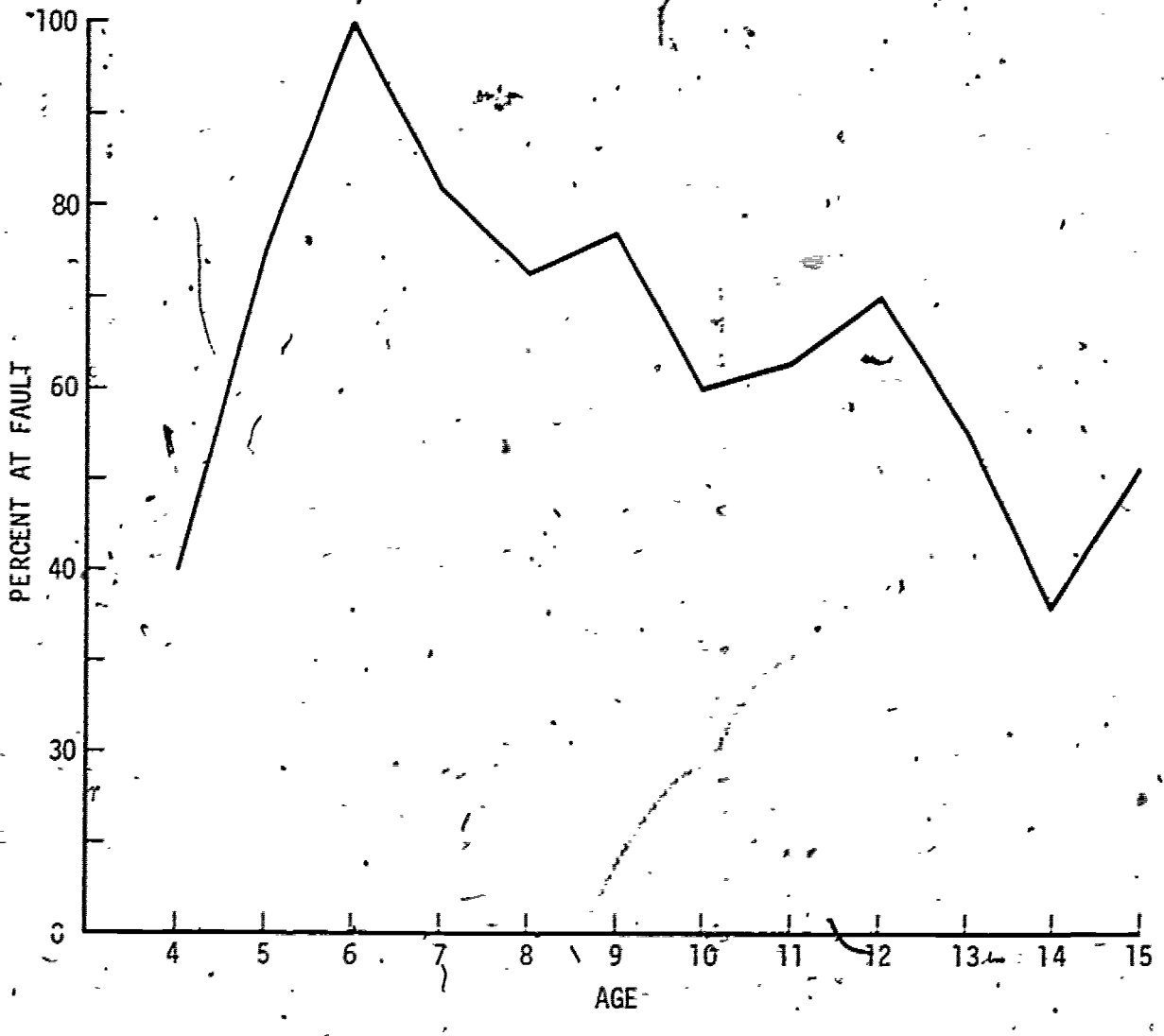
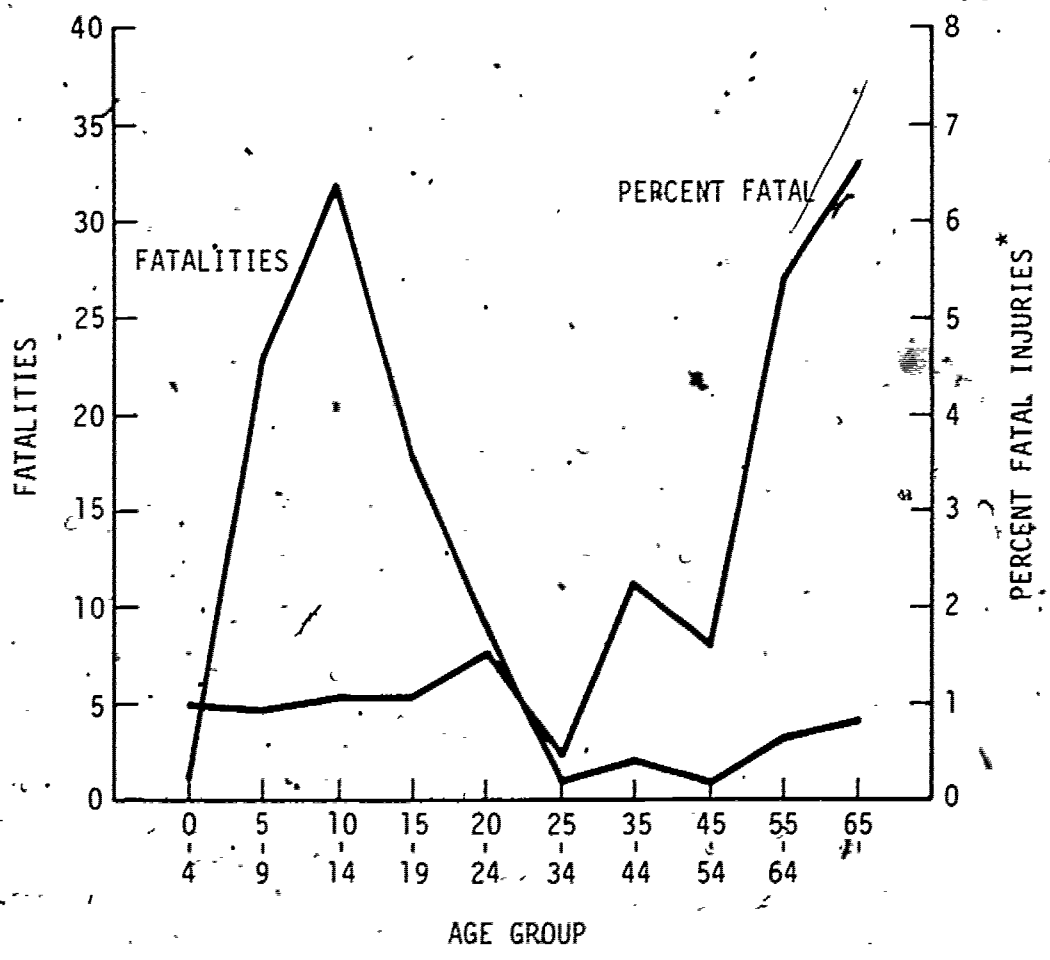


Figure 5. Accident blame by age, based on 247 accidents in age group 4 through 15 (Ref. 4): Santa Barbara, Calif.

Bicyclists' Age	Fatal		Injured		Total Injuries	
	1971*	1972	1971	1972	1971	1972
0- 4	1	3	101	152	102	155
5- 9	23	23	2,165	2,324	2,188	2,347
10-14	32	32	2,054	4,286	3,086	4,338
15-19	18	22	1,916	2,387	1,934	2,409
20-24	9	2	599	731	608	733
25-34	1	10	290	434	291	444
35-44	2	1	88	123	90	124
45-54	1	2	59	112	60	114
55-64	3	3	52	59	55	62
Over 65	4	9	56	68	60	77
Not Stated	1	1	98	167	99	168
Total	95	128	8,478	10,843	8,573	10,971

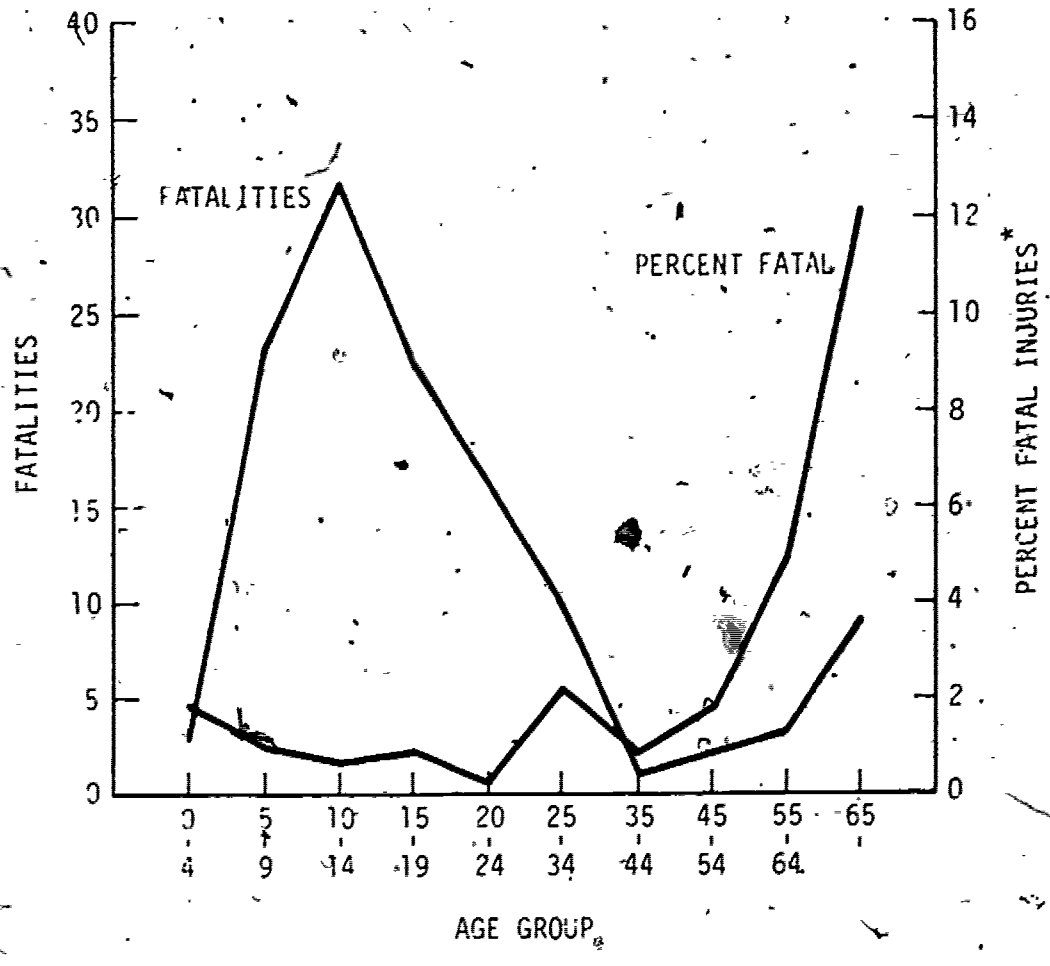
Note: There are minor discrepancies between these figures and those reported above due, apparently, to some delay in reporting or some procedural change.

Table 1. Bicycle fatalities and injuries by age group, California, 1971 and 1972 (Refs. 7, 8).



*(THIS IS THE PERCENT OF ALL INJURIES FOR A GIVEN AGE GROUP THAT WERE FATAL; e.g., THE OLDER GROUP IS SIGNIFICANTLY HIGHER).

