Waller, P.A., Reinfurt, D.W., Freeman, J.L. and Imrey, P.B. (1974). Methods for Measuring Exposure to Automobile Accidents. Chapel Hill, NC: University of North Carolina Highway Safety Research Center.

METHODS FOR MEASURING EXPOSURE TO AUTOMOBILE ACCIDENTS

Patricia F. Waller

Donald W. Reinfurt

Jean L. Freeman

Peter B. Imrey

Presented at the 101st Annual Meeting of the American Public Health Association, November 8, 1973, San Francisco, California

November, 1974

~~HSRC-A29~~

UNC/HSRC-74/11/1

METHODS FOR MEASURING EXPOSURE
TO AUTOMOBILE ACCIDENTS

Patricia F. Waller
Donald W. Reinfurt
Jean L. Freeman
Peter B. Imrey

November 1974

This study was partially supported by the North Carolina Governor's Highway Safety Program (Traffic Records Project No. 310-74-001-001), and by the National Highway Traffic Safety Administration.

In traffic accident research a major difficulty has been a lack of information concerning the population at risk. While a look at accident statistics will reveal many interesting findings, such as the fact that men are involved in many more accidents than women, such information in and of itself is of limited usefulness. If men account for 80 percent of all driving and only 70 percent of all accidents, their "high" proportion of accidents would actually reflect a lower accident rate than that for women. Without some reasonable measure of exposure to risk, appropriate accident rates cannot be ascertained.

Good information on accidents can be obtained, although not without difficulty. However, good information on exposure to risk is extremely complicated to come by. Some investigators have been content to use the file of licensed drivers or registered vehicles as a measure of exposure, but it cannot be assumed that all driver classes or all vehicle classes are exposed to the same amount and kind of risk. Driver estimates of exposure have been used with limited success, but there are difficulties with the accuracy of such estimates as well as the cost of obtaining them. On-road surveys have also been made and have the advantage that they do not rely on a driver's honesty and ability to report accurately. However, the cost of on-road surveys is prohibitive in most instances. The very hours that one might be most interested in are often the most difficult to cover, namely, nights and weekends.

Thorpe (1964) has proposed and developed a method for determining exposure to risk of accident by using information routinely available from most accident reporting systems. Briefly his method is based on the following assumptions.

(a) Single-vehicle accidents are caused entirely by attributes of the driver-vehicle combination concerned.

(b) Collision accidents are caused by the first two vehicles to hit. In each such collision, there will be a "responsible" and a "not responsible" driver-vehicle combination.

(c) The relative likelihood of a driver-vehicle combination being the "responsible" combination in a collision accident will be the same as the relative likelihood of that combination being involved in a single-vehicle accident.

(d) The likelihood of any particular driver-vehicle combination being "innocently" involved in a collision accident will be the likelihood of meeting that combination on the road (i.e. will constitute the exposure distribution).

Since most collision accidents involve only 2 vehicles, the first part of assumption (b) does not appear critical. However, assumption (a) does not allow for crashes resulting from being run off the road by the "phantom driver" or other unforeseen circumstances that might result in a single vehicle crash with a "blameless" driver.

The indirect or induced method then determines relative exposure for certain classes of drivers, vehicles, driving environments, etc., by obtaining the corresponding distributions for "non-responsible" driver-vehicle combinations in collision accidents. The advantage of such an induced (or, some would argue, deduced) measure of exposure is that one's population at risk can be determined both quickly and economically. In addition, it will generally be based on large samples. However, to accept induced exposure as a valid measure of the population at risk some independent check needs to be made.

This study compared a measure of induced exposure, based on accident reports from North Carolina during the summer of 1971, with a measure of reported driving exposure provided by a state-wide sample of driver license applicants reporting to examining stations. Because in North Carolina original licensing may occur at age 16 and renewal licensing is required only once every four years, only applicants age 20 and over were included in the analysis since those persons under 20 should have been applying for an original license and thus should have had very little previous driving exposure. Likewise, only drivers age 20 and over were included in the analyses of accident data.

The accident data included the following: age and sex of driver, state of licensure (in-state versus out-of-state), hour of day crash occurred, type of crash (single vehicle or two vehicle), make and year of vehicle, and in the case of double vehicle crashes whether or not the driver was found to be in violation. That is, responsibility is determined by which driver in a two-vehicle collision is found to be in violation. Drivers found to be in violation are not always charged with a violation. The "Violation Indicated" variable appears to be a more sensitive indicator in that many more drivers have violations indicated than are arrested. Drivers not found to be in violation are considered "innocent" and according to Thorpe's formulation are representative of the population exposed to risk of accident. In addition, only those two-vehicle collisions involving a "guilty" driver and an "innocent" driver are of concern.

