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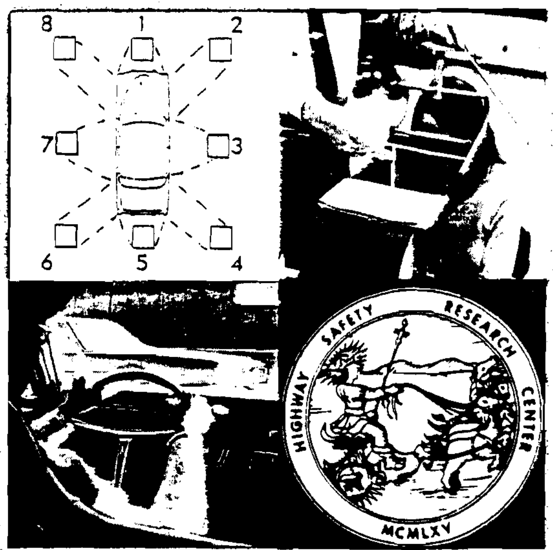

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HIGHWAY SAFETY
RESEARCH CENTER

University of North Carolina, Chapel Hill, N.C.

December 1974

The UNC Highway Safety Research Center was created by an act of the 1965 North Carolina General Assembly. A three-point mandate issued by the Governor authorized HSRC to 1) evaluate the state's highway safety programs, 2) conduct research, and 3) instruct and train other working professionals in highway safety.

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This study was partially supported by the North Carolina Governor's Highway Safety Program as part of project # 305-74-002-001, entitled, Driver License Road Testing, contracted with the North Carolina Department of Motor Vehicles and the University of North Carolina Highway Safety Research Center

The opinions and findings contained in this report are solely those of the authors, and are not necessarily those of the project's sponsors.

ABSTRACT

In an effort to determine possible relationships between lateral vision and accident involvement, the visual fields of over 52,000 North Carolina drivers were measured. The results indicated that:

1. Relatively accurate visual field data can be gathered in the field by driver license examiners.

2. Less than one percent of North Carolina drivers have total visual fields of 120 degrees or less.

3. Visual field is related to age with a higher proportion of older drivers having "limited" visual fields.

4. Overall two year retrospective accident experience of those with "limited visual fields" (140 degrees or less) does not differ from drivers with "normal" fields of view (greater than 160 degrees).

5. When examinees are divided into five age categories (≤25 years, 26-40 years, 41-60 years, 61-70 years, >70 years) there is again no significant evidence that narrower visual fields are related to higher accident involvement for any age group.

6. Restricted visual fields may be slightly related to a higher <u>proportion</u> of side-collisions.

While the results should not be interpreted as meaning that peripheral vision is unimportant in the operation of a vehicle, they do indicate that use of this particular tool as a driver screening measure should not be expected to result in any appreciable accident savings.

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ACKNOWLEDGMENTS

The authors wish to express their appreciation to the Driver License Division of the North Carolina Department of Motor Vehicles for their efforts in the data collection process. Without this, the study could not have been done.

Special thanks are expressed to Ms. Dorothy Ellis of the Department of Motor Vehicles and to Ms. Diane Pozefsky of HSRC for handling the computer programming necessary in this project.

I. INTRODUCTION

"Each state shall have a driver licensing program: (a) to insure that only persons who are physically and mentally qualified will be licensed to operate a vehicle on the highways of the state, and (b) to prevent needlessly removing the opportunity of the citizen to drive. The program shall provide, as a minimum, that: . . .

III. Each driver:

A. Passes an initial examination demonstrating his . . . visual acuity, which must meet or exceed State standards.

B. Is reexamined at an interval not to exceed four years, for at least visual acuity . . ."

The material above is part of the Highway Safety Program Standard No.5, Driver Licensing, one of the standards established by the National Highway Traffic Safety Administration as minimum goals for State Highway Safety Programs. At present all states require a test of either static or dynamic visual acuity in the initial examination of license applicants, and most require a test in the reexamination. However, fewer than half the states measure visual fields.

On intuitive grounds one might expect a person with a limited visual field, or "tunnel vision," to be involved in more accidents than he should simply because he is not able to monitor the total visual environment without greater than normal head movement. If this were found to be true, then it would appear to be necessary to identify these drivers within the driver licensing examination and reexamination process, and to "treat" them by either license restrictions or retraining.

At present, North Carolina is attempting to decide whether or not to use visual fields as a screening measure. While the state has had a driver license program since 1943, and has measured the static visual acuity of all license applicants in the initial licensing process and in the periodic reexamination for the past 22 years, visual field measurements have never been part of the licensing process. As a result of a long range program aimed at upgrading the licensing process, three basic questions concerning visual field have arisen.

1. Can the visual field of driver license applicants be accurately measured with available equipment by the state's driver license examiners?

2. How widespread is the problem of "tunnel vision," or limited visual field, among North Carolina drivers?

3. Is there a relationship between visual field and accident experience?

This report relates the results of a series of studies aimed at answering these three questions.

II. RESEARCH REVIEW

A cursory examination of the research literature on lateral vision and driving reveals little evidence to suggest what the minimum performance requirements of peripheral vision should be for safe driving. This lack of criteria is reflected in the choice of minimum binocular fields by states requiring lateral field measurements (i.e., ranges from 90 to 150 degrees). Opinions among those closely involved with research in the area also differ. Some feel that total visual fields of less than 160 degrees may seriously hamper safe driving performance (Allen, 1969), while others believe that driver and vehicular adjustments (more head and eye movements, side mirror usage, etc.) adequately compensate for even extremely limited fields of view (Richards, 1967). A recent report published by AAMVA and the American Optometric Association (Milkie, 1974) proposes criteria to be used by state driver licensing agencies. Based on past research, the author concludes that a total composite temporal horizontal field (the sum of the individual fields for each eye) of 140 degrees should be considered the minimum standard.

