VISUAL TESTS FOR DRIVER LICENSING

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Officials have long sought a valid and reliable testing technique for use in driver licensing. The 3 general types of screening techniques in common use today (driving tests, "rules-of-the-road" written examinations, and one or more vision tests) have been selected because of their "face validity" and because of cost considerations; there is no substantial evidence that they do an adequate job of measuring driving ability or of predicting driving performance. The dramatic upsurge in interest and of activity in traffic safety brought about by creation of the National Highway Safety Bureau in 1966 has led to a critical evaluation of all aspects of driver licensing, an evaluation that is still under way.

The choice of vision tests for use in driver licensing should be based on factual information concerning the relations between various aspects of visual performance and driving performance. Research in this area has until recently failed to define basic relations between any of the various vision-screening devices and driving ability, regardless of the measure used. Goldstein (13) reviewed research on vision and driving up to 1961 and found no study that obtained more than a very slight correlation between accident records and measures such as visual acuity. Burg (3, p. 20) extended this review to 1964, at which time he stated that "...at the present time there is no widely recognized evidence that vision is related to driving." Two years later, another report (19, p. 76) contained the following statement: "At the present time, valid information is not available on relationships between various visual impairments and accidents."

Since the A. D. Little report (19) was published, however, findings from a major study of vision and driving conducted in California provide evidence that a small but significant relation exists between certain visual performance capabilities and driving record (9). The following sections will discuss these and other research findings and will explore their implications for driver licensing.

CURRENT VISION-SCREENING PRACTICES IN DRIVER LICENSING

The most recent data on driver licensing practices (20), when compared with the findings of earlier surveys (1, 12), reveal that there is an unmistakable movement toward greater uniformity among the states, both in administrative practices and in level of visual performance required for driver licensing. Undoubtedly, the emphasis placed on uniform driver-licensing practices among the states by the National Highway Safety Bureau [now the National Highway Traffic Safety Administration (NHTSA)] has played a large role in bringing about this trend toward uniformity of vision-screening procedures. The 1969 survey (20) revealed the following information about practices among the states at that time.

All 50 states and the District of Columbia required a visual acuity test of first-time applicants, but only 26 states and the District of Columbia regularly included a vision test in their reexamination of renewal applicants. Six additional states required reexamination, presumably including vision, after the applicant reached a certain age (varying from 65 to 75). Thus, in 18 states, no visual examination was scheduled after the initial license was issued. (It is possible that these figures may have changed somewhat in the 3 years since this survey was conducted.)

According to the 1969 survey, visual requirements for initial issue of a driver's license in the 50 states (plus the District of Columbia) may be summarized as follows:

1. Testing of depth perception is required in 25 states, is administered in special cases in the District of Columbia, and is optional with examiners in one state;
2. Fusion tests are given in one state (in place of depth perception);
3. Testing of color vision is required in 43 states and the District of Columbia and is administered in special cases in one state; and
4. Eye-foot reaction time is tested in 2 states, is optional with examiners in one state, and is tested in special cases in one state and the District of Columbia.

Data relating to acuity and visual field requirements are given in Tables 1 and 2.

In view of the long history of interest in night vision, the large number of research reports dealing with various aspects of night vision as it relates to driving, and the fact that more than one-half of all fatal accidents occur at night, it is particularly significant that at the present time no state includes a test of night vision in its testing program. It is also significant that, in spite of the dynamic nature of the driving task, no state currently utilizes any measure of the dynamic aspects of visual performance. The dynamic aspects of visual performance do not include only dynamic visual acuity or the coordination of the eye-movement musculature. They also include the perception of angular movement and movement in depth, in terms of both absolute threshold of detection and difference among thresholds. In addition, the dynamic aspects of visual performance include the ability to interpret the relevance of angular or in-depth movement to the observer by extrapolating to future positions those objects in the environment whose projected pathways constitute a hazard.