The information provided by driver license applicants included the following: age and sex of applicant, amount driven during a recent day, amount driven during a specified period of time (the period varied for different applicants so that the entire week was covered), and the make and year of the vehicle used most during the time period asked about.

Thus the accident drivers were classified by age and sex; in-state versus out-of-state; single vehicle, guilty double, or innocent double; and vehicle make and year. The license applicants were classified by age and sex, miles driven the previous week, and make and year of car. Accident drivers were distributed to show the proportion of total accidents within each classification by age and sex. License applicants were also distributed according to the proportion of total fleet mileage reported by each age and sex group.

According to Thorpe's notion of induced exposure, the in-state innocent drivers in double vehicle crashes should distribute themselves by age and sex in very much the same fashion as the license applicants with regard to mileage. Furthermore, drivers in single vehicle crashes and guilty double drivers should resemble each other but should not resemble the distribution of innocent double drivers.

Table 1 and Figures 1 through 3 show these comparisons. Figure 1 compares the exposure distribution with the distribution of drivers found guilty in two vehicle accidents, that is, the "guilty doubles." As can be seen, for both males and females the middle-aged drivers show an under-representation in accidents compared to their proportion of the exposure.

Figure 2 shows the comparison between exposure and drivers not in violation in two vehicle accidents, or the "innocent doubles." Again, the middle-aged drivers are underrepresented in crashes compared to their proportion of the exposure. However, comparing Figure 2 with Figure 1 shows that the "innocent double" drivers more closely resemble the exposure distribution than do the "guilty doubles." According to the induced exposure hypothesis it is these innocent double drivers that should provide a measure of "real" exposure, and they indeed approximate the exposure distribution more closely than the guilty doubles. For females the similarity is remarkable.

Figure 3 compares the single vehicle accident drivers with the exposure distribution. Here there are marked discrepancies, primarily because of the large proportion of single vehicle accidents involving young drivers. It should be noted that while single drivers by definition are

Table 1. Proportion of Reported Fleet Mileage and Accidents by Age and Sex

Age & Sex	Reported Mileage	Guilty Double	Innocent Double	Single	Total Accidents
Males					
20-24	.166	.249	.238	.382	.287
25-34	.252	.221	.261	.278	.254
35-44	.258	.141	.180	.133	.153
45-54	.187	.145	.157	.104	.136
55-64	.095	.124	.104	.064	.097
65-74	.032	.083	.051	.028	.054
75+	.009	.037	.011	.011	.019
Females					
20-24	.195	.234	.224	.307	.249
25-34	.268	.243	.284	.282	.269
35-44	.225	.190	.217	.178	.197
45-54	.185	.161	.153	.131	.150
55-64	.097	.106	.091	.068	.090
65-74	.027	.055	.028	.030	.038
75+	.003	.011	.005	.004	.007