The extent to which the peripheral system is used is not entirely clear, although it is likely to play an especially important role as an object/motion detector. In this respect, resolution of details of an object is not nearly as important as the detection of "some" object either at rest or moving relative to the observer. Detail analysis on the other hand, is reserved for central vision. Recent work by Rockwell and his associates tends to support this view (Mourant, Rockwell, and Rackoff, 1969; Mourant and Rockwell, 1971). Other research indicates that peripheral vision may also be important for maintaining headway and roadway position (Bhise and Rockwell, 1971), planning subsequent eye movements (Mackworth, 1965; Sanders, 1966), and estimating speeds (Salvatore, 1968).

Although desirable, it may be unrealistic to expect simple visual field tests to gauge the soundness of peripheral vision for driving. While simple tests for the detection of non-moving objects do give one piece of information about the visual sensitivity of the retina to space around the observer, they do not reflect the more active role of eye and head during driving. In the real driving world, head and eye movements often effectively help increase the extent of visible space, and compensate for limitations in peripheral sensitivity. Such movements serve to improve what might be described as the functional (or usable) field of view. If a relationship does exist, it seems more likely that it would be found for those situations in which side vision is especially important (e.g., intersectional situations, side-swipes, etc.).

III. METHODOLOGY

In order to obtain information on the visual fields of a large sample of North Carolina drivers, driver license examiners throughout the state were used as data collectors. Bausch and Lomb Ortho-raters were equipped with perimeter testing devices consisting of a semi-circular arc calibrated into 5 degree intervals with a white circular target. The subject was seated in front of the device and instructed to fixate on a point directly in front of him. Each eye was tested separately.

The white target was then moved horizontally along a circular path from directly in back of the subject to the point on his side where he indicated he could see the target. The same procedure was then repeated with the other eye. Readings for the right and left eyes were summed to yield a total visual field. The entire procedure was conducted by the driver license examiner as part of the overall test of vision. Data for each subject and other identifying information were recorded on a special form for later analysis.

Subjects were North Carolina residents who had entered a driver licensing station to apply for a license during the month of December, 1972. Data were collected at almost all driver license stations across the state, except at a few stations in and around Raleigh where equipment was not available. All applicants were tested regardless of whether they were requesting an original license or a renewal license. The information was collected for research purposes only and was not used to help determine whether or not an applicant was granted a license. A total of 52,397 tests of applicants were run during the 30 day period.

(As will be discussed later, some of these were repeated tests on the same applicant.) Although it is conceivable that a "better" sample could have been drawn by testing randomly throughout a four year period, there is little reason to expect bias in the sample used since North Carolina drivers are required to return to a licensing station for reexamination on or slightly before their birthday every four years.

IV. RESULTS

To provide information on the three questions noted in the Introduction section, two basic analyses were conducted. The first involved studying repeated measures on a given individual to provide additional baseline information on the accuracy of the examiner-equipment system. Two previous studies by HSRC had indicated that the perimeter devices could be used by examiners to gather accurate data (Neil & Johns, 1972; Allen, Wood, & Wright, 1972). The second analysis explored the extent of the limited visual field problem and its relationship to accidents.

Examiner-Equipment System Accuracy

In an effort to provide further information concerning the accuracy of the examiner-device system, a subset of the data was analyzed. This subset was comprised of applicants who had been examined more than once during December 1972, either because the examiner conducted and recorded repeated tests, or because the applicant had failed some part of the licensing test (not necessarily the visual acuity test) earlier in the month and was returning for another try. In one group the applicant was tested by the same examiner more than once, while in a second group the same applicant was tested by different examiners. Of course, when using these "repeated measurements," the implied assumption is that the visual field of the applicant remains constant between tests, (i.e., remains constant over some time period less than or equal to 30 days).

In the sample of applicants tested, 315 were tested at least twice by the same examiner. Of these, 59 were tested twice on the same day (i.e., two data forms for the same applicant were completed the same day), and the remaining 256 were tested by the same examiner but on different days. The former group might be expected to contain some subjects who were tested twice because the examiner was "unsure" of the results of the first test for some reason and, therefore, immediately retested the applicant. The latter group would be composed of applicants who failed some part of the test procedure and returned on a different day for a second test under the same license examiner. There were also 370 applicants who were tested at least twice by different driver license examiners, either on the same day or on different days. Table 1 presents the results of comparing the data for the three groups of subjects with themselves. Here, the two left eye readings for the same subject were compared, the two right eye readings were compared, and the total visual field readings were compared (columns 1 through 3). Frequencies represent the number of times the readings were equal and the number of times they were unequal.

Table 1. Frequencies of equal and unequal visual fields for two trials for same subject.