Figure 6. Bicycle accidents and fatalities by age group: California 1971 (Ref. 7,8).



*THIS IS THE PERCENT OF ALL INJURIES FOR A GIVEN AGE GROUP THAT WERE FATAL.

Figure 7. Bicycle accident fatalities by age group: California 1972 (Ref. 7,8).

obtained from the statistical section of the California Highway Patrol in Sacramento, *bicyclists under 15 years of age suffered 60.9 percent of all bicyclist fatalities in 1972 and 61.2 percent in 1973.** If usage data were available so that a true accident *rate* could at least be estimated it is likely that these figures would be seen to represent a gross understatement of the special risks attending the child and bicycling.

The figures shown above for California also hold--only more so--on a national scale. In 1971, for example, 73 percent of all bicycle-related traffic deaths and injuries were suffered by bicyclists 14 and under.[9] This figure has actually decreased from 87 percent in 1961, reflecting an increase in the number of older cyclists rather than any improvement of the record among younger children.**

A Swedish study of traffic accidents involving children[10] reports that during the period 1956-1961 an average of 123 children under 15 were killed annually; an average of 391 were seriously injured. These data, obtained from an analysis of 14,437 police-investigated accidents, are shown in Table 2.

A further analysis of all cases of children's accidents in the greater Stockholm area was undertaken for a period of 1 year; included were those cases in which medical care was sought. Of the

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*Figures for 1973 totals may change somewhat because of late reports, etc.

**All reports of accidents reviewed show the usual greater involvement of males; it has not been made special issue of here.

	Dead	Seriously Hurt	Slight Hurt	All	In Motor Vehicles	As Cyclists	As Pedestrians	Others
Preschool	353	830	3,964	5,127	1,335	278	3,002	501
School	407	1,514	7,389	9,310	2,942	3,230	2,780	243
All	760	2,344	11,353	14,437	4,277	3,508	5,782	844
Annual Average	127	391	1,892	2,406	713	585	964	141

Table 2. Police-reported accidents among children under 15 in Sweden, 1956-1961*[10]

total of such accidents, only about 10 percent were traffic accidents, and about 60 percent of those involved bicycles only (or about 6 percent of all traffic accidents). The relatively small group of traffic accident victims nonetheless accounted for 25 percent of all children admitted to the hospital for injuries, *and 34 percent of all fatal accidents.* Some additional information concerning these accidents is given in Fig. 8. It is notable that 46 percent of the accidents occurred when children were in a hurry for one reason or another; 23 percent happened while the children were at play; only 4 percent while on their way to or from school; 3 percent were on errands; and 24 percent had a definite destination.

*There are minor arithmetical discrepancies in these figures that are accounted for by the author.

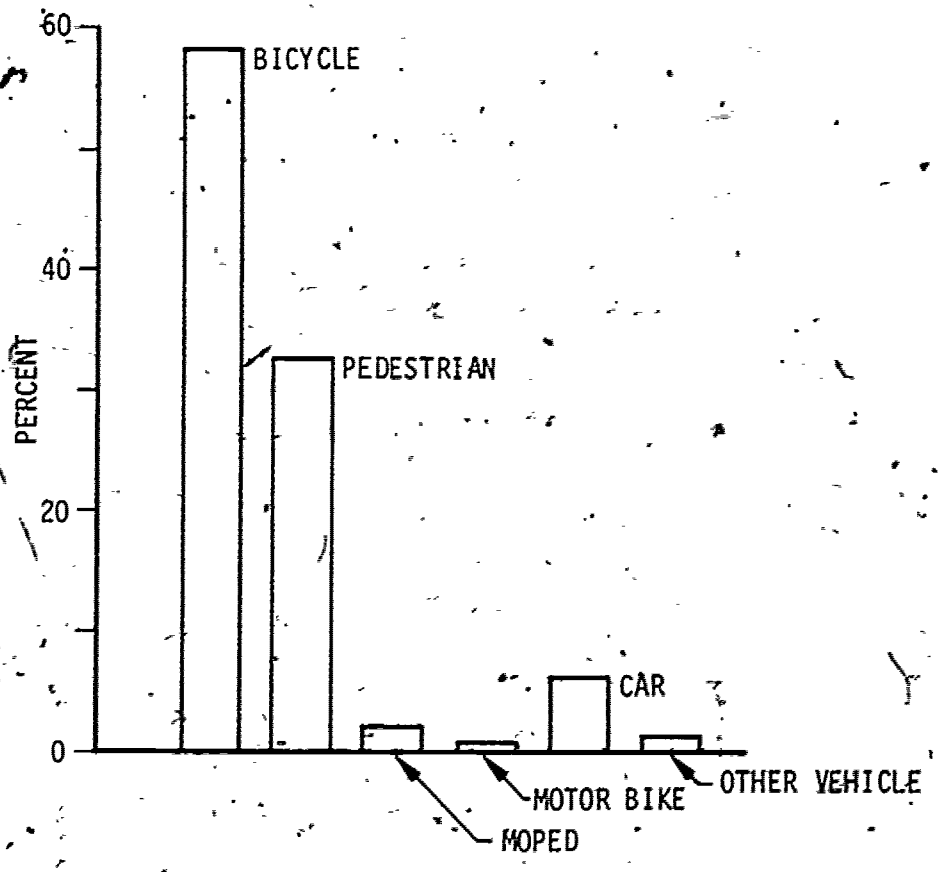


Figure 8. Traveling method of children injured in traffic accidents, Stockholm (Ref. 10)

These researchers classified accidents by types: turning over, those involving a private motor vehicle, another bicycle, other vehicles, and static objects. The "turning over" accident made up 43 percent of the total compared with 31 percent classified as collisions with private vehicles. And there were repeaters: 54 percent of those involved in turning over accidents had been previously injured.

Another source[11] notes that in Sweden, traffic accidents involving children follow a familiar pattern. There is an increase in pedestrian accidents until age 9 or 10 and then a gradual decrease; bicycle accidents start at about age 6 and increase through age 14 when children can ride mopeds. The moped accidents then predominate and increase "incredibly" until at age 18 the survivors can drive cars.

A thorough-going study of children's performance in traffic has been reported in Ref. 12. This research is focused on traffic accidents in Sweden during 1968 and 1969 that involved children through age 10. Source data were drawn from 1,906 accidents reported to the Swedish Control Bureau of Statistics. Because a previous study was unable to establish any difference between reported and unreported accidents, the data contained in this report are considered representative of all bicycle accidents. Concern was with "active road users," meaning children riding bicycles, walking, etc. Excluded are single bicycle or pedestrian accidents

and children injured as passengers in other vehicles. Again, boys were involved in more than twice as many accidents as girls.

Considering all traffic accidents, a peak is shown at about age 7 with the rate remaining high through about age 9 (see Fig. 9). Most of those injured were pedestrians: 1,204; bicyclists accounted for 625 of the victims. Seriousness of injury was about the same for cyclists and pedestrians but 10-year old cyclists were less seriously injured than were the younger cyclists. In the 0 to 10-year age group the risk of fatal injury is shown to be higher than for any other except the elderly group.

Perhaps of interest: 845 of the 1,204 pedestrian accidents occurred on stretches of straight road and 15 percent of all pedestrian accidents happened in crosswalks. In the latter regard it is of further interest that the majority of children stopped before proceeding into the intersection.

The total number of bicycle accidents (625) for boys and girls through age 10 is shown in Fig. 10. As shown, the accident rate is high for children in the 7 through 10 age group, averaging well above 70 accidents per 100,000 children for each age. Most of the accidents are characterized as having occurred when the cyclists and motorists crossed paths. In 280 instances, those involved were on intersecting courses. The second most frequently occurring accident has the cyclist swerving in front of the motor vehicle. Most commonly noted in the bicycle accidents, as well as in

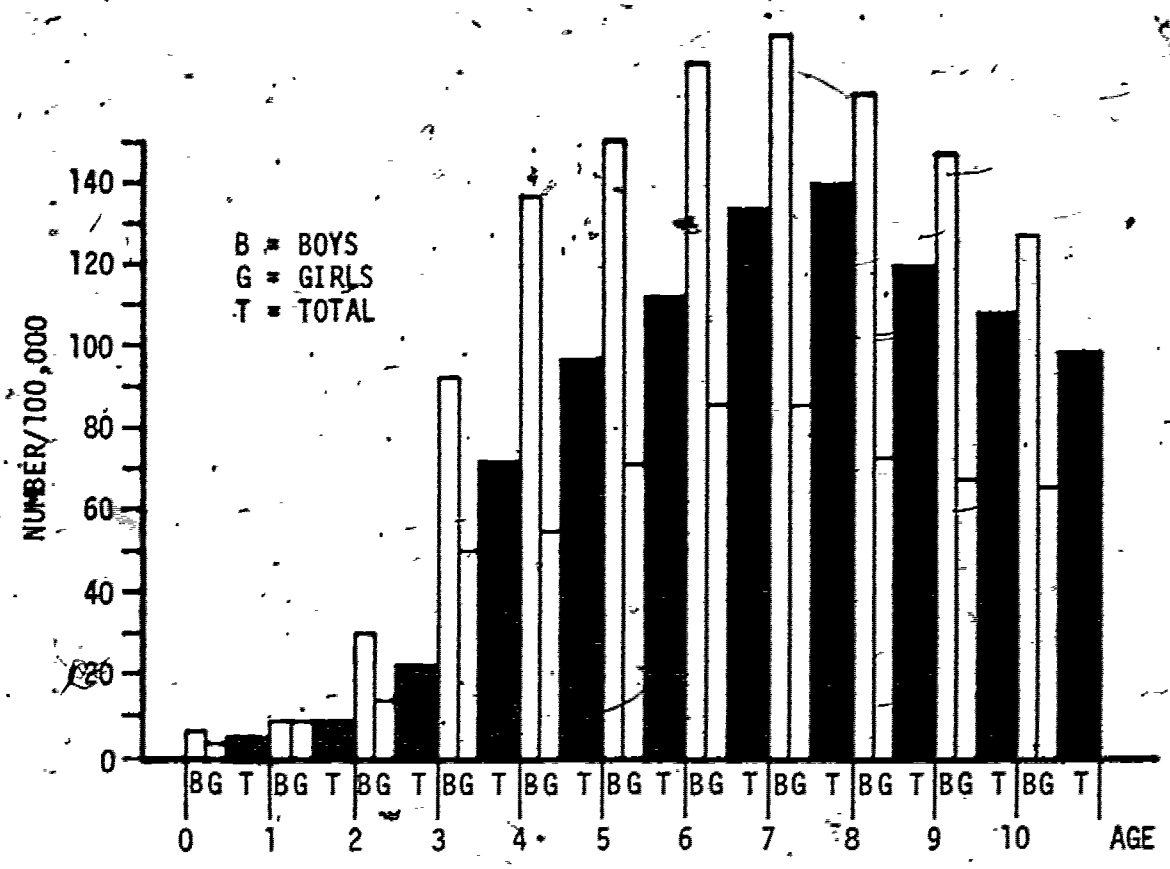


Figure 9. Traffic accidents involving children per 100,000 children of each age: Sweden, 1968 and 1969 (Ref. 10).