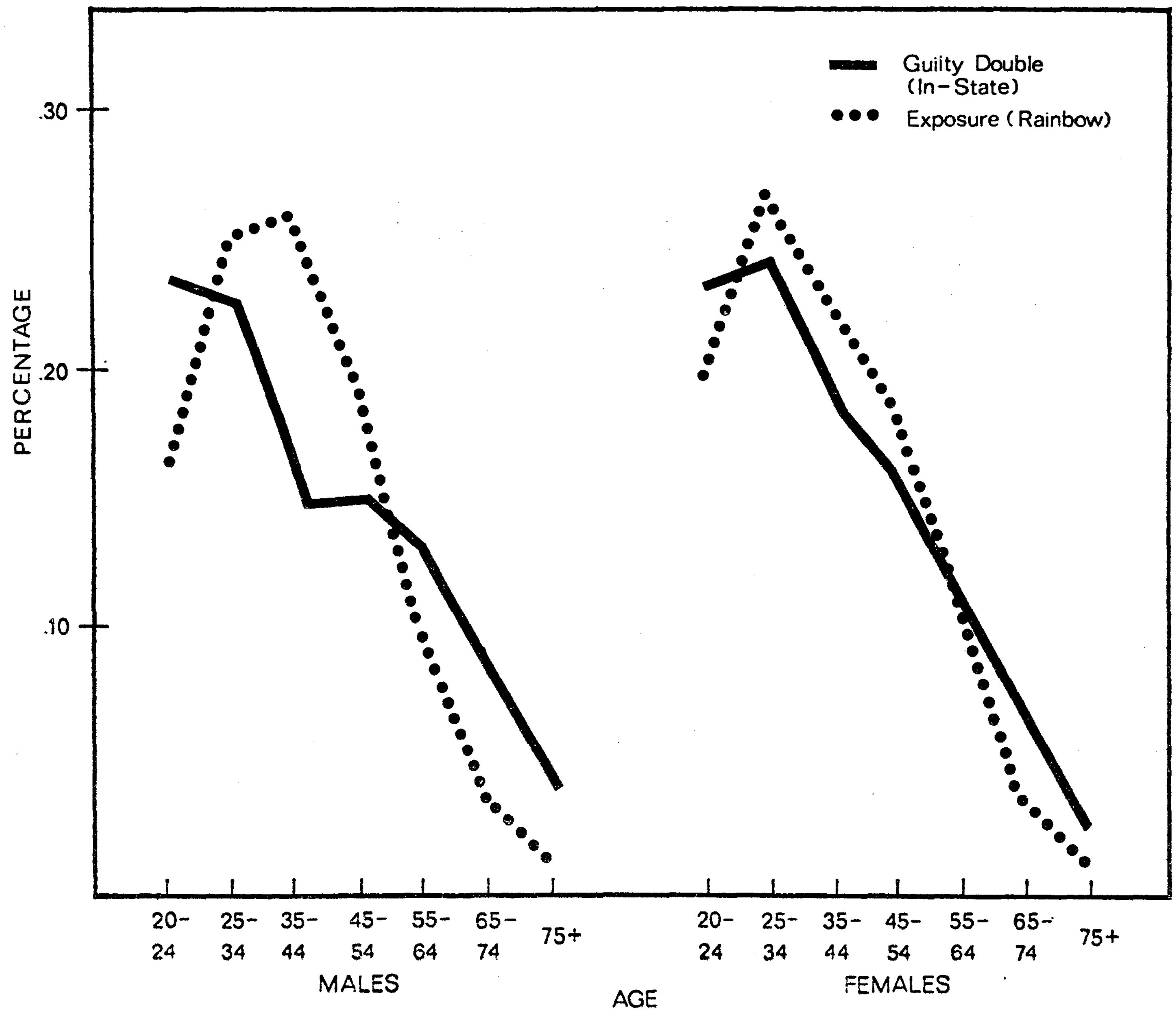

Figure 1. Percentage distribution by age and sex of population at risk (Exposure) and guilty drivers in two-vehicle accidents (Guilty Double).