There are valid reasons why there are no tests for night vision or dynamic vision currently in use by any of the states. In order to justify its application in driver license screening, a vision test should be valid, i.e., predictive of driving performance; reliable, i.e., capable of producing repeated, uniform measurements; standardized, i.e., be widely used to permit development of normative values for scoring purposes; cost-effective, i.e., be of sufficient value in weeding out applicants who are potentially unsafe drivers (without mistakenly rejecting good drivers) to justify the cost of purchase, maintenance, and administration of the equipment; and commercially available.

Although a number of researchers (2, 6) have developed experimental devices for measuring visual performance under mesopic levels of illumination (as are encountered

Table 1. Static acuity requirements.

Both Eyes	Number of States	One Eye	Number of States
Without Glasses			
20/40	47	20/20	2
20/45	1	20/25	2
20/50	1	20/29	1
20/70	2	20/30	10
		20/33	1
		20/40	34
		20/50	1
With Glasses			
20/40	38	20/25	1
20/50	4	20/30	8
20/60	1	20/40	36
20/70	8	20/45	1
		20/50	1
		20/60	2
		20/70	2

Table 2. Visual field requirements.

Minimum Binocular Field (deg)	Number of States
90	1
100	2
110	1
120	3
130	1
140	4
150	1

Note: In 3 states range of minimum binocular field is not specified; in one state test is optional with examiners.

in night driving), none of these devices has yet been proved sufficiently valid to warrant its inclusion in the driver licensing procedure.

With regard to the dynamic aspects of vision in driving, again no appropriate tests are available. An experimental dynamic visual acuity test has been developed (4, 5) that is reliable, appears to have some validity, and has been administered to a sufficiently large number of drivers to provide normative data; however, this test is not commercially available, it is bulky, and its cost-effectiveness has not yet been established. The latter requirement will be difficult to meet, considering the relatively low predictive value of this test with regard to driving record (7, 8).

With regard to the dynamic aspects of vision, many of the parameters involved are not simple visual functions in the same sense as static acuity or visual field; they are more complex psychological phenomena that involve complex judgments and that may be sensitive to training and experience. Although consideration of these phenomena greatly complicates the development of an appropriate test, such consideration may be necessary.

NHTSA has not yet promulgated any formal standards with regard to vision testing for driver licensing application. NHTSA's most recent manual (15) in the area of driver licensing provides guidance to the states concerning preferred practices. It recommends the use of tests for static or dynamic visual acuity and visual field for initial licensing, with at least the acuity test repeated every 4 years thereafter at the time of license renewal.

No specific tests, procedures, or cutoff scores are indicated by NHTSA, which is not surprising in view of the current level of knowledge in this area. It is reasonable to assume that NHTSA will issue specific standards for vision testing procedures and scoring as soon as sufficient factual information is available to provide a basis for appropriate decisions.

Current thinking in the medical profession is perhaps best reflected in a recent publication (10), which puts forth provisional standards for driver licensing (Table 3). The report also discusses stereopsis, heterophoria, dynamic visual acuity, night vision, ocular pathology, and other areas of concern, but specific recommendations concerning testing procedures and scoring in these areas are not made.

RELEVANT RESEARCH FINDINGS

Relevant research concerning the relation between visual performance and driving performance has been summarized elsewhere (3, 13, 19) and will not be reviewed here. None of these reviewers found any incontrovertible evidence to confirm the widely held conviction that vision is related to accident involvement in driving. This means, of course, that this relation, which must inevitably exist, has been almost impossible to "tease out." Past attempts to uncover basic relations between vision and driving performance have proved unsuccessful for one or more of the following reasons:

1. Vision is only one of many factors that influence driving performance. This makes it difficult to demonstrate a close relation between a given vision characteristic and measures of driving performance such as number of accidents or convictions for traffic citations.

Table 3. Provisional standards for driver licensing.