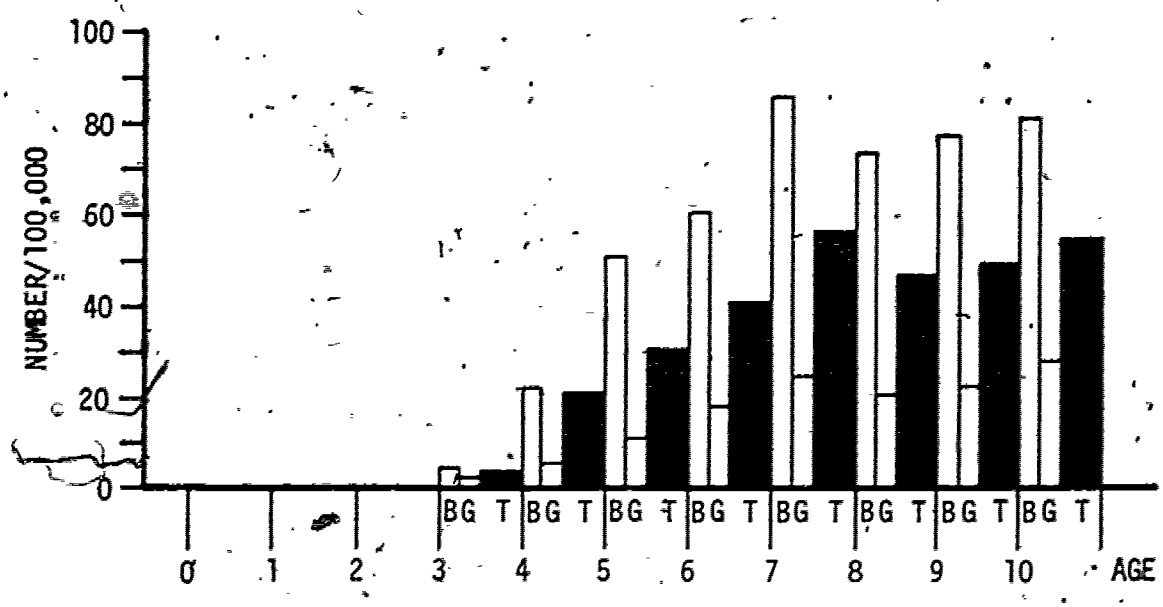


Figure 10. Number of bicycle accidents per 100,000 children in each age group: Sweden, 1968 and 1969 (Ref. 12).

those involving pedestrians, is the "dashing out" accident, defined to include those cases where the child suddenly appears in front of a motorist (e.g., exiting a blind driveway into the path of a passing car) and those cases in which, for reasons probably unknown even to himself, the child cyclist suddenly executes a maneuver which causes him to be struck by an approaching vehicle. The author's comment: "...the same age groups are always (internationally) involved in this type of accident as we have found in Sweden." About 55 percent of the bicycle accidents reported in this study involved the dashing out characterized by sudden emergence and 45 percent involved the unexpected maneuver or swerving. There is a general pattern which has the younger children involved in the 'sudden emergence' accidents with the older children more often caught up in the swerving type of accident. In Fig. 11, the children's behavior when the accidents happened is shown.

Figure 12 shows the extent to which visual obstruction was involved in the bicycle accidents studied. The obstructions comprise such things as parked and moving vehicles, hedges, corner buildings, etc. It is reported, however, that limited vision caused by other vehicles is far less frequently encountered in bicycle accidents than in pedestrian accidents.

These researchers also looked into the motor vehicle drivers in the accidents studied and report that the "youngest drivers, aged 18-22 years, were involved in the majority of the children's

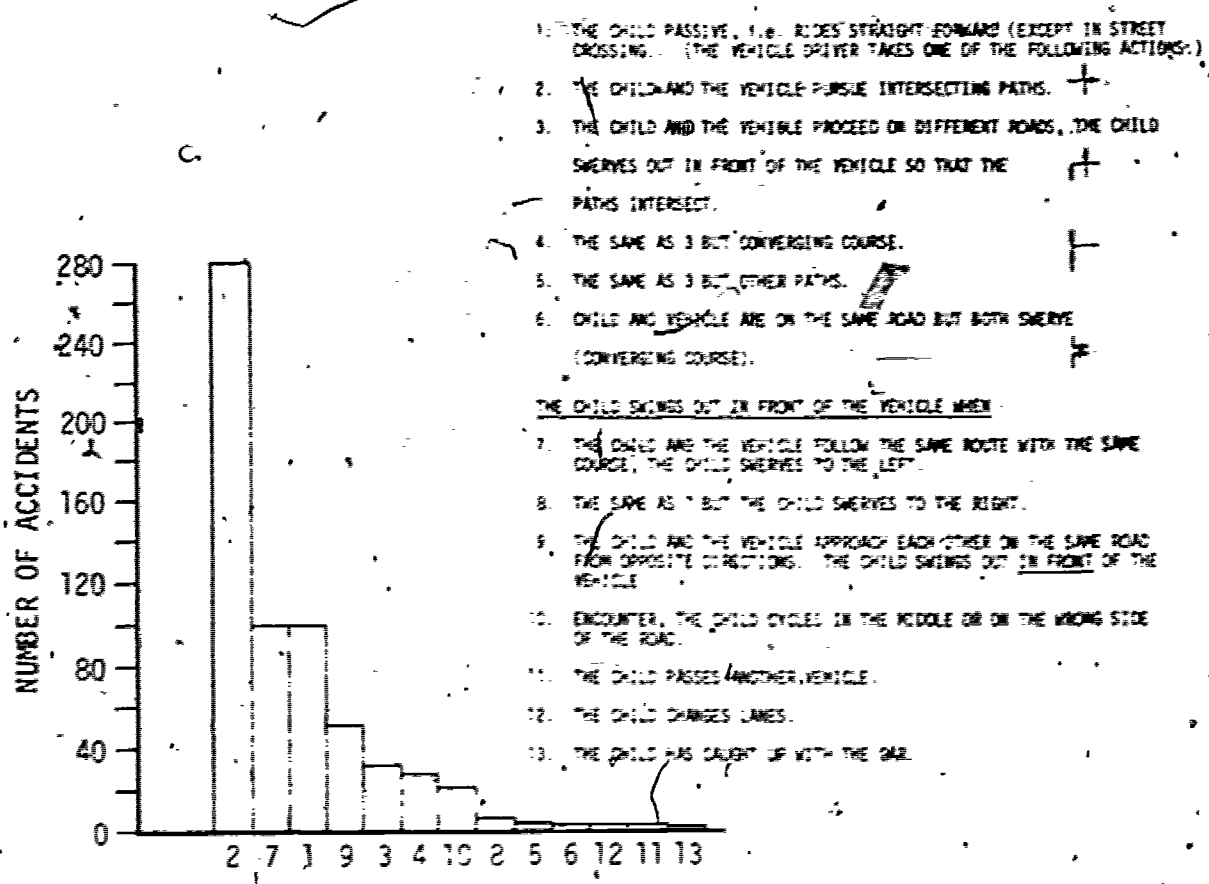


Figure 11. Child's behavior at time of bicycle accident: Sweden, 1968 and 1969 (Ref. 12).

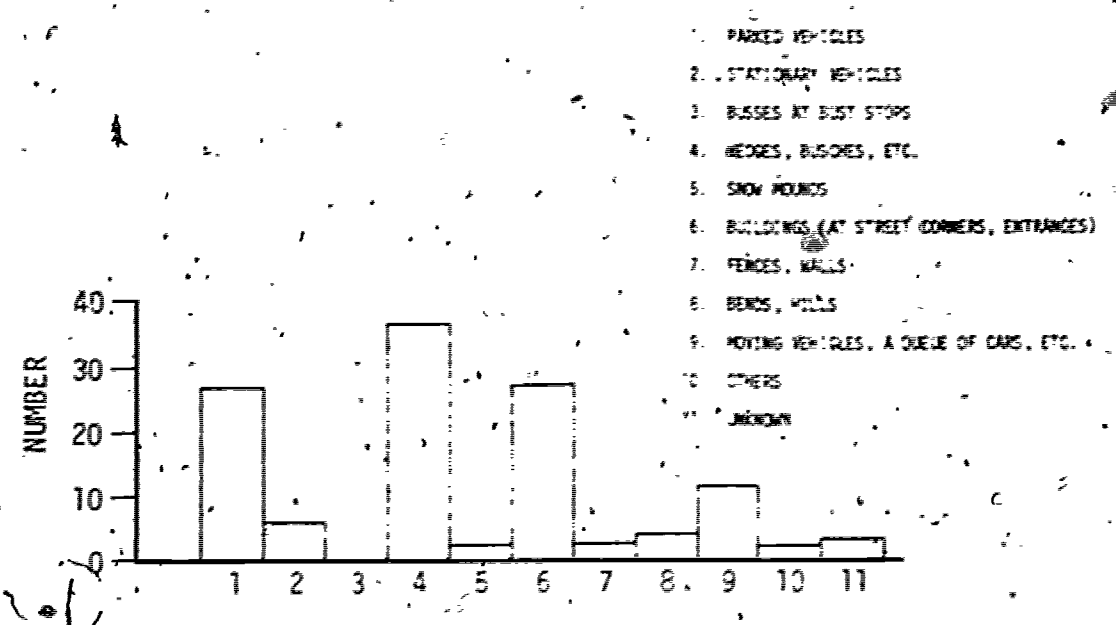


Figure 12. Visual obstruction as a factor in bicycle-motor vehicle accidents.

accidents taken up here." They also found drivers licensed one to five years more often involved than the new licensee or those who had been driving more than five years; most of the drivers were male. Interestingly, children injured by the younger drivers were more often seriously hurt.

Concerning the seriousness of injury incurred by the young traffic accident victim, statistics reported in Ref. 12 show a much greater fatality rate among children under 7 years of age. That study, of 768 accident victims admitted to the hospital, shows the fatality rate for those children to range from about twice to four times that of other victims ages 7 through 65. *There seems to be an indication that because of the nature of the traffic accidents involving young children there is an increased probability of serious injury;* perhaps in some way the unexpectedness of the child's behavior in traffic is a factor.

Referring again to Ref. 12, the under-7 age group is heavily involved in pedestrian accidents but bicyclists still make up a surprising 23 percent of the total injured. As noted in other studies, the bicyclist involvement increases with age, being, in this case, about 37 percent of the total accidents in which children 7 through 15 years were the victims.

In Great Britain, there has been a steady increase in fatalities among cyclists 9 years and under. In this age group there were 511 fatalities in 1961 and 796 in 1971. During the same

period, fatalities decreased in other age groups, especially in the 15 to 19 group which shows a decrease of more than 60 percent.[21] The significance of these figures is more sharply apparent when they are viewed in light of a constant and substantial (>50 percent) decrease in bicycle usage from 1962 through 1972. Usage figures of 5.8 billion miles in 1962 and 2.34 billion in 1972 are given.[22]

The hazards of bicycle riding in general are emphasized in other statistics pertaining to Great Britain which give death and serious injury rates for cyclists and drivers of all motor vehicles per 100 million miles traveled. (The changes shown from 1967 through 1971 occurred in a constant manner. The figures are from Ref. 21.)

Fatalities	1967	1971
Cyclists	13.4	16.0
Drivers	1.4	1.5
Serious Injuries		
Cyclists	180	204
Drivers	20	18

That is, in 1971, cyclists in Great Britain were killed at a rate slightly more than eleven times that of motor vehicle drivers and were being seriously injured at a rate just under eleven times that of the drivers.

The tragic proportion of the traffic accident problem, as it involves children, is neatly summarized in study data taken from

the records of eight countries.[13] *Expressed as a percent of all fatal accidents involving children* traffic accidents accounted for

26.5 percent of fatalities in 1-4 age group;

[illegible].8 percent in the 5-9 group;

35.7 percent in the 10-14 group.

Traffic accidents constitute 10-15 percent of all childhood accidents, result in 25-30 percent of all childhood hospitalizations caused by accidents, and produce 35 to 40 percent of all accidental deaths. Boys as always, dominate these statistics: they make up 63 percent of the injured 5-9 year-olds, 75 percent of the 10-14 year-olds, and 66 percent overall from 0-14.