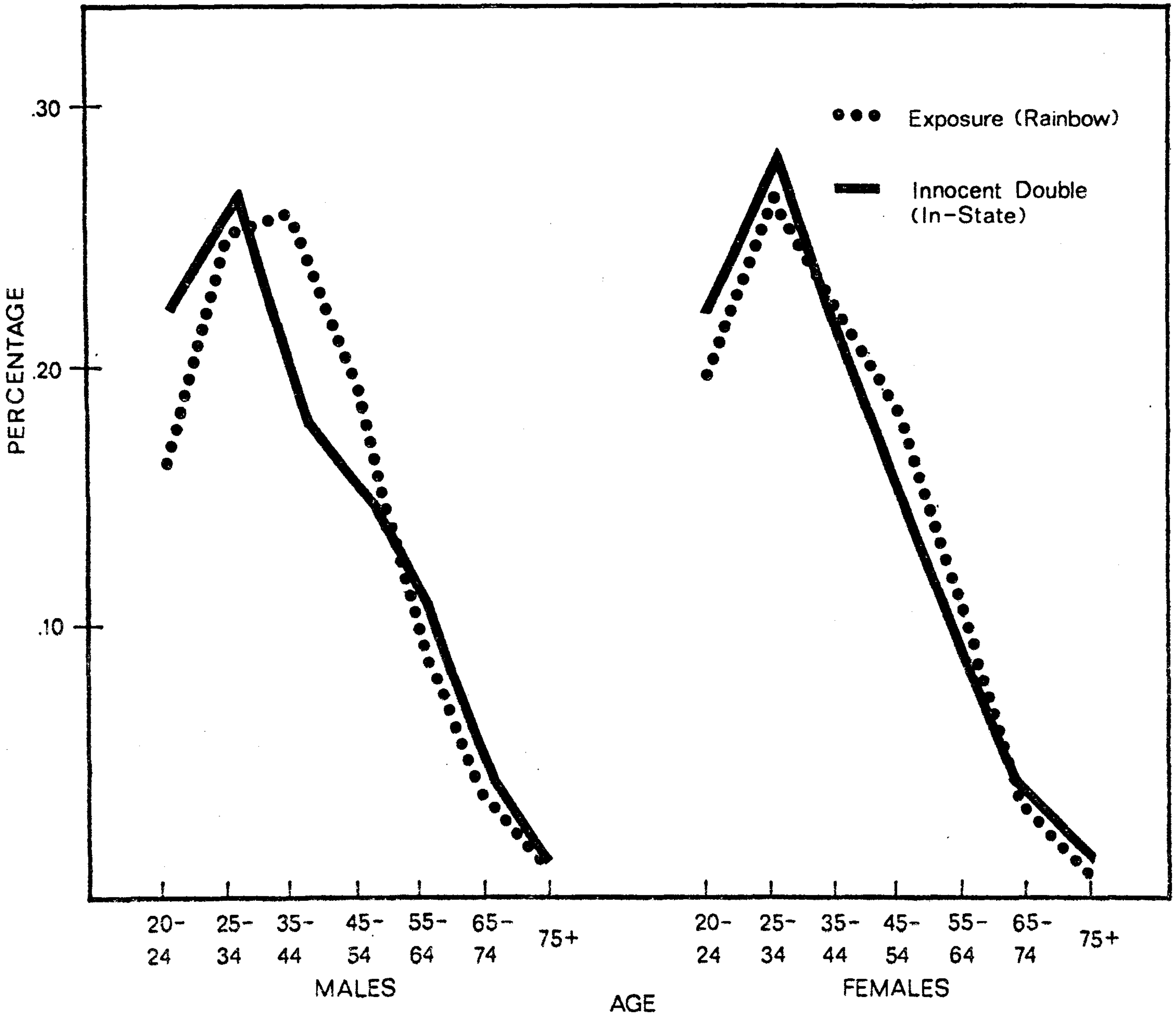

Figure 2. Percentage distribution by age and sex of population at risk (Exposure) and innocent drivers in two-vehicle accidents (Guilty Double).