	Left Eye	Right Eye	Total
Same examiner: same day	49 equal (83.1%) 10 unequal 59	49 equal (83.1%) 10 unequal 59	47 equal (79.7%) 12 unequal 59
Same examiner: different day	207 equal (80.9%) 49 unequal 256	208 equal (81.3%) 48 unequal 256	203 equal (79.3%) 53 unequal 256
Different examiner	275 equal (74.3%) 95 unequal 370	273 equal (73.8%) 97 unequal 370	266 equal (71.9%) 104 unequal 370

As might be expected, the frequencies in the table indicated that the highest degree of agreement between two readings on the same subject when readings were made by the same examiner on the same day; next were the cases in which the same examiner tested the same individual on different days; and last were those cases in which different examiners tested the same individual. Of most interest here, however, are the actual percentages of equal readings for the three groups. In all cases for each eye and total visual field, the two readings were equal at least 71.9 percent of the time. This lowest percentage of equal readings occurred in the total visual fields when two different examiners conducted the two tests on the same subject. The highest percentage of equal readings was noted in left and right eye visual field measurements when the same examiner tested an individual twice on the same day (83.1 percent of the readings were equal). Conversely, these data indicate that the readings _did not_ agree in up to 29 percent of the tests.

To examine the statistical importance of these differences, data in each of the nine cells were analyzed. Because the two readings were for the same applicants, and therefore not independent, the data were viewed as "paired" data. The null hypothesis tested was one of no differences between the two readings (i.e., the calculated difference between the readings was not different from zero). The test statistic used was:

$$t = \frac{|\bar{d}|}{\sqrt{\left(\frac{\sum_{i}^{n}(d_i - \bar{d})^2}{n\,(n-1)}\right)}}$$

where d_i = the difference between the two readings in question (i.e., left eye trial one minus left eye trial two).

$\bar{d} = \frac{\sum_{i}^{n} di}{n}$ = the mean difference between the two readings in question for the cell involved (i.e., same examiner, same day, left eye visual field).

Analysis of the top three cells (same examiner-same day) indicated that the calculated difference between the two readings for right eye, left eye, and total visual fields were not significantly different from zero at the $\alpha = .05$ level. Analysis of the next row of cells (same examiner-different day) indicated significant differences from zero for the left eye ($\alpha = .05$) and total visual fields ($\alpha = .05$) but not for the right eye. Analysis of the final row of cells (different examiner) indicated that, just as in the first group, the calculated differences were not significantly different ($\alpha = .05$). While these results are somewhat confusing because of their lack of consistency, the tentative conclusion might be drawn that the examiner-device system appeared to measure visual fields accurately.

Further support for this tentative conclusion is provided by the data in Table 2 below. Here, the frequencies of equal and unequal total visual fields are presented when a $\pm$ 5 degrees and $\pm$ 10 degrees tolerance is allowed. That is, for a given subject, if the total visual field in trial 2 was within $\pm$ 5 degrees (or $\pm$ 10 degrees) of the total visual field in trial 1, the readings were called "equal." Here "equality" of reading was noted in at least 77.6 percent of the cases with a $\pm$ 5 degree tolerance and in at least 87.8 percent of the cases when a $\pm$ 10 percent tolerance was allowed.

Table 2. Frequencies of "equal" and "unequal" total visual fields with tolerance allowed.

Total visual field with $\pm 5°$ tolerance	Total visual field with $\pm 10°$ tolerance
50 equal (84.7%)	54 equal (91.5%)
9 unequal	5 unequal
59	59
210 equal (82.0%)	226 equal (88.3%)
46 unequal	30 unequal
256	256
287 equal (77.6%)	325 equal (87.8%)
83 unequal	45 unequal
370	370

These figures indicate that in the majority of cases, the examiner-device system accurately measured total visual field to within $\pm$ 10 degrees. Again, however, the fact that there were some cases in which the readings did not "agree" (at least 8 percent) points out the need for caution when using the system as a basis for determining restrictions on driving.

Visual Field and Accidents

The second set of analyses explored questions concerning the extent of the limited visual field problem and its relationship with accidents. In the following discussions, visual fields were grouped into ten degree ranges. Table 3 indicates the number of applicants whose visual fields fell in each of these ranges. The 44,999 subjects included in this table are those subjects who could be matched with names in the North Carolina Driver file on January 31, 1973.

Of particular interest in Table 3 is the furthermost column on the right where the cumulative percentage of total visual field at or less than a particular limit is presented. Again, total visual fields were determined by summing the visual fields of both the left and the right eyes of a subject. It is notable that only two of the 44,834 applicants tested (.0044 percent) had a visual field less than or equal to 50 degrees, which is a severely limited visual field. Less than one-tenth of one percent (.0848 percent) of the applicants had total visual fields less than or equal to 90 degrees. Less than one percent of the applicants

Table 3. Right eye, left eye, and total visual field (both eyes) of applicants tested.

Visual Field	Frequency	%	Frequency	%	Frequency	%	Cumulative %
1-10°	7	0.02	2	0.00	0	0.00	0.00
11-20°	3	0.01	3	0.01	0	0.00	0.00
21-30°	18	0.04	8	0.02	1	0.00	0.00
31-40°	47	0.10	38	0.09	0	0.00	0.00
41-50°	165	0.37	122	0.27	1	0.00	0.00
51-60°	469	1.05	422	0.94	4	0.01	0.01
61-70°	1899	4.23	1586	3.53	2	0.00	0.02
71-80°	10968	24.45	10610	23.64	5	0.01	0.03
81-90°	29973	66.81	30639	68.27	25	0.06	0.08
91-100°	1311	2.92	1445	3.22	61	0.14	0.22
101-110°	3	0.01	6	0.01	72	0.16	0.38
111-120°					245	0.55	0.93
121-130°					360	0.80	1.73
131-140°					1098	2.45	4.18
141-150°					2110	4.71	8.89
151-160°					7634	17.03	25.91
161-170°					12212	27.24	53.15
171-180°					19401	43.27	96.42
181-190°					1582	3.53	99.95
191-200°					17	0.04	99.99
201-210°					2	0.00	100.00
211-220°					2	0.00	100.00
Subtotal	44863	(100.01%)	44881	(100.00%)	44834	(100.00%)	
*Error	136		118		165		
Total	44999		44999		44999		

* This category includes keypunch errors, erroneous data, etc.