Note should be made of some figures that show comparative accident data for various countries. As reported in Ref. 14, however, there are significant differences in the way accident statistics are compiled and one should be sure that figures being compared are in fact comparable. For example, the practice in the United States is to record as a traffic fatality anyone who dies, of injuries sustained, within 1 year of the accident. In Denmark, Germany, England, Norway, Sweden, Switzerland and the Netherlands, those who die within 30 days are recorded. In Italy, the victim must die in 7 days to make the statistics, within 6 days in France, and within 3 days in Austria. In Belgium we have the limiting case: dead on the spot or go uncounted. The figures shown in Table 3 are of interest. In this comparison, the United States

has the better record, the Netherlands showing a fatality rate nearly 2.5 times greater. Again, most of the victims among younger children are pedestrians with cyclists second in order.

	Fatalities/100,000
Netherlands	11.5
France	7.1
Italy	5.2
United States	4.7

Table 3. Comparative traffic fatality figures per 100,000 children in 0-14 age group: 1968 (Ref. 14).

2

THE CHILD: SOME THINGS HE CAN AND CAN'T DO

4. COGNITIVE DEVELOPMENT. The following is a brief description of some of the elements and characteristics of the cognitive development process as it occurs in children.

To attempt a brief characterization of children is a difficult task, one that could easily become mired in a multiplicity of terminologies, ideas, opinions, theories, interpretations, and sheer fancy. But the purpose here is limited to a look at some of the things we know about childhood development that bear on the study objective of passing judgment on the child's innate ability to cope with traffic. So emphasis is focused on the experimentally derived data that relate to the child's cognitive capacity as he moves toward maturity.

The principal hypothesis of the study is concerned with the proposition that at some age the child is developmentally unable to understand and interpret traffic laws, rules, and the traffic environment sufficiently well to function in that environment with acceptable risks of injury. As one would expect, there is no great abundance of data relating specifically to the issue at hand. Strictly speaking, there is probably little information--good valid information--available about child development. Man's knowledge of

the boy--as his knowledge of the man--is not all that good. As Piaget said, it is surprising how unrefined is the state of our knowledge of children's intellectual development.

Nevertheless, and thanks mostly to Jean Piaget, much more is known of the cognitive development of children than previously; enough certainly to give insight into the child's abilities and to justify interpretations of experimental data as they would likely affect a child's behavior in traffic. Much of what follows owes to Piaget and to those who have written further of his work.

One thing emerges unmistakably from a study of childhood development: the child is not a little adult, lacking only in knowledge and learning. Rather, throughout the first several years of life, his learning, his abilities, are limited by a still developing physical capacity to perform the cognitive functions. It is the nature of a child to perform as a child because he is incapable of any other performance. Adults fail to understand children--fail to know what can be expected of them--to whatever extent they fail to grasp the sometimes monumental differences in perception and conception that separate child and adult. Ignoring the limitations within which the child must function can result clearly in anything from adult-child misunderstandings to many tragic accidents.

5. SOME TERMS. It is usually agreed that all the characteristics and abilities a person possesses derive from the processes of maturation and learning, most often through interactions of

the two. *Maturation* can be defined to describe those changes that occur within the individual's body that are independent of environment or experience. Maturational changes are, therefore, organic or structural changes.

Learning, as are all these terms, is defined in a multitude of ways. A useful definition says *learning* is change--in behavior, performance, or ability--induced by or resulting from experience. Most would probably agree with Boyd McCandess, that maturation is essential to learning.

There is usually a distinction made between perception and conception. *Perception* is often taken to involve the organization and interpretation of simple sense impressions and, for Piaget at least, more mature perception is dependent on further neurological development and learning. *Conception*, on the other hand, or concept formation, usually has to do with the so-called higher mental processes and involves the discovery and definition of the critical features of objects or events, abstractions, and problem solving. Piaget used cognition as a collective term comprising all activities of the mind, such as thinking, remembering, and perceiving.

6. JEAN PIAGET. There are, of course, many points of view about child development. But both in terms of quality and quantity, perhaps no other researcher has even approached the output of Jean Piaget, the Swiss scientist. Educated in natural science, Piaget

regards himself as a geneticist whose main interest is in the development of knowledge. His work with the cognitive development of children was begun in 1921; it is comprehensive beyond any other in the field (he is the author of about 30 books on the subject).

Jean Piaget is described as "one of the most influential of living thinkers."[16] His ideas about the development of cognition in children are affecting research, curriculum planning, pre-school programs, and many other areas of psychology and education. Above all, his studies help us to understand how children perceive the world and to know therefore what to expect of them.

Piaget has conducted countless experiments with children. His work is thoughtful, the design of his experiments brilliant yet simple. "Today, fifty years and many followup studies later, Piaget's ideas have been pretty well corroborated."[16]

Based on his extensive research data, Piaget has produced a pattern of childhood development that is characterized most importantly by three periods. Although discussed in terms of precise stages the development he describes is, of course, a continuous process, one phase merging with the succeeding.

7. PREOPERATIONAL PERIOD. Ranging from about 2 to 7 years, the preoperational child's performance is characterized by his intuitions--often illogical--based on his perceptions of the world around him. In this development stage the child progresses from

the simple sensory-motor activities of infancy to the use of language and other symbolic manipulations. His thinking at this point must rely solely on often faulty perceptions.

8. PERIOD OF CONCRETE OPERATIONS. From age 7 to 11 or 12, the child becomes able to function in thought but his range is limited to those "concrete" objects with which he is in contact. He can do some logical thinking, and can start rejecting some of his previously accepted fallacies which were the result of unquestionably accepting surface appearances. But he still cannot work with abstractions, such as verbal propositions. His reasoning at this point is only elementary at best.

9. PERIOD OF FORMAL OPERATIONS. This final developmental period, starting at age 11 or 12, sees the beginning of the child's ability to think about thoughts, to "operate on operations." The child's developing intellect can think in generalities that he reasons to from specifics, he can deal with the *form* of reasoning separately from its content. This is why the period is called that of "formal operations." At this stage the adolescent can handle the idea of proposing hypothetical solutions and can reason about what would the results be if the hypotheses were true. The operational child can move back and forth in time and space, which makes all the difference.[17] In short, he has probably attained his intellectual capacity as it relates to development; lacking now is experience.

10. CONSERVATION . . Piaget did a great deal of experimental work in an effort to demonstrate the nature of an ability he calls *conservation* and to show that it could act as a discriminator in defining levels of cognitive development. Conservation refers to the ability to understand that certain attributes of a substance are unvarying, even though there may occur superficial changes in the substance's appearance.

In one series of experiments, children were shown two clay balls which they understood to be of equal size. The shape of one ball was then changed--before the children--into a cylindrical mass and the children then questioned about the amount of clay in each shape. Results consistently pointed up the child's inability to grasp the idea of constancy or conservation that seems so obvious to the adult. Most children in the preoperational stage of cognitive development think the cylinder contains more clay than the sphere because the cylinder is longer. Even though the experimenter returns the cylinder to its original shape and repeats the procedure, the child will still insist that the cylinder contains more clay. At some point in his cognitive development the child will start to notice that an increase in the length of the clay cylinder is accomplished by a decrease in its diameter and he may then decide that the cylinder contains less clay than the sphere. Eventually, he comes to realize that a relationship exists between the dimensions of the clay objects as their shape is changed. When able to note consistently that changes in length and diameter

go together the child has progressed to the period of concrete objects.

> *"This conservation of substance is simply a logical necessity. The child now understands that when there is a transformation you come back to the point of departure and once again have the ball. He knows that something is conserved but he doesn't know what. It is not yet the weight; it is not yet the volume, it is simply logical form...a logical necessity. There, it seems to me, is an example of progress in knowledge, a logical necessity for something to be conserved even though no experience can have led to this notion."*[16]

The inability of the preoperational child to note the constancy of substance in these experiments demonstrates the lack of an ability called reversability, or the ability to follow a series of size or shape transformations and then think back to the original. This preservation, in thought only, of the original is not possible for the younger child.

Having reached that point in his cognitive development where he is able to deal with the conservation of substance, the child still does not understand that the related characteristics of weight and volume are also conserved. Interestingly, experiments show that the cognitive development associated with these ideas of conservation of substance, weight, and volume always occur in that order, that is, in the direction of increasing complexity. Not until age 11 or 12 can most children demonstrate an accurate understanding of the conservation of volume.

Experiments have also been carried out in an effort to change the order in which these particular cognitive functions appear. That they have been unsuccessful is taken as *evidence that the levels of cognitive development as established experimentally are real stages of what can be called maturational advances prerequisite to the concepts of conservation.*

This same developmental order of the conservation of substance, weight, and volume, has been shown to occur in other cultures although there may be an age displacement. For example, a delay of about 4 years in the attainment of these concepts has been observed among subjects in Martinique.

Piaget thinks it possible to 'teach' children some of these concepts but feels they would only be learning correct answers to a limited experimental set of stimuli and that real learning would not occur. In fact, children so instructed would rapidly revert to those errors consistent with their developmental level. *This because the logical structures necessary to an understanding of the concepts involved simply are unavailable to the child* until he reaches the necessary level of cognitive ability.

The importance of the preceding experimental data lies chiefly in what they imply for educators and others who try to hurry up these stages of cognitive development. *These experiments have been repeated by others in other places and the reliability of the*

results certainly indicates that limiting factors do exist which must be considered if we are to intelligently gauge the capabilities of children at various ages.

Children's inability in these matters can be demonstrated in any number of ways. Even though the child himself pours out equal amounts of liquid into tall slender containers and wide, flat ones, he will insist that the tall containers hold more liquid. Try convincing children that equal portions of a treat, cut into unequal parts, are equal. They will insist that the portion cut into five pieces is more treat than the same portion cut into three pieces. Again, these basic phases of the developing cognitive ability, changing toward the grasp of more complex forms, have been well established.

In a similar fashion, experiments show the development of conservation of number and length. The pre-operational child will say that of two equal lines, one displaced to the right, that the one extending to the right is the longest. He is also unable to grasp the greater length involved in an undulating line when compared with a straight line so long as the lines being viewed begin and end at the same points:

On the other hand, once he has acquired the intellectual or cognitive maturity necessary to this kind of understanding he is

never again fooled. As one boy is quoted: "Once you know, you know for always."

11. SPEED CONCEPT. Following his extensive experiments with children in his efforts to describe the cognitive development essential to the ideas of movement and speed, Piaget concluded: *"The concept of speed as a relationship between distance traversed and time passed does not begin to appear in children until nine or ten years of age."*

Piaget designed many experiments to learn how well the child can deal with the simple order of objects on which the most basic ideas of speed and movement are premised. So it is that a simple recognition of the order of a series of positions is essential to the concept of speed.

In studies of children and their ability to assimilate the ideas of order, several experiments were formulated that had to do with the alternate directions of travel of balls moving down an incline, passing out of view through a tunnel, and emerging on the other side. Using three balls of different color, referred to here as A, B, and C, the experiment posed a series of different directions of travel; the children were then questioned about the order of the emerging balls.

For example, if the balls moved from right to left in the order ABC, most children 4 to 8 years of age *could* successfully

predict the ABC order of emergence from the other side of the tunnel. But preoperational children could not predict the order if the ABC balls were allowed to reverse their path and move through the tunnel from left to right.

Although this reversal appears simple, because the child sees such reversals frequently in his experience, they simply cannot anticipate the emergence order of CBA. The child's reasoning, however, seems to consist simply in retracing, by the act of representation, events just as they were perceived, instead of imagining an alternative or reversal."