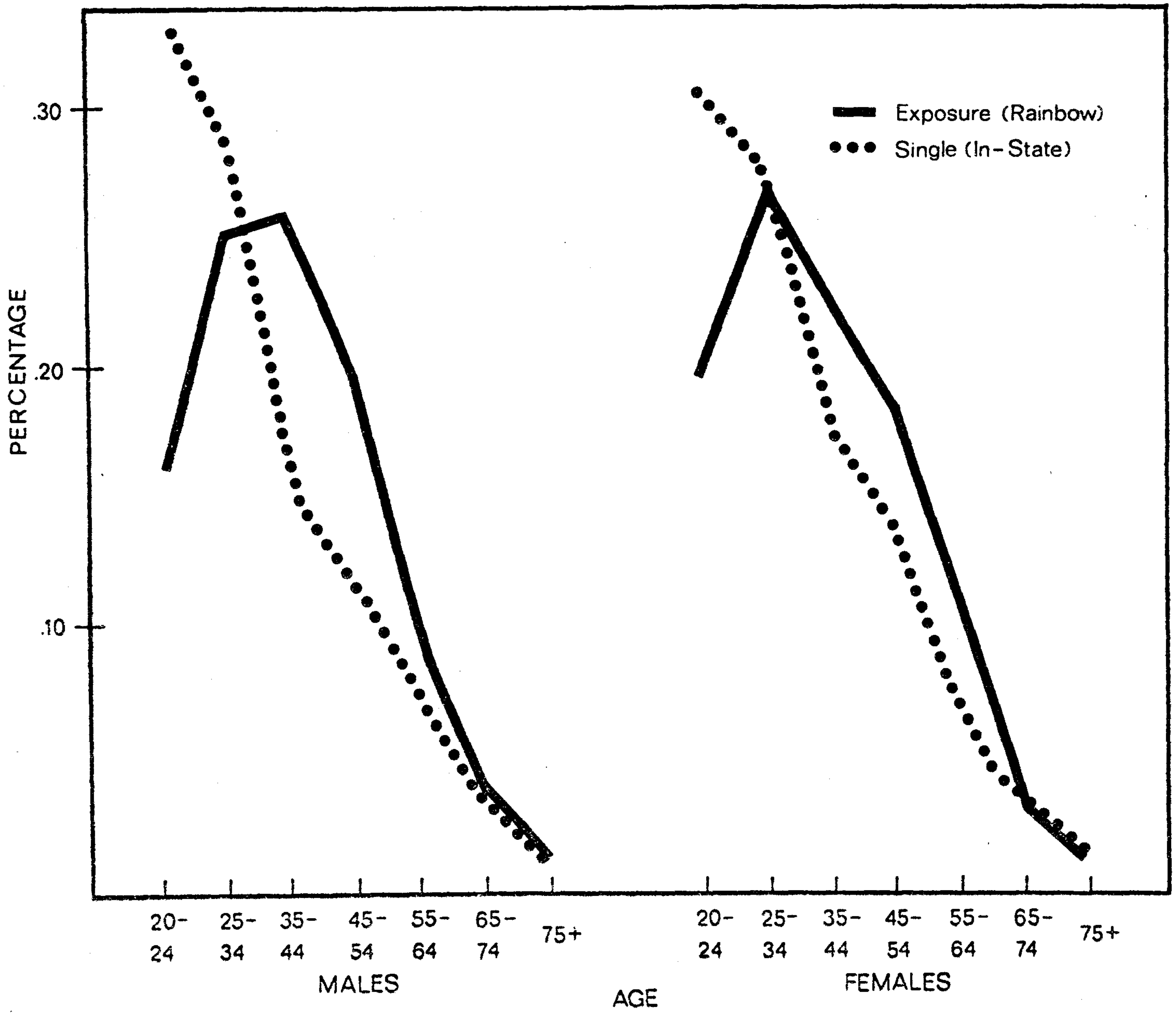

Figure 3. Percentage distribution by age and sex of population at risk (Exposure) and drivers in single vehicle accidents.

considered guilty, their distribution is quite different from that of the guilty doubles. Such discrepancy would indicate that single drivers could not be used as a basis for determining the distribution of guilty drivers in multivehicle accidents, as has been suggested by Haight (1970). Also, while single drivers may be considered guilty by definition, one should note the close correlation between single drivers and exposure in the case of the elderly (age 55 and older).

In Figures 1 and 2 the guilty doubles and the innocent doubles differ from the exposure distribution in much the same manner with one notable exception. In the case of the innocent double drivers the overrepresentation persists until the third age category, in contrast to the guilty doubles where the overrepresentation drops after the first age category. In other words, overrepresentation in the innocent double group continues until an older age than does overrepresentation in the guilty double group. To account for this phenomenon it is hypothesized that drivers learn not to make driving errors that cause accidents at an earlier age than they learn to avoid becoming the victim of other drivers' errors. Defensive driving appears to occur at a somewhat later age than does avoidance of accident causation.

Because our measure of exposure consists of drivers' estimates of mileage driven, there is some question of the accuracy of such estimates. As a partial check, a comparison was made with an independent measure of summer exposure, namely trips included in an origin and destination survey conducted by the State Highway Commission. The major differences between the O & D exposure measure and the drivers' estimates of exposure are the following:

1. Drivers' estimates of exposure were obtained during the summer of 1971, while the O & D trips were observed during the summer of 1972.

2. Drivers' estimates included weekend mileage, while the O & D survey included only weekday trips (Sunday midnight to Friday midnight).
3. Driver estimates were collected state-wide, while the O & D survey was limited to the area surrounding a large town in the eastern part of the State.
4. Drivers' estimates were made by persons coming to examination stations for driver licenses, while the O & D observations were made for persons in passenger cars with North Carolina license plates.
5. Drivers' estimates of exposure included driving in all types of vehicles while the O & D observations were based on passenger cars only.
6. All North Carolina vehicle accidents for the summer of 1971 were compared with drivers' estimates of exposure, while the O & D trips were compared with only the weekday summer accidents involving North Carolina passenger cars occurring in the general area of the O & D survey.

With these differences in mind, comparisons can be made between Figures 4 and 5. Figure 4 shows a comparison of the drivers estimates of exposure and all accidents combined--single, innocent double, and guilty double. Figure 5 compares exposure as measured by the O & D trips and the corresponding accident data.