(0.928 percent) had visual fields less than or equal to 120 degrees. And less than five percent (4.18 percent) had visual fields less than or equal to 140 degrees, the AAMVA criterion. Approximately 75 percent of the tested subjects had total visual fields greater than 160 degrees. These data seem to indicate that having a severely limited visual field is not a common characteristic of North Carolina driver license applicants. Indeed, only a very small proportion of the applicants appear to have a "limited" visual field.

To examine the relationship between limited visual field and accident involvement, the 44,834 subjects who were tested in December, 1972 were linked with the North Carolina Accident File, and information on the number and type of accidents that these applicants were involved in over the previous two years (Jan. 1, 1971 - Dec. 31, 1972) was examined. Because some of the subjects were applicants for original N.C. licenses and others had held a North Carolina license for less than two years, the sample was limited to the 37,372 subjects with a valid North Carolina license on January 1, 1971 and whose age as of January 1, 1973 was known. Thus, all subjects in the remaining sample could have accumulated accidents over the same two-year period.

Since this study design is retrospective in nature, it is handicapped by the bias inherent in this type of design (i.e., the implicit assumption that the visual fields measured in December, 1972 would have been the same over the two-year period beginning in January, 1971 for each subject). However, it is felt that the nature of the variable measured is such that meaningful conclusions can be drawn from analyses of these retrospective data.

The total visual fields for this sample of applicants, the number of accident-involved applicants, and the number of accidents accrued by these applicants within each 10 degree visual field range are shown in Table 4. For example, there were 67 subjects with total visual fields between 101 and 110 degree (.18 percent of 35,372), and 8 of these subjects were involved in 11 accidents (.183 percent of all accidents).

In analyzing these data, a comparison of the distribution of visual fields of the accident-free applicants with that of the accident-involved applicants was conducted using the Kolomogorov-Smirnov test for a difference between two independent samples. (Note that the first of these two samples is not explicitly shown in Table 4, but is obtained by subtracting the frequencies of accident-involved applicants (column 4) from the total number of applicants (column 1)). This sample was then compared to the sample presented in column 4. This analysis indicated that the distribution of visual fields of the accident-involved sample was indeed different from the distribution of the accident-free sample ($p < .001$). Surprisingly, however, the distribution of visual fields for the accident-involved drivers was shifted upward from that of the accident-free drivers. That is, the accident-involved drivers had slightly <u>larger visual fields</u> than the sample of drivers who had no accidents. It

Table 4. Number of applicants, number of accident-involved applicants, and number of accidents involving applicants within each 10° total visual field range.

Total Visual field range	Number of Applicants	Percent of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0.000	0	0	0.000	0.000
11-20	0	0.000	0.000	0	0	0.000	0.000
21-30	1	0.003	0.003	0	0	0.000	0.000
31-40	0	0.000	0.003	0	0	0.000	0.000
41-50	1	0.003	0.006	0	0	0.000	0.000
51-60	4	0.011	0.017	0	0	0.000	0.000
61-70	2	0.005	0.022	0	0	0.000	0.000
71-80	5	0.013	0.035	0	0	0.000	0.000
81-90	21	0.058	0.093	2	2	0.033	0.033
91-100	58	0.155	0.248	8	9	0.150	0.183
101-110	67	0.179	0.427	8	11	0.183	0.366
111-120	228	0.610	1.037	29	30	0.500	0.866
121-130	331	0.886	1.923	54	66	1.100	1.966
131-140	1002	2.681	4.604	116	140	2.333	4.299
141-150	1883	5.039	9.643	239	268	4.466	8.765
151-160	6580	17.607	27.250	874	996	16.597	25.362
161-170	10164	27.197	54.447	1319	1493	24.879	50.241
171-180	15742	42.122	96.569	2351	2731	45.509	95.750
181-190	1266	3.388	99.957	220	250	4.166	99.916
191-200	14	0.037	99.994	4	5	0.083	99.999
201-210	1	0.003	99.997	0	0	0.000	99.999
211-220	2	0.005	100.002	0	0	0.000	99.999
Total	37372	100.002		5224	6001	100.000	

should be noted, however, that this upward shift was of a very small magnitude. This difference should not be interpreted as meaning that larger visual fields "cause" accidents, since any other factor which covaries with visual fields (such as driver age) may also convary with accident rates.

What is important, however, is that there is no indication in Table 4 that drivers with limited visual fields account for <u>more</u> than their share of accidents. Comparing column 3 with column 7 (cumulative percentages of visual fields with cumulative percentages of accidents) makes this even more graphic. Here, for example, .091 percent of the applicants had total visual fields of less than or equal to 90 degrees. This group of drivers accounted for only .033 percent of the accidents. If these people had accounted for their "share" of accidents, they would have been expected to account for approximately .091 percent of the accidents. Similarly, the 1.036 percent of the applicants who had visual fields of less than or equal to 120 degrees accounted for .867 percent of the accidents, and the 4.602 percent of the drivers who had visual fields of 140 degrees or less accounted for 4.299 percent of the accidents. The rate of accident involvement for both of these groups is less than their "share." Although it is obvious that the difference between observed accident percentages and the "expected" percentages are not significant, the data do indicate that people with "limited" visual fields may <u>not</u> be involved in more than their share of accidents.