After mastering this part of the experiment, the children were moved to the other side of the table and again questioned about the order of the balls (which had remained in the tunnel) as they emerged. The children had learned that when the balls in order ABC moved from right to left that A always appeared first. In their new position, the children could not understand that the order of emergence, with the balls ordered ABC would have C the first to appear when the balls moved from the right to the left. *Children, instead of reversing the order, seem able only to understand the relative direction of travel.* That is, the child "does not reason in terms of direction of travel in relation to the tunnel but in terms of static indications of which he simply records the absolute results."

Further demonstration of the child's limited intuitive thought, rather than operational thought (characterized by logical thought

processes which are reversible) is gained by other experiments of this kind. If the tunnel is rotated 180 degrees, with the balls inside and in an order known to the child, the child does not change emergence orders; he doesn't even consider tunnel rotation in trying to predict the order. Neither can he grasp what happens when the tunnel is rotated 360 degrees, even after he know the result of the half rotation.

Again, if the child were capable of operational thought he would see the 360 degree rotation as a return to the original position. But thinking intuitively he only knows that each half turn causes a change in the emergence order. Throughout these alternate direction of travel studies, the younger children are often seen to think that of the three balls ABC even B can emerge first, this even though they clearly understand that the tunnel allows for no passing.

Piaget conducted many experiments concerned with relative motions in which children were questioned about distances traversed by a toy animal moving along a strip which itself could be moved, either in the same or opposite direction. Again, the younger children cannot grasp many of the concepts involved.

Change of location studies clearly show that in perceiving movement of an object, or themselves, from one position to another, the thinking of younger children is dominated by consideration of the point of arrival. The child pays little if any heed to the

path taken in moving from one position to another. That is, the child views a change of position strictly in terms of the goal. Moreover, the way in which these perceptions of position develop has been experimentally shown to be fairly constant among children. First, they consider only the point of arrival; next, they become concerned with point of departure; and lastly, they think about the path traversed. The adult's intuition considers the path of the movement as basic to the change of position.

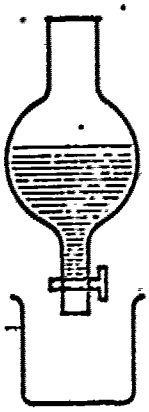
Various other studies with toy cars moving at different speeds but along parallel courses, so that one overtakes and passes the other are considered to show that children intuitively are able to think of speed only as an order among positions. In these studies children think the cars are moving with the same speed, for example, if they are both stopped at the same time, even though one car has obviously moved up from the rear of the other, passed it, and pulled on ahead. "It is as if the child judged speed by the finishing point alone, regardless of distance traveled."[17] In cases where the ratio of speeds between the two cars was increased to as much as six to one, younger children might say that one traveled faster but because that thought was inconsistent with the intuitive reasoning available to him, he would soon return to his original error; that is, even in the case of such an obvious speed differential, there is no real learning. Children are especially unable to perceive relationships between movements unless the movements occur together; if they occur in succession the relationships are lost.

The picture of the child that evolves from these studies is one of inability to understand because of an actual lack in cognitive development. Velocity as an expression of distance traveled in a given time requires a sophistication of cognitive ability of which the child is not capable until about the period of formal operations--perhaps 11 or 12 years of age. Rate problems in which the child must master the idea of rate × time = distance are therefore beyond the capability of most children until the fourth grade level.

12. TIME CONCEPT. There is a commonality between the concepts of time and speed as pointed out in Piaget's work. Both require a concept of order: speed is an order of positions and time, an order of events. It follows that the concepts of speed and time would develop along parallel courses and not really be stabilized until the child can reason operationally--at about 11 or 12 years of age.

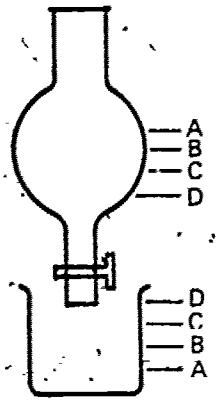
Piaget's time experiments were designed on the premise that a concept of time involves two things: (1) the order of succession of events; and (2) the duration of time intervals. To study the child's ability to handle the idea of the order of succession of events, he used a setup as follows:

In these studies, children were furnished several sketches of the apparatus shown here and asked to color in the changing levels as



the experimenter released fixed amounts of water from the flask. Following several releases, each of which was observed and recorded on a new drawing by the children, the sketches were mixed up. The task for the subjects was the proper reordering of the sketches with the lowering flask level corresponding to a rising level in the bottom container. Younger children—preoperational children—could not rearrange the sketches. The results prompted Piaget's comment that a sequence of perceptions does not necessarily mean there has been a perception of a sequence. When each sketch of flask and bottom container was separated and the children asked to rearrange them, they were either unable to do so or had great difficulty in complying until about age 9. Note that this task involves a double series of events: first, the proper relation between top and bottom portions of the sketches and then the arrangement of the sketches in the proper order of quantity in flask and container. This ordering of a series of events is considered a prerequisite to the construction of time and not a consequence of it.

The same kind of apparatus was used in studies of the duration of time intervals, or as it can be interpreted, as a study of the inverse relationship between time and speed. In this case, the flow intervals, of liquid from flask to container, were equal, but



the flow level in the flask, because of its shape, did not drop in equal vertical segments. On the other hand, the level in the bottom container would increase in equal stages. Preoperational children think that the intervals accompanied by the greatest drop in the flask level also took a greater time. At the concrete operational stage of cognitive development, that is ages 7 to 11 or 12, there is the dawning of the inverse relationship involved, and finally the formal operation's child can figure out the equality of the experimental time intervals.

Younger children consistently think that a direct relationship exists between speed and time. In several experiments, where they could observe the hands of a clock while performing some experimental task, they regularly equate rapid movements on their part with faster turning of the hands. Because of the logical operations necessary to the idea that successive and equal time durations are reflected in equal movement of the clock hands, most children cannot tell time until about age 8, at least not with any real understanding.

13. DISTANCE CONCEPT. That the child is at a disadvantage when judgments of length and distance are required has also been demonstrated experimentally. For example, if shown two objects

some distance apart, the child will think them farther apart when viewed with no other object between. Again, if shown rods of equal length and agreeing to their equality, the preoperational child will think one rod longer if it is moved to project ahead of the other. In other standard experiments, aimed at studying perception of length, object B will be seen as larger when shown with A -- if the two objects stand as A < B -- than when seen alone. There is a twofold significance in this perceptual error: (1) it is evidence of *systematic* errors of perception, the recognition of which helps explain why children have difficulty in performing certain tasks; and (2) it serves to remind us that adult perception is highly developed and refined as the result of years of experience and that *things simply don't look the same to a child as they do to an adult.*

14. THE CHILD IS EGOCENTRIC. Much insight of what a child is, what he expects, and what can be expected of him, can be had once it is understood that the child thinks the world was made for him, that it shares his feelings and desires, and, what's more, that he can control the whole thing.

It is not within the province of childhood capability to understand how things are from another point of view. Studies in which child and experimenter view a scene from opposite points consistently show the child unable to select correctly pictures showing the experimenter's view.[16] Even if he leaves his side of the experimental scene and takes the experimenter's place he still can't

visualize the view from the position he just left. In other studies, children have been asked to draw simple scenes in which they are asked to show the basic position of an object as seen from another point of view; until 7 or 8 years of age, they have little success. Some feel, Piaget among them, that it is probably not until age 10 that most children can properly handle (with marginal accuracy) problems posed by changes in perspective.

The concept of right and left is not fully mastered by most children until age 9 or 10, and even then they (and indeed many older persons) are unable to respond correctly to a left-right question if the response must be made without hesitation. But once he can demonstrate that he knows right from left, he is still unable to identify right and left for a person facing him. *That is, a child has great difficulty in trying to put himself in another's position.*

Likewise, children cannot understand how others feel; they will pester mother even though she explains she doesn't feel well or must do something else. This characteristic of childhood--a sort of perfect egocentrism--pervades everything children do. A child's story or relation of events are often unintelligible because of his indiscriminate use of unrelated pronouns. He assumes that the listener knows the story as well as he. Unable to think in terms of another's position he *"assumes that all the world shares his thoughts and feelings and that therefore he need not explain them."*[17] For this

same reason, the conversations between children seem to run on in parallel with precious little communication taking place.

This simple fact, that children think we as adults know what's on their minds without explanation, together with their inability to view themselves as others see them, has obvious and significant impact on the whole issue of child traffic safety.

15. RULES CONCEPT. Piaget has observed that until the age of seven or eight years, the developing child has little awareness of or use for rules. As he develops, the child subsequently becomes keenly aware of rules and even looks upon them as edicts of God or parents.

An interesting transformation in this respect then takes place at about age 10: instead of some sacred orders to be accepted without question, rules are viewed as something to be changed at will, especially if there are other children concerned who agree to the changes.

Again, the younger children are simply unaware of a need for rules in their games. They will play as if they knew the rules, but are in reality doing little more than going through the motions.

So there is among younger children an unawareness of any need for rules and a failure to understand them, and on the other hand a substantial respect for them. Later at about 10, the child views rules as arbitrary constraints, readily changed or broken if

his peers agree. Another source reports that not until age 11 or 12 do children develop stable and refined rules in their games.[18]

An important and reasonable conclusion drawn from the investigation of children and rules: if children neither demand nor understand rules in their games, which engage their attention so thoroughly, it seems "...as if the complicated traffic rules should not either be possible to comprehend and to follow below the same age.[18]

3

THE CHILD IN TRAFFIC

16. THE ENVIRONMENT. The traffic environment was created by adults for the use of adults.[18] It has been described as perhaps the most complicated and difficult environment in which most *adults* will ever be required to perform. Not surprisingly, much of that environment is beyond the developing understanding of the child. He is simply overwhelmed by its magnitude and multiplicity of objects and motions. Expressed in terms of his cognitive development, the child undoubtedly lacks the logical structures necessary to a meaningful grasp of the many-faceted activity that is traffic.

17. PROBLEMS OF THE CHILD IN TRAFFIC. Riding a bicycle demands the entire attention of the child. Lacking a mature coordination system, and astride an unstable vehicle, the child must concentrate on simply maintaining his position on the bicycle.[12] Unable to divide his attention, this concentration is usually accomplished at the expense of the child's awareness of the traffic around him. Mounted on a vehicle noted for its instability, especially at lower speeds, operating with immature coordination, unable to fully understand the traffic in which he moves because of cognitive deficiencies, to say nothing of the multitude of childhood behavior characteristics that ill-equip him for his role, the child bicyclist is off to a bad start.

18. THE CHILD PLAYS . Perhaps above all else, the child is by nature a creature given to play--one who interprets and evaluates most everything in his immediate environment in terms of its usefulness as a plaything. He is, in his actions, undivided of attention. When he plays, he plays wholeheartedly, concentrating only on his play. And play to the child is often expressed in sudden and violent physical motions.[18] It is not surprising that so many traffic accidents involving children result from a motorist's inability to respond to some totally unexpected behavior on the child's part.

19. TRAFFIC SIGNS . There has been research aimed at learning more about the child's interpretation of specific traffic requirements. In one such study[18] children in the 4-10 age group were evaluated in terms of their comprehension of common traffic signs. The findings show age to be the most important single factor affecting the understanding *but in no age category were all children able to correctly identify any one sign.*

20. TRAFFIC INSTRUCTIONS . Instructions are difficult for children; in fact many adults score poorly when it comes to following instructions. But at least, *most* adults are *capable* of taking instructions; perhaps the child is not.