	Class of License[a]		
Characteristic	1	2	3
Static visual acuity	Both eyes corrected to 20/25	One eye corrected to 20/40; the other corrected to 20/60	One eye corrected to 20/40
Field of vision	140 deg for each eye (90 deg temporal and 50 deg nasal)	140 deg for each eye (90 deg temporal and 50 deg nasal)	140 deg for both eyes together
Color vision	Able to discriminate among red, green, and amber with each eye separately	Able to discriminate among red, green, and amber with both eyes open	Not required

[a]Class 1 consists of bus drivers, for example; class 2 of truck drivers; and class 3 of passenger car drivers.

2. There may be considerable disparity between an individual's visual capability and the degree to which this capability is utilized in driving.
3. The extent to which individuals compensate for their defective vision is unknown, and compensation tends to obscure the true relation between visual performance and driving.
4. Most studies have dealt with a restricted range of visual acuities because they used subjects who had already been screened on the basis of their visual abilities. This restricted range limits the size of the correlation that can be expected between vision and driving.
5. The vision tests used may not have measured the same functions as those important to the driving task.
6. The reliability and validity of the tests or of the criterion measure(s) of driving used may be low.
7. There may have been methodological shortcomings in the study, such as a small or unrepresentative sample of drivers (or driving behavior) or a failure to control relevant variables such as exposure.

A search of the literature appearing since the A. D. Little review has been conducted as part of a study by Henderson et al. (14). This survey found a large number of studies directed at increasing our general knowledge of vision and visual performance, defining more accurately how the visual sense is used in driving, describing and defining the visual environment associated with driving, and isolating and measuring the relative effectiveness of various cues on specific driving behaviors or maneuvers. The body of literature in each of these areas is voluminous. Richards (18), for example, cited 196 documents that appeared between 1967 and 1969 related to vision at levels of nighttime road illumination. However, a complete review of this literature is clearly beyond the scope of the present paper.

Although such a review, or a series of reviews by subject area, would be of interest, it would not provide answers to the basic questions asked by driver licensing administrators; i.e., which vision capabilities should be tested? and which scores should be used as the cutoffs for granting a license?

To be of direct use in formulating policy concerning driver licensing practice, a study must be concerned with establishing the relation between visual performance and some direct criterion of driving safety, such as number of accidents. Only 2 such studies have appeared in recent years. Crancer and O'Neall (11) administered a number of visual tests to 2 groups of male drivers between the ages of 50 and 70. One group of 108 subjects had clean 2-year driving records; the other group of 177 subjects did not. They found the poor-record drivers as a group to be "visually more competent" than clean-record drivers in terms of static and dynamic visual acuity and glare vision. They conclude that the results of their tests warrant continuation of existing testing for static acuity and recommend future research to develop a test for glare vision and recovery and to study ways of integrating a visual examination with a driving simulator test to determine aspects of static and dynamic visual acuity more directly related to the driving task. Unfortunately, the results of the Crancer and O'Neall study are open to criticism because of the lack of scientific rigor with which the study was conducted. For example, the small sample size and lack of adequate control for the effects of age and miles driven tend to reduce the generality of the findings.

A large-scale study under way since 1961 at the University of California, Los Angeles, has reported experimental evidence showing that performance on several measures of visual capability may be of limited value in predicting driving record, i.e., accidents and convictions for traffic citations (7, 8, 9). Several visual capabilities were measured on nearly 18,000 California drivers of both sexes and all ages, and, of these, 4 measures were found to have significant, if limited, predictive value. These were static visual acuity, dynamic visual acuity, visual field, and night vision. Of these, dynamic visual acuity shows by far the strongest relation to both 3-year and 6-year driving records, with the other 3 trailing far behind. These results obtained when the effects of age, sex, and miles driven were controlled.

IMPLICATIONS OF RESEARCH FINDINGS FOR DRIVER LICENSING

The results of the research conducted to date have a number of implications for driver licensing and suggest several courses of action.

First of all, it is clear that there are a number of unanswered questions, such as the following:

1. What relation exists between specific visual performance measures and specific types of accidents and violations?
2. How would vision-driving relations change if qualitative (as well as quantitative) exposure to risk (type of driving) is taken into account?
3. Is it possible to specify cutoff scores for the various tests that might be useful to driver licensing administrators?