Because of the strong relationship between age and visual field shown in previous studies (Burg, 1967), it was felt that there might well exist relationships between visual field and accidents within age groups which might not be evident when all age groups are combined as above. Such hypothesized relationships, if found, would provide rationale for using visual field as a screening tool for special age groups of driver license applicants, even though other age groups might be excluded from such screening.

To examine this, the applicants tested were divided into five age groups ($\leq$25 years, 26-40 years, 41-60 years, 61-70 years, $\geq$71 years). Table 5 on the next page indicates that there are indeed differences between the visual field distributions of these age groups ($\chi^2 > 6000$, $p \leq .001$). As might be expected, the visual fields of older drivers appear to be more limited than those of younger drivers. This can be seen in Table 5 by reading the column labeled "Cumulative Percent" for a given visual field range. For example, in the ninth row of the table, only 0.037 percent of the youngest group and only 0.030 percent of the next youngest group of drivers have visual fields of 90 degrees or less, whereas 0.053 percent of the 41-60 year old group, 0.397 percent of the 61-70 year old group, and 0.776 percent of the oldest group have visual fields of 90 degrees or less. This rather systematic increase in the percentage of drivers with a given visual field as age increases is also evident in the remaining rows. Thus, there is little doubt that the

Table 5. Age and visual fields of applicants tested.

	AGE									
	<25		26-40		41-60		61-70		>71	
Total Visual Field	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent	Frequency	Cumulative Percent
1-10	0	0	0	0	0	0	0	0	0	0
11-20	0	0	0	0	0	0	0	0	0	0
21-30	0	0	0	0	1	0.008	0	0	0	0
31-40	0	0	0	0	0	0.008	0	0	0	0
41-50	1	0.007	0	0	0	0.008	0	0	0	0
51-60	0	0.007	2	0.015	0	0.008	1	0.003	1	0.078
61-70	0	0.007	0	0.015	0	0.008	1	0.006	1	0.155
71-80	0	0.007	0	0.015	0	0.008	3	0.165	2	0.310
81-90	4	0.037	2	0.030	6	0.053	7	0.397	6	0.776
91-100	3	0.059	8	0.089	24	0.233	11	0.761	15	1.939
101-110	3	0.081	9	0.155	24	0.413	16	1.290	21	3.569
111-120	27	0.281	39	0.443	60	0.864	61	3.307	59	8.146
121-130	48	0.635	36	0.708	133	1.863	82	6.019	59	12.723
131-140	125	1.558	183	2.059	398	4.852	235	13.790	149	24.282
141-150	307	3.826	377	4.841	838	11.146	397	26.918	189	38.945
151-160	1528	15.111	1917	18.989	2945	33.266	879	55.985	346	65.787
161-170	3514	41.064	3720	46.443	3936	62.829	763	81.217	253	85.415
171-180	7293	94.926	6714	95.993	4614	97.484	542	99.140	177	99.147
181-190	678	99.934	536	99.948	333	99.985	25	99.967	9	99.845
191-200	7	99.985	6	99.993	2	100.000	1	100.000	1	99.922
201-210	1	99.993	1	100.000	0	100.000	0	100.000	0	99.922
211-220	1	100.000	0	100.000	0	100.000	0	100.000	1	100.000
	13540		13550		13314		3024		1289	

$\chi^2 > 6000$ with 72 df , $p < .001$

proportion of older drivers who have limited fields of vision is greater than the proportion of younger drivers with this limited field -- regardless of how "limited" is defined.

The important question, however, is whether there exist strong relationships between these visual fields and accidents within these age groups. Tables 6-10 present data comparable to that of Table 4 for each age group. Again all applicants in these tables had driving records of greater than two years and the accident data used is for the same two-year period as before (i.e., two years immediately prior to testing).

In order to test for differences between the visual field distributions of the accident-involved and accident-free drivers within each age group, the Kolomogorov-Smirnov test for a difference between two independent samples was again used. The only one of the five tests which was significant at the <.01 level involved the 41-60 year old drivers. Here the accident-free drivers were characterized by more limited visual fields than their accident-involved counterparts, a finding which is not in the direction which would support use of visual fields as a screening device.

Because this particular analysis involved only accident-free versus accident-involved drivers (i.e., one or more accidents), it would not detect difference in groups with multiple accidents versus those with only one accident. Since it might be hypothesized that drivers with limited visual fields are more likely to be involved in repeated acci-

Table 6. Number of applicants, number of accident-involved applicants, and number of accidents involving applicants within each 10° total visual field range for applicants less than 26 years of age.

Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	1	0.011	0	0	0.000	0.000
51-60	0	0.011	0	0	0.000	0.000
61-70	0	0.011	0	0	0.000	0.000
71-80	0	0.011	0	0	0.000	0.000
81-90	3	0.044	0	0	0.000	0.000
91-100	3	0.077	0	0	0.000	0.000
101-110	2	0.098	0	0	0.000	0.000
111-120	21	0.328	2	2	0.098	0.098
121-130	36	0.722	11	15	0.734	0.832
131-140	83	1.630	14	18	0.881	1.713
141-150	210	3.927	44	50	2.446	4.159
151-160	1015	15.032	193	232	11.350	15.509
161-170	2303	40.229	421	494	24.168	39.677
171-180	5000	94.934	955	1121	54.843	94.521
181-190	457	99.934	95	109	5.333	99.884
191-200	5	99.989	2	3	0.147	100.000
201-210	0	99.989	0	0	0.00	100.000
211-220	1	100.000	0	0	0.00	100.000
	9140		1737	2044		

Table 7. Number of applicants, number of accident-involved applicants, and number of accidents involving applicants within each 10° total visual field range for applicants from 26 through 40 years of age.

Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	0	0.000	0	0	0.000	0.000
51-60	2	0.017	0	0	0.000	0.000
61-70	0	0.017	0	0	0.000	0.000
71-80	0	0.017	0	0	0.000	0.000
81-90	1	0.025	1	1	0.053	0.053
91-100	7	0.085	0	0	0.000	0.053
101-110	8	0.153	1	1	0.053	0.106
111-120	36	0.458	8	8	0.421	0.527
121-130	35	0.755	6	7	0.368	0.895
131-140	166	2.163	28	31	1.632	2.527
141-150	341	5.055	50	57	3.000	5.527
151-160	1660	19.135	244	274	14.421	19.948
161-170	3257	46.760	428	473	24.895	44.842
171-180	5807	96.014	803	944	49.684	94.527
181-190	464	99.949	89	104	5.474	100.000
191-200	5	99.992	0	0	0.000	100.000
201-210	1	100.000	0	0	0.000	100.000
211-220	0	100.000	0	0	0.000	100.000
	11790		1658	1900		

211-220	0	100.000	0	0	0.000	100.000
	11790		1658	1900		

Table 8. Number of applicants, number of accident-involved applicants, and number of accidents involving applicants within each 10° total visual field range for applicants from 41 through 60 years of age.

Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	1	0.008	0	0	0.000	0.000
31-40	0	0.008	0	0	0.000	0.000
41-50	0	0.008	0	0	0.000	0.000
51-60	0	0.008	0	0	0.000	0.000
61-70	0	0.008	0	0	0.000	0.000
71-80	0	0.008	0	0	0.000	0.000
81-90	5	0.049	0	0	0.000	0.000
91-100	22	0.227	2	2	0.130	0.130
101-110	22	0.405	6	7	0.456	0.587
111-120	55	0.850	6	6	0.391	0.978
121-130	121	1.829	14	19	1.239	2.216
131-140	382	4.920	35	40	2.608	4.824
141-150	774	11.184	87	96	6.258	11.082
151-160	2757	33.495	280	314	20.469	31.551
161-170	3643	62.976	383	429	27.966	59.518
171-180	4259	97.443	517	584	38.070	97.588
181-190	314	99.984	35	36	2.347	99.935
191-200	2	100.000	1	1	0.065	100.000
201-210	0	100.000	0	0	0.000	100.000
211-220	0	100.000	0	0	0.000	100.000
	12357		1366	1534		

Table 9. Number of applicants, number of accident-involved applicants, and number of accidents involving applicants within each 10° total visual field range for applicants from 61 through 70 years of age.

Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	0	0.000	0	0	0.000	0.000
51-60	1	0.035	0	0	0.000	0.000
61-70	1	0.070	0	0	0.000	0.000
71-80	3	0.176	0	0	0.000	0.000
81-90	6	0.387	0	0	0.000	0.000
91-100	11	0.773	3	4	1.105	1.105
101-110	16	1.335	0	0	0.000	1.105
111-120	58	3.373	4	4	1.105	2.210
121-130	80	6.184	16	17	4.696	6.906
131-140	225	14.090	20	23	6.354	13.260
141-150	378	27.372	42	49	13.536	26.796
151-160	816	56.044	114	128	35.359	62.155
161-170	720	81.342	68	77	21.271	83.425
171-180	508	99.192	54	60	16.575	100.000
181-190	22	99.965	0	0	0.000	100.000
191-200	1	100.000	0	0	0.000	100.000
201-210	0	100.000	0	0	0.000	100.000
211-220	0	100.000	0	0	0.000	100.000
			321	362		

Table 10. Number of applicants, number of accident-involved applicants, and number of accidents involving applicants within each 10° total visual field range for applicants greater than 70 years of age.

Total Visual Field Range	Number of Applicants	Cumulative Percent	Number of Accident Involved Applicants	Number of Accidents	Percent of Accidents	Cumulative Percent
0-10°	0	0.000	0	0	0.000	0.000
11-20	0	0.000	0	0	0.000	0.000
21-30	0	0.000	0	0	0.000	0.000
31-40	0	0.000	0	0	0.000	0.000
41-50	0	0.000	0	0	0.000	0.000
51-60	1	0.081	0	0	0.000	0.000
61-70	1	0.161	0	0	0.000	0.000
71-80	2	0.323	0	0	0.000	0.000
81-90	6	0.807	1	1	0.621	0.621
91-100	15	2.018	3	3	1.863	2.484
101-110	19	3.551	1	3	1.863	4.348
111-120	58	8.232	9	10	6.211	10.559
121-130	59	12.994	7	8	4.969	15.528
131-140	146	24.778	19	28	17.391	32.919
141-150	180	39.306	16	16	9.938	42.857
151-160	332	66.102	43	48	29.814	72.671
161-170	241	85.553	19	20	12.422	85.093
171-180	168	99.112	22	22	13.665	98.758
181-190	9	99.839	1	1	0.621	99.379
191-200	1	99.919	1	1	0.621	100.000
201-210	0	99.919	0	0	0.000	100.000
211-220	1	100.000	0	0	0.000	100.000
	1239		142	161		

dents, further analysis involved the mean number of accidents per driver for various groups of drivers. Within each age group, the number of accidents/driver for drivers with visual fields of $\leq$ 90 degrees, $\leq$ 100 degrees, $\leq$ 110 degrees, $\leq$ 120 degrees, $\leq$ 130 degrees, and $\leq$ 140 degrees were compared with the number of accidents/driver for drivers with visual fields of $\geq$ 161 degrees (the "normal" visual field group).