If we assume that instructions are unambiguously given, it follows that our comprehension of them and subsequent reactions to them, are determined primarily by our language ability, other

things being equal. And the child's language ability, both in light of accuracy of interpretation and completeness of logical structure, is seriously incomplete.

Traffic instructions, it follows, would be expected to present real difficulties for the child. He brings to such instruction his lack of real interest, his likely inability even in the most basic way to understand the flow of traffic, plus his limited facility with the language in general and the jargon of traffic in particular. Words are not as clear in their meaning to children as they are to adults; meanings for them are often obscure. It is probably always difficult, and often impossible, for an adult to accurately gauge the meaning a child assigns to a word, a sentence, and therefore, to even the simplest instruction. Viewed in this way it is less surprising to see the "traffic-trained" child dutifully stop before crossing the street, then dash in front of on-coming traffic. He wasn't really looking for the traffic in the first place because he doesn't really understand what it is he's being careful of and is only, in his properly child-like way, doing what he was told.

21. WHICH IS RIGHT ? We have seen that a reasonably clear idea of the fundamental right-left concept is not well established until about age 9 and likely is not a reflex sort of thing until much later. It is, for example, a fairly common observation that a real differentiation of right and left, when considered in terms of a fast reaction time, is lacking in many adults.

The tests, conducted in the determination of the age at which the right-left idea emerges, measured children's responses in a relatively easy indoor environment. How well would these children perform if we were to measure their responses in a busy traffic situation, replete with the confusion of many and rapidly moving vehicles, noise, and dozens of unnamed distractions? What if the child's safety in the latter environment depended on his almost instantaneous and correct interpretation of the question: which way is right?

22. SYNTHESIS OF PERCEPTION. Children are bewildered by traffic, as reported in Ref. 18. Perhaps this is because the child brings to the traffic environment his perceptual inadequacies in general and those related to his perception of details and unity among details in particular. The child does not, for example, view even a simple figure such as a cross as having a structural unity; he perceives it rather as four individual lines sharing a common point of origin. It is only later, after further maturation and learning that children can at once perceive the details as well as the unity of a given object or scene. Again, it is because of this cognitive inability that some researchers (notably Ref. 18) think the child is so overwhelmed, especially at intersections. Adults who understand traffic control and flow at intersections, regard the scene as one of sense and order; the child sees an incomprehensible confusion of cars moving in all directions. No wonder children prefer to cross streets in mid-block where they feel more secure.

23. WHAT THE CHILD SEES. What the child sees is emphatically not what the adult sees in traffic. His size is a limiting factor, relegating him to a clear view of wheels and other things that share his nether view. And obviously, when the child's view is obstructed, so is the motorist at a disadvantage in visually picking up the child.

As noted elsewhere, the child is also denied, because of his inexperience, the important adult ability to sense an intimation of something and then complete his mental picture of the probable situation by supplementing it with details learned over many years. The subtlest of stimulus, one that would pass unnoticed by most children can, therefore, produce for the adult a complete set of the most probable accompanying circumstances for his instant review and subsequent reaction. In this regard, other studies[18] have shown that children's sensory abilities (sight and hearing) do not at all compare favorably with those of adults when measured in the traffic environment. It is not a matter, of course, of keenest of senses but most likely one of the child's inexperience that causes the observed differences.

24. TRAFFIC BEHAVIOR. Perhaps not totally unlike his adult counterparts, the child knows better than he performs in traffic. The important difference is the child's evident inability to perform in a manner commensurate with his knowledge level--probably because he doesn't really know or understand the traffic rules he can be taught to recite.

One investigator reports that when children were observed in traffic and their behavior recorded periodically during the day, the results showed only that there was complete inconsistency of behavior. A child rated excellent on one observation was rated lowest on another. What was demonstrated was complete unreliability. That what a child can presumably demonstrate as knowledge of traffic rules is not a determinant of his traffic behavior is also clear. Boys in these studies knew more about traffic than girls but behaved worse.

4

THE PARENTS' VIEW

25. PURPOSE. As noted previously, this feasibility study of a minimum age requirement was one recommendation derived from an analysis of bicycle-motor vehicle accidents.[4] Although there was little doubt that study findings had focused attention on the young cyclist as an especially acute aspect of the bicycle accident problem, there was recognition too of the possibility that any age requirement--regardless of supporting evidence--would be rejected out of hand by parents. There would exist, obviously, the practical implications for those whose children rode bicycles to school and the possibility as well that indifference, springing from an unawareness of the special risks accompanying the child in traffic, would generate a significant opposition.

Consequently, a survey of parental opinion was undertaken to provide, at least to some extent, a measure of probable reaction to the minimum age idea by those who would be most affected by it: namely, the parents of elementary school children.

26. SURVEY INSTRUMENT. The survey form used in the survey is reproduced in Figs. 13A and 13B; it was printed in Spanish as well as English to accommodate a large local Mexican-American population.

28 January 1974

Dear Parent:

A recently completed study of Santa Barbara bicycle accidents disclosed a tragic fact: children under 13 years of age make up only about 8 percent of the bicycle riders but are victims in more than 30 percent of the bicycle-motor vehicle accidents.

There is good reason to believe that young children are *unable* to fully understand the basic traffic rules, even though they receive repeated safety training. That is, we are likely expecting our children to do something of which they are not yet capable when we let them ride bicycles on public roadways.

As part of our on-going research, we are asking your opinion about the idea that an age be determined below which children would not be allowed to ride bicycles on public roadways. Evidence shows that such a requirement would substantially reduce the number of serious accidents involving children bicyclists and motor vehicles.

Would you take a moment now to help us by answering all the questions below and having your child return this letter to his classroom teacher tomorrow?

Thank you for your cooperation,

Lloyd N. Popish, Researcher for
Santa Barbara Bicycle Safety Study

1. How many children do you have who are between 5 and 13 years of age? _____

2. Do you think the bicycle is a *necessary means of transportation* for those children? Yes ____ No ____

3. Have any of your children been involved in a bicycle-motor vehicle accident? Yes ____ No ____

4. How old do you think a child should be before riding a bicycle on public roadways? ____ years

Figure 13a. Survey instrument

Estimados Padres:

Recientemente se completó un estudio acerca de los accidentes de ciclismo en Santa Bárbara, y se descubrió un dato trágico: solamente el 8% de los niños menores de 13 años viajan en bicicleta, pero de éstos el 30% son víctimas de accidentes ocurridos entre bicicleta y vehículos motorizados.

Existe una buena razón para creer que los niños no están capacitados para comprender y obedecer las reglas de tránsito, a pesar de que reciban repetido entrenamiento. Eso quiere decir, que esperamos que los niños desempeñen actividades para las que no están todavía preparados cuando les permitimos conducir su bicicleta en la vía pública.

Para continuar con nuestra investigación, necesitamos su opinión acerca de la idea de establecer una edad determinada para que los niños puedan andar en bicicleta sin peligro. La evidencia muestra que esta medida de seguridad ayudará a reducir el número de accidentes serios entre los niños en bicicleta y los automóviles.

Se les suplica que nos ayuden, contestando todas las preguntas del cuestionario que se encuentra en la parte inferior de esta hoja, y que la envíe con su niño, mañana mismo, para que se la entregue a su maestro.

Muchas gracias por su cooperación.

Lloyd N. Popish, Investigador
Santa Barbara Bicycle Safety Study

1. ¿Cuantos niños tiene Ud. entre los 5 y los 13 años de edad? _____

2. ¿Piensa Ud. que la bicicleta es un medio de transporte indispensable para sus niños? SI _____ NO _____

3. ¿Alguno de sus niños ha sufrido algún accidente entre bicicleta y automóvil? SI _____ NO _____

4. ¿Cúal es la edad que Ud. considera sea la mejor para que el niño empiece a manejar su bicicleta en la vía pública? _____ años

Figure 13b. Survey instrument

Kept brief to encourage response, the questionnaire asked only four questions: one relating to the number of younger children; another about the necessity of the bicycle as a means of transportation; a third about accidents; and lastly the one about what the minimum age should be. A predominantly low-age response would indicate an unfavorable reaction, a high-age response would suggest basic approval.

27. SURVEY DISTRIBUTION. As originally conceived, the survey was to be distributed to a limited sample--about 500--of parents with children enrolled in Santa Barbara's elementary schools. The sample was expanded, however, and survey forms were distributed and 1300 responses obtained. The cooperation of school officials and classroom teachers made the survey possible and undoubtedly accounted to a large extent for the unusually high response ratio.

The sample comprised nine public elementary schools: McKinley, Wilson, Roosevelt, Lincoln, Franklin, Cleveland, Adams, Washington, and Peabody; one parochial school, Our Lady of Mt. Carmel was also surveyed.

28. AVERAGE AGE. There were 1,373 survey forms returned, most of the respondents answering each of the four questions. The overall average age chosen was about 11 years. There were 309 responses in favor of an age under 10 years, and 323 named an age greater than 12 years. There was a total of 1,264 replies to the question asking what the minimum age should be. Represented in the

total 1,373 replies are the parents of 2,764 children between 5 and 13 years old, the ages likely to be affected by implementation of a minimum age requirement. The distribution of responses to the minimum age question is shown in Fig. 14 in which the number of responses in relation to the various ages has been plotted. As shown there is a high secondary mode at age 12.

Among the respondents there were 107 who completed the Spanish-language form. This group chose an average age of 12.5 years, significantly higher than the overall average. Neither did they select any of the very young ages: there were 25 choices of ages under 7 years for the entire group, none for this Spanish group. Furthermore, about 58 percent picked ages greater than 12 years, compared with an overall survey figure of 25.6 percent.

29. BICYCLE AS TRANSPORTATION . One questionnaire item asked the parents if they considered the bicycle necessary as transportation for their young children. There were 1,373 responses to the question with a surprising 1,059 negative replies; that is 77.2 percent do not think the bicycle is necessary, 22.8 percent think it is.

The replies indicating the bicycle to be essential as transportation were further analyzed to see what effect, if any, this group had on the overall survey results. Of the 314 affirmative replies, 275 made a minimum age choice.(the remainder chose no particular age, a greater no-response to the age question than obtained