The exposure measures obtained through the two methods are not identical, but it cannot be ascertained whether this is because of measuring errors or because of the differences in what was actually measured, e.g., weekday versus entire week, one area of the state versus the entire state. However, particularly in the case of the males, the age trends for exposure are fairly consistent. The relationship between the exposure measures and

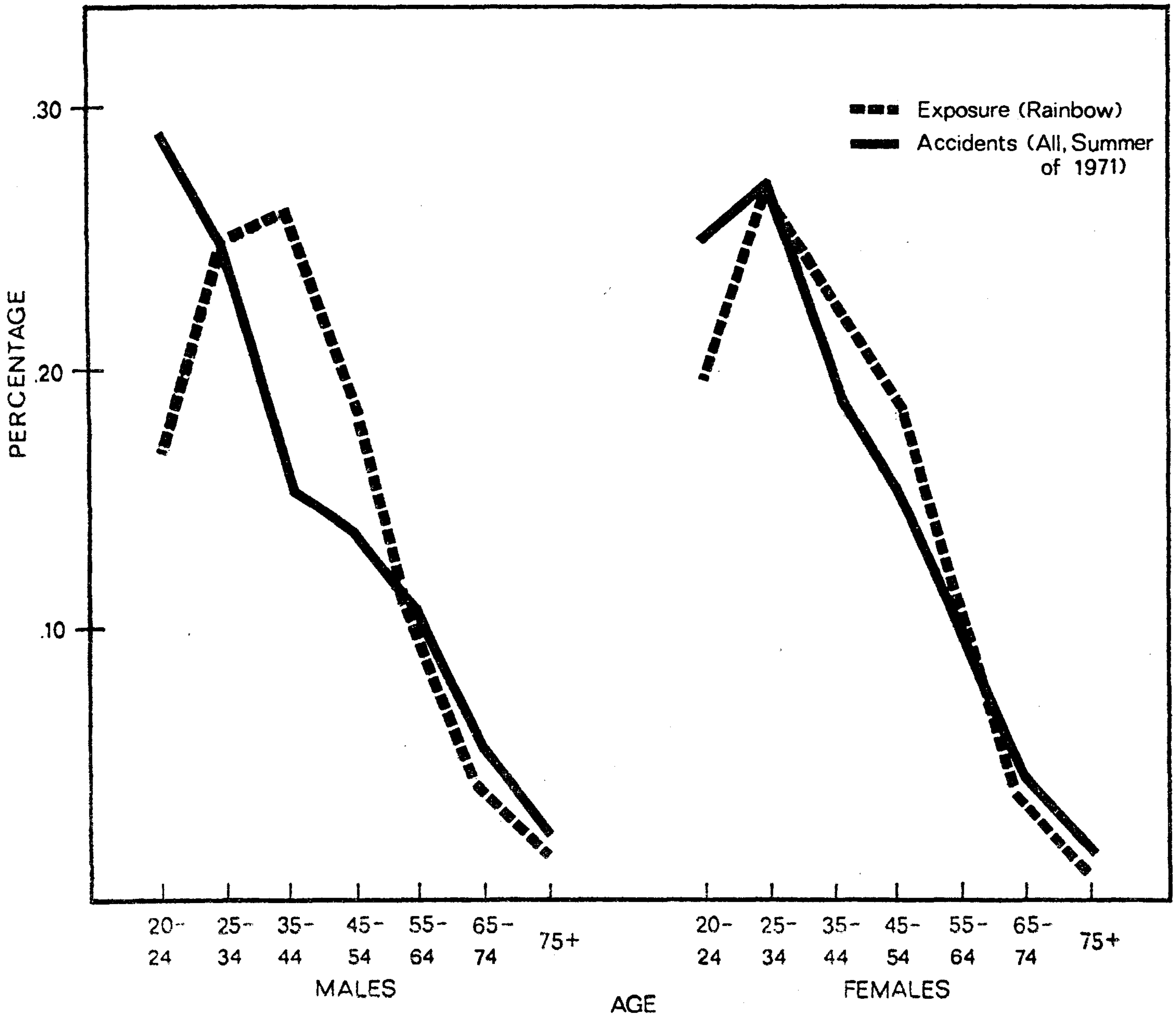

Figure 4. Percentage distribution by age and sex of population at risk (Exposure) and drivers in all summer accidents.