Table 11 presents the data as used in these analyses. For each age group, the number of drivers with 0, 1, 2, 3, 4 or 5 accidents are presented within each visual field range. (Note that drivers with visual fields of $\leq$ 90 degrees would also be in the $\leq$ 100 degrees category, etc.). Also presented are the average number of accidents per drivers and the variance for accidents/driver. Because the means and variables were approximately equal, underlying Poisson distributions were assumed, and normal approximation of the difference between two Poisson distributed means was used where sample sizes permitted. The values for and the corresponding p-values are given for cases where the tests were significant at the $\alpha \leq .10$ level.

It is noted that in only two cases are the difference between the means significant at a $\alpha \leq .10$ level. For the $\leq$ 25 age group, the mean number of accidents/driver for drivers with visual fields of 120 degrees or less is significantly less than the mean accident/driver for the normal group ($p < .01$), a finding in the opposite direction than would be expected. However, similar significant differences are not found in

Table 11. Frequency of accidents and mean and variance of accident/driver for various "limited" fields of vision and a "normal" field of vision.

Age	Total Visual Field	Accidents 0	1	2	3	4	5	$\overline{x}$	s^2	z
≤ 25	$<90°$	4	0	0	0	0	0	0	0	
	$\leq 100°$	7	0	0	0	0	0	0	0	
	$\leq 110°$	9	0	0	0	0	0	0	0	
	$\leq 120°$	28	2	0	0	0	0	.066667	.064368	-3.337 ($p<.01$)
	$\leq 130°$	53	9	4	0	0	0	.257576	.317249	0.506 (NS)
	$\leq 140°$	122	20	6	1	0	0	.234899	.302558	0.276 (NS)
	$\geq 160°$	6293	1251	194	25	2	1	.222380	.247901	
26-40	$<90°$	2	1	0	0	0	0	.333333	.333333	.521 (NS)
	$\leq 100°$	9	1	0	0	0	0	.100000	.100000	-.595 (NS)
	$\leq 110°$	16	2	0	0	0	0	.111111	.104575	-.634 (NS)
	$\leq 120°$	44	10	0	0	0	0	.185185	.153739	.479 (NS)
	$\leq 130°$	73	15	1	0	0	0	.191011	.179009	.699 (NS)
	$\leq 140°$	211	41	2	1	0	0	.188235	.192774	1.031 (NS)
	$\geq 160°$	8214	1146	152	17	5	0	.159534	.182980	
41-60	$<90°$	6	0	0	0	0	0	0	0	
	$\leq 100°$	26	2	0	0	0	0	.0714286	.068783	1.133 (NS)
	$\leq 110°$	42	7	1	0	0	0	.180000	.191429	.842 (NS)
	$\leq 120°$	91	13	1	0	0	0	.142857	.142857	.407 (NS)
	$\leq 130°$	198	22	6	0	0	0	.150442	.181711	.791 (NS)
	$\leq 140°$	545	52	11	0	0	0	.121711	.143317	.381 (NS)
	$\geq 160°$	7282	831	97	7	1	0	.127768	.141638	
61-70	$<90°$	11	0	0	0	0	0	0	0	
	$\leq 100°$	19	2	1	0	0	0	.181818	.251082	.674 (NS)
	$\leq 110°$	35	2	1	0	0	0	.105263	.150782	-.0667(NS)
	$\leq 120°$	89	6	1	0	0	0	.083333	.098246	-.781 (NS)
	$\leq 130°$	153	21	2	0	0	0	.142045	.145422	1.0684(NS)
	$\leq 140°$	358	39	3	1	0	0	.119701	.135636	.486 (NS)
	$\geq 160°$	1129	110	9	3	0	0	.109512	.126397	
≥ 71	$<90°$	9	1	0	0	0	0	.100000	.100000	.0471(NS)
	$\leq 100°$	21	4	0	0	0	0	.160000	.140000	.723 (NS)
	$\leq 110°$	39	4	0	0	0	0	.159091	.276427	.673 (NS)
	$\leq 120°$	88	12	1	0	0	0	.138614	.140594	.839 (NS)
	$\leq 130°$	140	18	2	0	0	0	.137500	.144497	.920 (NS)
	$\leq 140°$	267	33	4	2	0	1	.169381	.271870	+1.930 ($p<.10$)
	$\geq 160°$	377	42	1	0	0	0	.104762	.098784	

the other groups of "limited" fields of vision for these young drivers. For the oldest group of drivers (i.e., age $\geq$ 71) the number of accidents/driver is greater for drivers with fields of vision $\leq$ 140 degrees than for the "normal" group ($p < .10$). Again, the differences associated with all the other "limited" groups (i.e., $\leq$ 90 degrees, $\leq$ 100 degrees, $\leq$ 110 degrees, $\leq$ 120 degrees, $\leq$ 130 degrees) for this age group are not significant.

Thus, comparisons of accidents/driver for various "limited" visual fields with the accidents/driver for "normal" visual fields indicate no strong relationships between visual fields and driving records. The only association indicated was for the oldest driver with visual field of 140 degrees. Even this relationship was relatively weak, and was not significant in other levels of limited fields (perhaps because of sample size). This method of analysis was also used to attempt to determine what should be a "cutoff" point for defining visual field. No such level of visual field is evident. These findings for different age groups further support the original overall findings which showed no relationships between visual field and accident record.