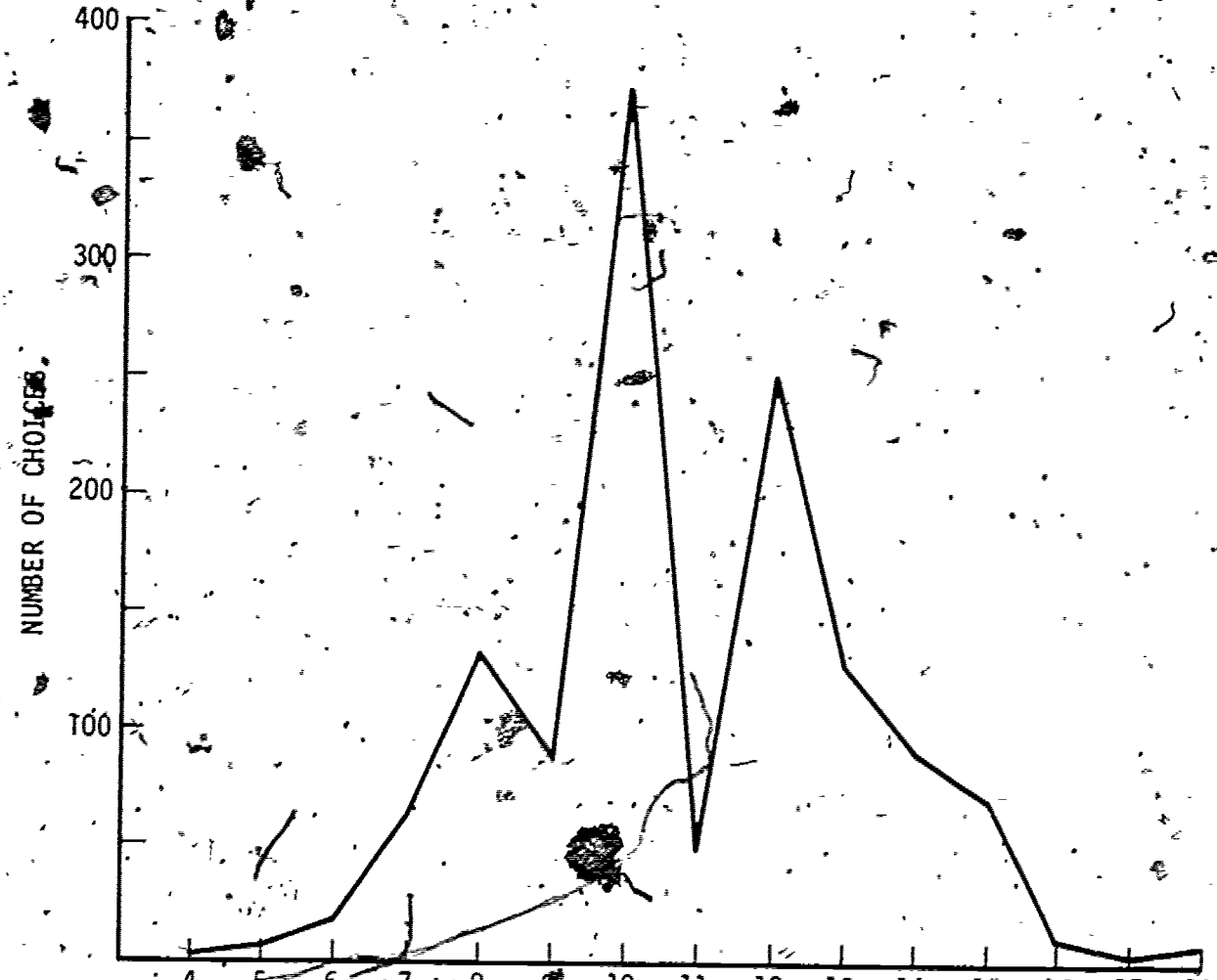


Figure 14. Parental selections* of minimum age from 1,264 survey replies.

*All parents in sample have children in the 5 through 13 age group.

for the entire sample). Significantly, the average age selected by those for whom the bicycle is deemed necessary as transportation for their children drops to about 9 years (9.2 years). Of interest, of course, is the possible effect of practical necessity on the chosen minimum age rather than a simple concern for a child's safety.

It is interesting, too, to see how the choices of the bicycle-is-necessary group were distributed when expressed as a percent of the total responses choosing some particular age. For example, there were 1,264 responses to the age question. Of those, 14 thought the minimum age should be 6 years; 73.6 percent of those selecting age 6 were members of the bicycle-is-necessary group that represents 22.8 percent of the sample population. Data for the other ages are shown in Table 4. In terms of total responses, 303 chose an age 6 through 9 years; about 47 percent of those choices were made by 22 percent of the respondents (the bicycle-is-necessary group).

Age	Sample, N_s	Bicycle Necessary, N_b	N_b as Percent of N_s
6	19	14	73.6
7	61	38	62.4
8	133	56	42.2
9	90	35	39.8
10	377	75	19.9
11	47	10	21.3
12	227	20	8.7
13	130	17	14.1
14	86	4	4.6
15	73	1	1.4

Table 4. Minimum age choices of those for whom the bicycle is necessary (22.8 of sample) expressed as percent of total responses

30. ACCIDENT RATE. Another survey question asked parents: How many of your children have been involved in a bicycle-motor vehicle accident? There were 1,373 replies, 1,297 of which were negative. Nonetheless, the 76 affirmative replies reflect a surprisingly high accident rate. Expressed in other terms, about 3 percent of a child population of 2,764 had been victims of bicycle-motor vehicle accidents. *This gives an accident rate for this 5-13 age group of about 3,000 per 100,000 children bicyclists.* Obviously, these data are for Santa Barbara and may include the effects of factors not necessarily prevailing in other communities. It is difficult to think, however, why the rate of bicycle accidents among young children in Santa Barbara would differ markedly from that in other areas. On the contrary, one is led to think of mitigating factors--relatively small and quiet town, good weather, few children either dependent on or choosing to use bicycles as school transportation. Nonetheless, any *accident rate* data are of interest; my experience has indicated a serious lack of such information, indeed to such an extent that qualitative judgments of the bicycle accident picture are extremely difficult, if not impossible to make.

From Ref. 12, which shows in one case the number of bicycle accidents per 100,000 children of each age from 3 through 10 years, one can develop an overall rate of about 270 per 100,000. These figures--the 3,000 and 270--are not, of course, directly comparable. The lower rate is only for children through age 10. More

important, the lower figure is for *reported* accidents whereas the figure reported by parents in this survey undoubtedly includes every minor confrontation that the children had mentioned at home. If 5 percent of the survey-reported accidents were serious enough to have been reported, the rates would be similar. Other information, discussed previously, shows the United States rate to be better by far than several European countries but about on par with Sweden where the 270 per 100,000 figure was developed. In this matter of accident rates another perspective is added if we recall the motor vehicle drivers under age 20 show an accident rate of about 14,000 per 100,000 drivers.

31. SCHOOL DIFFERENCES. Some differences between the schools used in the survey of parental attitudes toward a minimum age are shown in Table 5. The average minimum age selected is seen to range from 11.5 to a low of 9.9 at Mt. Carmel. Differences between the public schools are slight; it is thought that the lower age at Mt. Carmel, a Catholic school, is the reflection of a greater dependency on the bicycle for transportation (41 percent of the Mt. Carmel responses said the bicycle was necessary as transportation, compared with 20 percent at McKinley and 10 percent at Wilson).

There is a general relationship between the average age selected and the percent replying that the bicycle is necessary. Table 5 also shows the percent of respondents at each school who picked minimum ages greater than 10 and greater than 12.

School	Average Age	Percent Saying Bike Necessary	Percent Selecting Average Age >10	>12
McKinley	11.5	20	58.5	35.2
Wilson	11.4	10	66.6	44.5
Franklin	11	25	54.2	27.0
Cleveland	11	17	46.7	29.8
Adams	10.8	19	45.0	18.3
Washington	10.8	26	46.5	26.8
Lincoln	10.8	23	35.6	28.6
Roosevelt	10.7	33	43.9	41.2
Peabody	10.4	27	40.0	15.4
Mt. Carmel	9.9	41	32.0	19.1

Table 5. Parental response differences to minimum age survey questions.

32. SUMMARY OF SURVEY FINDINGS. The findings of the survey of parents with children in the age group 5-13 are summarized in Table 6.

33. PARENTAL COMMENTS. Of the 1,373 questionnaires which were returned, 109 responses were listed in an "other" category, usually because the respondent declined to select a specific minimum age. Many others chose to write brief notes--in a few cases, letters--to explain their opinions and attitudes. Those questionnaires bearing written comments were sorted and some are quoted

1.	Average age selected	10.8 yr
2.	Number of responses under 10-yr = 309 or	23.8%
3.	Number of responses over 10-yr = 578 or	45.6%
4.	Number of responses over 12 yr = 323 or	25.6%
5.	Mode (377)	10 yr
	2nd Mode (277)	12 yr
6.	Question 1 - Bicycle necessary for transportation--	
	Yes (314 replies)	22.8%
	No (1,059 replies)	77.1%
7.	Question 2 - Ever have child in bicycle-motor vehicle accident--	
	Yes (76 replies)	5.5%
	No (1,297 replies)	94.4%
8.	Accidents per 100,000 population	
	Based on 76 accidents for survey population of 2,764	2740

Survey Totals -- 1,373 replies

1,373 replies to questions 1 and 2

1,264 replies to age choice

109 responses listed in other category, usually because respondents declined to make definite choice.

Table 6. Overall summary.

below. The quoted comments may be considered typical (in terms of tone and quantity) of respondents expressing additional opinions.

- *'Depending on each individual child. The extent of the child's maturity.*
- *I feel a rules of the road test and riding test be given to any child requesting and if passed be allowed to ride unsupervised.*
- *I think this is a way of saying a few don't behave so all must be punished. Don't take another privilege away from them.*
- *Age does not apply--If the child shows the responsibility of being aware of the situation, yes--not until.*
- *It depends on the child.*
- *We need less laws, not more.*
- *I would not obey any such requirement.*
- *No child should have a bicycle of any kind before the age of 7.*
- *We have too many do-gooders attempting to remove our parental freedom.*
- *13 years at least!*
- *Around our home--8. Public roads--I don't really know. I don't let mine go on them.*
- *16 years and after having instructions about safe riding.*
- *Personal experience as a parent and a teacher has shown me that when rules/laws are adequately enforced by authorities and re-enforced by parents the large majority obey the rules. I believe this can be done between ages 8-10.*

- 8 years old in neighborhoods, Jr. High age elsewhere. All children should be held responsible to obey the law. Elementary school children should not be allowed to ride bikes.
- 16 years -- This I feel is terribly important. You are allowing immature, unskilled drivers on the same roadway with licensed drivers and cars. Not until proper roadways or on sidewalks should any immature child be allowed on the streets.
- We would like to see some sort of examination for bikers before they are allowed to operate alone.
- 13--and only then after passing a test for street driving and receiving a street license similar to car license.
- I agree that we cannot expect our children to understand and act as responsibly as the situation on the road demands.

34. PARENTAL OPINION SURVEY: CONCLUSIONS. What conclusions can be drawn from the replies to the minimum age questionnaires? First of all, it seems clear that attempts to implement a minimum age requirement, even a relatively high one, not only would not encounter the strong opposition of parents, as some have assumed, but would be welcomed as a necessary protection for children. This conclusion is supported by the high average age selected--about 11 years--and by the response to the survey questions. More than 25 percent of the parents picked an age above 12. In fact, there were

many who picked higher ages: 130 selected age 13, 86 age 14, and 73 age 15. Additional support is certainly indicated by the comparative few--about 23 percent--who regard the bicycle as necessary transportation for their children. It has been repeatedly established that children do not use bicycles to the extent so often assumed and especially do we fail to see any great numbers using them for purposeful transportation. Survey data reinforce previous findings in this regard.

It is safe to assume greater acceptance of the minimum age concept by the general public than that indicated here. The data above are considered to be particularly valid because they come from parents who have children who would be directly affected by a minimum age standard. Presumably they are the only ones who could in any way be inconvenienced by an age requirement; consequently, little opposition would be expected from others.

Significant, too, is the following. Most of the parents surveyed selected relatively high ages for the standard purely on the basis of their experience and intuitive insights into the problem. Few of them could be expected to be aware of the considerable data base that shows the younger child to be likely incapable of reasonably safe traffic behavior, regardless of the quality or quantity of safety education.

5

THE CASE FOR A MINIMUM AGE: A SUMMARY AND RECOMMENDATION

35. SUMMARY OF FINDINGS. Some study findings that serve to guide us in evaluating the severity of the safety problem associated with the young cyclist, and other data that help in developing a basis for passing judgment on the capabilities of younger children as they relate to traffic performance, are summarized here.

Young bicyclists suffer the most in traffic accidents. One study finds children 13 and under accounting for 8 percent of street bicycle traffic and 30 percent of the motor vehicle-bicycle accidents. In California, bicyclists under 15 incurred 60.9 percent of all bicycle fatalities in 1972, 61.2 percent in 1973. Nationally, in 1971, 73 percent of all those killed and injured in bicycle-related traffic deaths were 14 years old, or younger. Statistics from European studies show a similar picture.