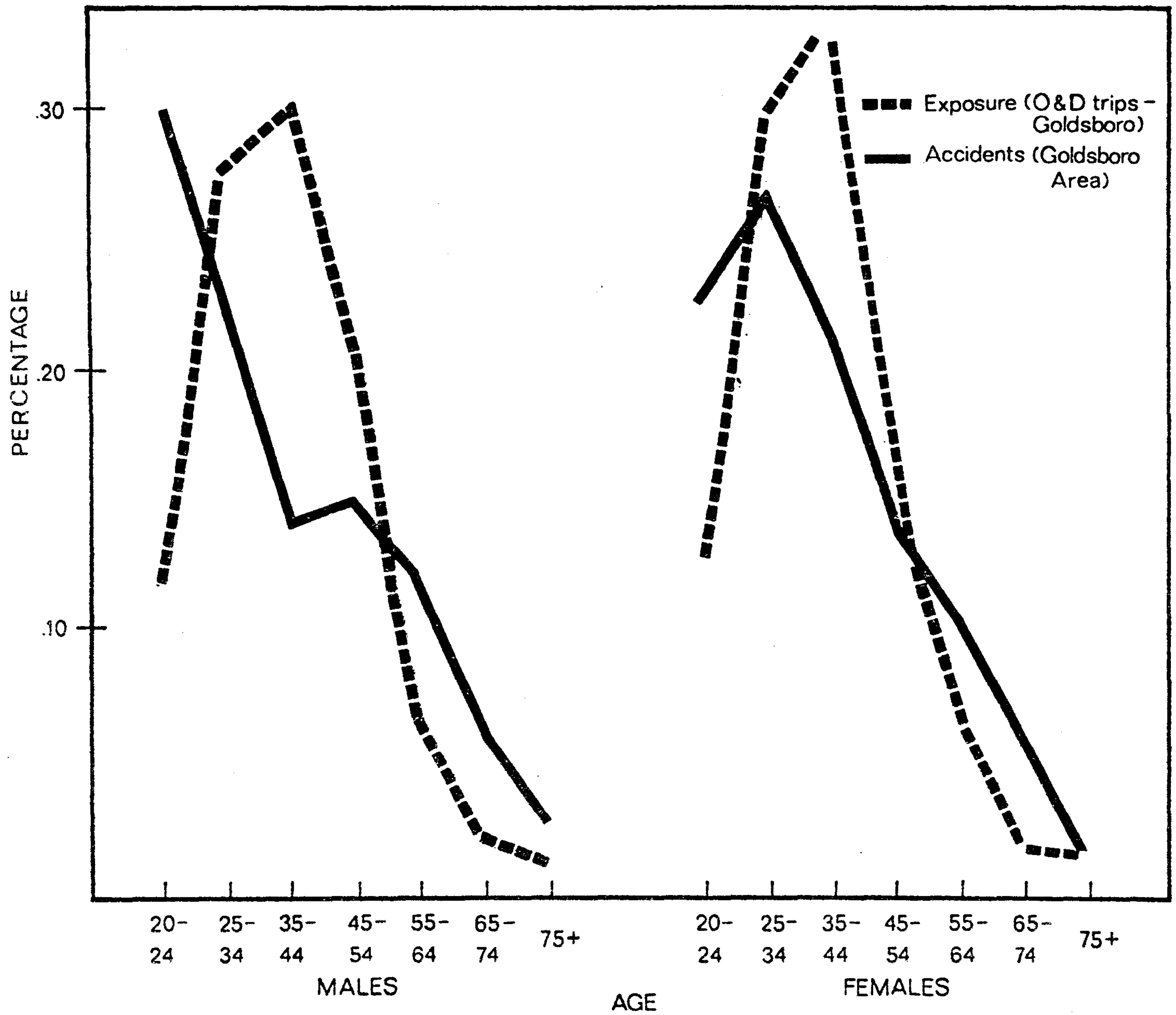

Figure 5. Percentage distribution by age and sex of population at risk and drivers in accidents in the Goldsboro area.

the corresponding accident distributions are also somewhat similar, with perhaps the most notable differences occurring for the 25-34 year age groups. The relationship between O & D trips and all accidents is most like the relationship between drivers' exposure and guilty double accidents, rather than the combination of single, innocent double, and guilty double.

Perhaps the major point to be made here is the general similarity between the exposure measures with the bulk of the travel accounted for by the middle aged drivers, and the similarity of the relationship of the two exposure measures to their corresponding accident distributions, with the middle aged groups the only ones not overrepresented in accidents.

What are the ramifications of the comparisons with respect to the validity and utility of the induced exposure concept? Do the observed differences between sampled exposures in terms of vehicle mileage and estimated exposures from accident statistics invalidate induced exposure as a useful concept, or are there alternative explanations for the discrepancies which do not reflect badly on the theoretical concept itself?