The data were also analyzed to investigate the possibility of a difference in type of accident between the drivers with "limited" visual fields and those with "normal" fields. It might be hypothesized that the limited group would be involved in more side collisions than the "normal" group because of the former's inability to effectively monitor the total visual environment. Here, the accident data for the group of drivers with total visual fields of less than or equal to 120 degrees, the criterion for a classification of "limited" for this analysis, were compared with the data for the group of drivers with total visual fields of greater than 160 degrees, who will be defined as having "normal" visual fields. It will be recalled that approximately 75 percent of the applicants tested would be included in this "normal" range.

Two accident related variables were examined, the initial point of contact and the TAD scale primary damage area. For each accident investigated in North Carolina, point of initial contact is entered on the Standard Accident Report Form. The figure below is present on this form, and the proper code is entered for later use. In Table 12 accidents involving the subjects are divided into "side collisions" (points 2, 3, 4, 6, 7, 8 in Figure 1) and "other collisions" (points 1 and 5 in Figure 1).

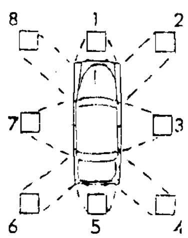

Figure 1. "Point of Initial Contact" drawing taken from North Carolina's Standard Accident Report Form.

Table 12. Frequency of accidents by point of contact and total visual field.

		Point of Contact		
		Slide	Other	Total
Total Visual Field	$\leq 120°$	34 (75.6%)	11 (24.4%)	45
	$>160°$	1720 (53.9%)	1474 (46.2%)	3194

$\chi^2 = 7.568$ (with Yates' Correction)

Analysis of these data revealed a significant difference between the "limited" and the "normal" visual field groups ($p < .01$). The "limited" group of drivers does indeed appear to be involved in a higher proportion of side collisions than the "normal" group.

Additional support for this finding is found when areas of damage as indicated by TAD scale[1] codes are examined. Table 13 presents the frequencies of accidents involving the "limited" and "normal" groups classified by area of major damage, either "side" or "other."

[1]*The TAD scale is a pictorial damage rating scale used by the North Carolina State Highway Patrol and various municipal police forces in their accident investigations.*

Table 13. Frequencies of accidents by TAD scale area of damage and visual field

		Side	Other	Total[1]
Total Visual Field	$\leq 120°$	11 (64.7%)	6 (35.3%)	17
	>160°	474 (36.1%)	841 (63.9%)	1315

$\chi^2 = 4.781$ (with Yates' Correction)

Again the analysis indicated a significant difference between the two groups of drivers ($p < .05$), and once again the "limited" group was found to be involved in a higher proportion of side-type collisions.

V. DISCUSSION

The Driver Licensing Division of the North Carolina Department of Motor Vehicles, in its continuing efforts to upgrade the licensing process, collected data on visual fields of 52,397 applicants who were tested during December, 1972. The analyses of these data indicate five basic findings.

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[1]*It should be noted that the difference in the "Total" columns of Tables 12 and 13 reflects the more extensive use of the "point of initial contact" across all accident investigations. At the time of this study, not all municipal police departments had been trained in the use of the relatively new TAD scale.*

First, examination of repeated tests of the same applicant indicate that the perimeter device/license examiner system could measure visual fields with a relatively high degree of accuracy, a result which supports previous laboratory work (Neil & Johns, 1972; Allen, Wood, & Wright, 1972).

Second, limited visual field appears to be a low probability phenomenon which affects only a very small part of the applicant population in North Carolina.

Third, this very small number of affected subjects does not appear to be involved in more than their share of accidents (i.e., their accident experience is no different than that of the "normal" group).

Fourth, even though visual field is strongly associated with age, no strong relationships are found between visual field and driving record, even within age groups.

And fifth, comparisons of corresponding groups of drivers whose visual fields are "normal" with those whose visual fields are "limited" appear to indicate that the latter groups are involved in more side-impact collisions.

The importance of these findings for a driver license administrator lies in their possible use as a basis for initiating this measure as a screening tool for driver license restrictions. The present results indicate that this measure should not be used for all drivers as a basis for determining licensing restrictions. The drivers whose licenses would be restricted by this process do not at present without restrictions have any more than their share of accidents. Therefore, any restrictions would be an unnecessary "penalty" to individuals with "limited" visual fields, because data indicate that they are no worse drivers than individuals with "normal" visual fields.

The last of the five findings, the one which indicates that drivers with "limited visual fields appear to be involved in more side-impact collisions, may be incorporated into an "educational" program. Such a program would consist of informing drivers with "limited visual fields that, in the past, drivers with similar problems have been involved in a greater-than-average number of side collisions. Hopefully, once drivers with "limited" visual fields have been given this information, they will be more careful when they encounter driving situations in which side collisions are likely to occur (e.g., negotiating intersections). The possible use of visual field information for these "educational" purposes raises some important benefit-cost questions. In addition to the basic equipment costs, use of the equipment in a driver licensing program would require additional time on the part of the examiner <u>and</u> the public. And again, these data indicate that 95 to 99 percent of the persons tested would not receive any benefit from such expenditures. Whether or not the benefit to the one to five percent of the driver license applicants who actually fall into the "limited" group is worth these accompanying costs is a question which administrators must answer.

Finally, it should be noted that these results should not be interpreted as meaning that peripheral vision is an unimportant factor in the operation of a motor vehicle. There may well be other and better ways of measuring this characteristic which might indicate its usefulness as a screening tool for special groups of drivers. Nevertheless, the present data do indicate that the use of the present system as screening tool should not be expected to result in appreciable accident savings.

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