As demonstrated in many ways, children are not mature, when we consider them in terms of cognitive development, until late into adolescence. One authority would even extend the period of adolescence to include age 25.[19] At various stages along the path of cognitive development, there are many general classes of activities of which the child is incapable--*not because of a learning lack but because he simply cannot grasp certain concepts.*

Younger children--2 to 7 years approximately--are limited in their thinking to their often faulty intuitions, based in turn on limited perceptions. From about 7 years to 11 or 12 the child begins to function in thought but is limited to the concrete objects with which he has experiential contact. He can do some logical thinking but still doesn't handle abstractions; his reasoning is, at best, elementary in nature. At about 11 or 12 the child begins a period of more logical operations. He can think of thoughts and range forward and back in time and space. He can reason from specifics to generalities, work with hypotheses, and imagine what would be the case if specified assumptions were to hold.

It has been shown that several basic cognitive milestones must wait their turn as the child matures. The ideas of conservation of volume, weight, and substance have been experimentally shown to follow definite patterns of development, beyond the cognitive capability of the child at one age, within his range of understanding at a later one. Attempts to change the order of the appearance of these cognitive capabilities by training the child have been largely unsuccessful, as have attempts to hurry the development process. *Results of these studies (they have been repeated by other investigators and in various cultures with much the same results) certainly indicate that, while much remains to be learned of cognitive development, there are limiting factors involved that preclude to a great extent the child's understanding of many things taken for granted by many adults.*

From one study: "The concept of speed as a relationship between distance traversed and time passed does not begin to appear in children until nine or ten years of age."[17]

Children have great difficulty with ideas of order; and the ideas of order, as they relate to an order of events, are essential to a comprehension of the concepts of speed (an orderly change of position) and time. Younger children have consistently shown, in experimental situations, that they think a direct relationship exists between time and speed. That is, the faster they do something, the more time it takes. Children cannot, in general, tell time until age 8 or older, at least not with any understanding of the idea that equal time durations are shown in equal movement of clock hands.

Studies of the child's perception and judgment of length and distance disclose systematic errors of perception.

The child is egocentric, unable to view things from another's point of view. He cannot, with any accuracy, show an understanding of a scene when asked to change his perspective, until about age 10. This means that if a younger child views something from one position and then moves to another position, he can't describe the perspective even from the place he just left. The concept of right and left is poorly developed in most children until age 9 or 10 and then they are still unable to identify right and left of an object facing them. Because he can't think from another's point of

view, the child "assumes that all the world shares his thoughts and feelings" and that therefore he need not explain them. *Children think we know what is on their minds*, a characteristic that has significant implications for their traffic behavior.

Children seem to have a happy unawareness of any need for rules in their games until later in their development—perhaps about 11 or 12. The younger child, up to about 7 or 8 sees little point to any rule but then regards them as almost sacred edicts. Later, they are inclined to look upon rules as arbitrary standards to be changed as suits the situation. If children neither demand nor understand rules in their games, which engage the child so thoroughly it seems "as if the complicated traffic rules should not either be possible to comprehend and to follow below the same age."

In perceiving movement of objects or themselves, children's thinking is dominated by a consideration of the point of arrival, not of the path taken to get there. Children view a change of position, therefore, strictly in terms of the goal. Children have been found to develop, fairly consistently, first a concern for point of arrival, then a concern with point of departure, and lastly a thought about the path between. Adults, of course, are principally concerned with the path traveled.

36. SHOULD THERE BE A MINIMUM AGE? The principal purpose of this study was to provide an answer to the question: Can an age be identified below which the child is, because of incomplete cognitive

development, incapable of performing, in an acceptably safe manner, in traffic?

Statistics clearly show that bicycle riding on public roadways is an activity that is significantly more hazardous for children than for older age groups. Furthermore, the unfavorable statistical picture of youthful cyclists is relatively consistent whether considered at the local, state, national, or international level.

What, then, are the probable causes of the disproportionate accident involvement of younger children? Perhaps there are many, but *one factor is of overriding importance to any effort aimed at reducing the number of bicycle-motor vehicle accidents in which children are the victims:*

> The traffic environment is extremely complex, even for many adults. It is an adult-created environment, with adult oriented uses, and rules. I think enough data are available to permit the conclusion that younger children are developmentally incapable of understanding the nature of traffic flow and its associated rules of performance. I think further that the deficiencies involved are not amenable to change that can be effected through intensified and expanded programs of safety education.

This latter statement does not, of course, preclude the possibility of enhancing the child's safety in traffic through innovative and perhaps yet untried training techniques designed specifically to cope with his developmental limitations.

37. WHAT SHOULD THE MINIMUM AGE BE? Professor Stina Sandels has been actively and continuously engaged with problems associated

with the child in traffic since 1960 in her work at the Institute for Child Development Research at the University of Stockholm. Professor Sandels says that *regardless of his training, a child's behavior in traffic cannot be trusted. He does not possess the necessary maturity to function as d "tolerably reliable pedestrian ...until the age of 9-12 years."* And more: *"...for certain not the maturity to cycle in urban traffic."* In sum: *We cannot expect traffic maturity from children sufficient for pedestrians until the age 9-12. Traffic maturity sufficient for cyclists demands a still more advanced age."*[18]

Elsewhere[20] and at an earlier date, Professor Sandels expressed her view that children should not be allowed to cycle in traffic until they are at least 12 years old. More recently:[18] *"If I were in the position to make the laws in this respect, I would now allow 15-year-olds to cycle in traffic;* 18-year-olds to drive mopeds, and 20-year-olds to drive cars."[11]

38. CONCLUSIONS. I think study findings support at least three conclusions:

1. A minimum age requirement for children bicyclists using public roadways should be established.
2. The minimum age should be no less than 13 years.
3. Parents of children in the affected age group will support the imposition of a minimum age.

The many reasons for setting the minimum age at 13 have been developed and discussed throughout this report. Some of the important ones: (1) an age of 13 advances the child into the cognitive development period of formal operations, thus ensuring, as much as possible, the cognitive structures necessary to an understanding of traffic flow and traffic rules; (2) although a lower age than some authorities would recommend, an age of 13 is at once practicable and compatible with their general thinking on the subject; (3) the effect of children's general unconcern for rules, evident through ages 11 or 12, would be circumvented; and (4) based on one bicycle-motor vehicle accident analysis, an age of 13 would eliminate about 70 percent of the accidents involving younger children (an age of 9 or 10 would eliminate about 25 percent).

There are other good reasons that dictate against lower age requirements. For example, there is little developmental change in children between the ages of 6 and 10 years, the changes that do occur being essentially social in nature. This is simply a way of saying that most anything that can be taught the 10-year-old can likewise be taught the 6-year-old. Logically, therefore, imposition of an age limit of 10 years would be tantamount to a minimum age requirement of 6 years, when considered in terms of the child's cognitive capabilities.

39. A SUMMARY STATEMENT. There is certainly ample precedent for the establishment of a minimum age requirement for younger

cyclists. In nearly all instances, the child's lack of responsibility and indeed his legal right to behave as a child are recognized and considered when various standards of conduct are defined. Children are not permitted to drive cars simply because driving imposes an adult responsibility of which a child is held incapable. There is a seeming incongruity in permitting children to operate bicycles on streets busy with motor vehicle traffic and imposing, as the vehicle code does, the same adult rules and regulations that apply to motorists.

When giving thought to controlling the child in traffic it is important that we recognize a fundamental difference in the responsibility owing to him and that due others. The difference derives because the child *cannot* perform safely, even though we may think he "knows" the rules; on the other hand is the older person who knows better but may *choose* to behave unsafely. In the first case there is an unmistakable duty to protect; in the latter case it is probably sufficiently responsible to educate and caution. The child is a special case.

6
IMPLEMENTATION

40. THE PROBLEM. Prohibiting the use of public roadways to bicycle operators under 13 years of age would--with great certainty --achieve a major reduction in the number of young cyclists killed and injured. But, assuming acceptance of the minimum age idea, how could, or how should, implementation proceed?

The nature of the bicycle as a vehicle and the nature of the bicyclist as a vehicle operator make any kind of regulation at best difficult and, to a great extent, ineffective. An analogous situation would prevail if control of motor vehicle traffic were to be attempted without registration or licensing of either vehicles or operators.

Undoubtedly, there are many ways to proceed with implementation of a minimum age requirement but it seems evident that all could be broadly categorized as either having or not having the force of law. In the latter case, there would be several alternatives to consider. For example, the implementation could proceed through the channel of parental responsibility with cognizant agencies undertaking public education and information programs soliciting voluntary parental imposition of the age limit. Schools could be called into a quasi-enforcement role (a role in which some already function in

this regard) by forbidding younger children to ride bicycles to school. Implementation could also be tried through the local option device. Certainly, many schemes could be suggested and undoubtedly all would have some merit. But all would suffer the inherent weakness that accompanys any sanction lacking enforcement potential.

It is my opinion that at best such responses to the implementation problem would be spotty in nature, ineffective and, most important, would represent an insufficient commitment to the serious business of saving the lives of and preventing serious injury to our younger cyclists.

41. A RECOMMENDATION. The effective and practicable implementation plan seems to be straightforward: Amend the California Vehicle Code to specifically deny use of public roadways to the younger cyclist. In effect, it should be unlawful for any person who has not yet attained the age of 13 years to operate any pedal driven vehicle on public roadways unless accompanied by an adult.

Given the status of law, enforcement of the minimum age requirement would still be infeasible unless the traffic field officer could determine the age of suspected offenders. And the most reasonable way to provide that information is to make it possible to identify not the younger cyclists but rather those 13 years old and above. This, of course, suggests licensing of bicycle operators.

On the other hand, I have not been and am not now an advocate of bicycle operator licensing, at least not when licensing is considered in the conventional sense. The Department of Motor Vehicles, the only logical agency to take on accountability for such a procedure, is already overburdened in many respects. To impose another and massive licensing program would be undesirable. Moreover, operator skill, or lack of it, has not been shown to be a significant causal factor in bicycle-motor vehicle accidents; objective assessment of operator skill would be difficult; and the equipment inspection that many would have integrated with a licensing requirement would accomplish little, because we know that equipment failure is a negligible factor in bicycle accidents. In short, a conventional licensing of bicycle operators seems relegated to a promise of ineffectiveness and wastefulness.

Instead of the usual licensing requirement, I recommend that all persons who operate bicycles on public roadways be required--by the California Vehicle Code--to have in their possession a standardized personal registration card that would be obtainable, for a small charge, from the Department of Motor Vehicles. The revenue generated could be used to cover administrative expenses and to provide some of the needed bicycle facilities. It is specifically recommended that no form of testing or equipment inspection be tied in any way to issuance of the registration card; its purpose is identification only.

The bicycle operator registration would show such things as the registrants birthdate and address. The registration form would be useful in other ways. It could, for example, show the serial number of the registrants bicycle.

This procedure of registration would: (1) impose a minimum amount of work on the Department of Motor Vehicles; and (2) would provide maximum effectiveness both for purposes of the requirement recommended here, and for all other bicycle-related enforcement.

In summary: It is recommended that:

1. The California Vehicle Code be amended to prohibit persons under 13 years of age from operating pedal-driven vehicles on public roadways.
2. The California Vehicle Code be amended to make mandatory the registration of all bicycle operators who use public roadways.

When should the minimum age requirement be implemented? Its implementation should be effected as soon as the legislative process necessary to its establishment can be completed. *The minimum age requirement is the most effective and certain way of immediately and significantly reducing the number of children who are going to be killed or seriously injured in bicycle accidents.*

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