One possibility is that observed differences might be due to sampling or statistical variability in either or both of the direct or induced exposure measures. For our data we can essentially exclude such variability in induced exposure measures as these are calculated from data on all North Carolina accidents officially reported in the given time period. The number of such accidents is sufficiently large so as to imply that variances of our induced exposure estimates were negligible. Further, though we have not completed analysis of variability of our direct exposure estimate, preliminary examination indicates that variation from this source is also small relative to the size of deviation from the induced exposure measure.

Another possibility is that our methods of directly ascertaining exposure are biased due to systematic tendencies to over or under estimate actual mileage, tendencies pronounced but different within various age specific or other subgroups within the driving population. This is a plausible explanation but one exceedingly hard to verify in a scientific manner. Another reasonable but unverifiable hypothesis is that the method we have used for determining guilt or innocence in a two car collision, i.e., violation or none, is a faulty indicator of true circumstances contaminated by "noise" unavoidable in the process by which participants and the investigating officer reconstruct the accident. Such "noise" would result in a curve for single accident drivers and for exposure representing boundaries within which "guilty" doubles and "innocent" doubles would fall, the "innocent" double curve falling closer to that of exposure.

However, let us suppose for the moment that none of these phenomena is occurring, that is, we assume that mileage is reported correctly, that investigating officers are readily able to distinguish guilt and innocence in a double car accident and that the induced exposure curve concept of Thorpe is essentially reasonable. Other factors nevertheless remain which might tend to produce the sort of differences observed here between the direct and induced exposure measures. This is so because we have chosen to directly measure exposure wholly in terms of vehicle miles. It is not widely recognized unfortunately that the concept of exposure used by Thorpe in deriving induced exposure methods, which refers to the probability of a vehicular encounter, is considerably different from the concept of exposure as measured by mileage. This is because the definition of exposure by "probability of encounter" implicitly assumes a dimension of duration, a time factor, whereas vehicle mileage itself does not.

To illustrate, consider two drivers on a stretch of roadway. One driver travels for ten miles at 30 miles per hour, the second for 20 miles at 60 miles per hour. For each ten mile stretch of roadway, a potentially "guilty" driver lies in wait for an "innocent" passerby. The "guilty" driver will collide with the passerby if the latter occupies a certain small interval of space within a particularly small interval of time. It can be easily shown that each of the two passing drivers have the same chance of being involved in a collision, though one experiences only half as much exposure as the other in terms of vehicle miles. This point may be made mathematically precise without difficulty. Thus speed affects exposure in terms of Thorpe's concept. Now suppose that those individuals who accrue highest vehicle mileage tend to travel on the average at a higher rate of speed than those who accumulate less mileage. This is probably true in the aggregate, urban taxi drivers being a notable exception. In terms of Thorpe's concept, exposure for the high mileage groups would be lower than indicated by vehicle mileage; conversely for the low mileage groups. This is consistent with our data. The use of vehicle mileage to indicate exposure from the point of view of "on the road encounters" obviously requires an assumption about speed being essentially equal for different groups of drivers. Other homogeneity assumptions (e.g. regarding road quality and conditions, traffic congestion), factors which make different vehicle miles unequal in terms of frequency of accidents, are also implicit in the comparison of induced exposure measures with vehicle mileage. Failures of such assumptions are an additional possible explanation for differences observed in our data.

The import of all these remarks is that it is impossible to disprove the induced exposure concept on the grounds of our comparison. Faulty reporting of vehicle mileage, faulty allocation of blame for accidents, or the possibility that induced exposure measures something qualitatively different than mileage - all may contribute to an apparent failure of induced exposure methods. On the other hand the vehicular encounter concept of exposure seems more reasonable than vehicle mileage as a basis for accident rate comparison. If the two types of measures differ, who is to say which is wrong.

In a practical sense however, we feel less comfortable with the idea of induced exposure than previously. If it is not reasonable to expect induced measures to describe vehicle mileage, it is nevertheless exceedingly difficult to specify exactly what they do describe in a manner subject to empirical verification. If induced exposure measures cannot be validated, their advocates become prophets who see a vision no one else can see. Such a vision is a poor base for scientific inquiry. If induced exposure is to prove a valuable tool, the issue of verification is of paramount importance. Until these measures can be associated with a well defined,confirmable pattern or parameter of roadway phenomema or until the theory behind it is otherwise substantiated such measures are unlikely to enjoy widespread use.

REFERENCES

Haight, Frank A. (1970). A crude framework for bypassing exposure. Journal of Safety Research 2, 26-29.

Thorpe, J.D. (1964). Calculating relative involvement rates in accident without determining exposure. Australian Road Research 2, 25-36.