Work is currently under way at U.C.L.A. in an attempt to find answers to these questions, which is the first course of action implied by the results.

Secondly, the results are encouraging enough to warrant effort toward developing an acceptable vision-testing device for driver licensing purposes. Such a device should be compact, reliable, not too expensive, easy to administer and score, and should permit measurement of several aspects of vision. These measures should include, at a minimum, one or more dynamic tests of visual performance, a static test of visual resolution, and useful horizontal visual field, and the instrument should permit these measurements to be made under a range of illumination levels. This course of action is currently under way in the form of a research and development program supported by the U.S. Department of Transportation.

In addition, study results indicate that static acuity vision testing, in universal use in the driver licensing procedure at the present time, is of some value, and its use should be continued until such time as the vision-testing device currently under development is completed and validated. The same statement may be made with regard to visual field testing, currently used for screening driver license applicants in a third of the states.

Finally, it should be pointed out that an enormous amount of information has been collected that can be used to describe driver characteristics, both personal and driving. These data can be useful in themselves in formulating operational decisions. For example, all of the research data clearly show the decline on the average in visual performance capabilities with advancing age. This finding suggests that licensing examinations (i.e., vision testing) should be given more frequently (especially to older drivers), which would result in shorter term licenses. This practice is already in effect in several states. Further research is necessary before we can recommend at what age or at what level of vision more frequent testing should begin.

In spite of these research findings, there still are insufficient data of a type necessary to provide real guidance to the administrator responsible for establishing screening standards. The necessary data concern total visual performance requirements for safe driving. Because the causes of automobile accidents are so diverse and complex, it may be fruitless to expect that a high degree of correlation will ever be found between individual visual functions and accidents—perhaps a different approach is required. Without elaborating in detail, it would appear that an alternative to past attempts to relate performance on individual visual functions to accidents would involve (a) identification, definition, analysis, classification, and cataloging of the complex man-machine-environment interactions that comprise the driving task and (b) identification, definition, and analysis of the visual requirements associated with the individual elements of driving behavior. This is what Michaels (17) has termed the systems approach to the study of highway safety. What may be required is not the study of accidents or violations, but an intensive analysis of the driving task to determine what the human is required to do in driving an automobile and to determine the demands made on him by the design of the vehicle, the roadway, and other aspects of the system. Of critical importance, also, is the interaction among various elements of the system. It is not sufficient to say that a person must have the capability to resolve the taillights and running lights of a truck at a given distance and to judge that distance accurately. He must also be able to perceive that he is overtaking the truck and to accurately estimate the rate of closure. Estimating rate of closure probably requires very complex judgment—it certainly is not a simple visual function—yet it is based on a complex of visual cues that do represent visual functions. However, because of complex interactions and other factors as yet not understood, satisfactory performance with respect to all of the individual functions does not guarantee that an accurate estimate of closure rate will be made, and, conversely, accurate closure rate estimation does not necessarily require satisfactory performance on all individual functions. Even though ability or lack of ability to perceive rate of closure may not correlate highly with frequency of accidents, it can be shown analytically that, at modern highway speeds and with current roadway geometrics, a minimum capability to judge rate of closure is required to avoid accidents and a still greater capability is required to avoid creating situations that, when combined with some slight additional perturbation in the roadway system, would result in an accident. This is but one example of the type of effort that may be required. Through careful analysis, modeling, and empirical research, the basic performance requirements of the human visual system in the driving situation can perhaps be determined without relying on accident statistics as the sole criterion. A start in this direction is discussed in the following section.

CURRENT RESEARCH

NHTSA is currently funding a research project to develop an Integrated Vision Testing Device for use in screening driver license applicants. As a part of this development effort, for the first time, a systematic analysis has been made of the basic visual requirements of the driving task. This analytical effort involved examination of the driving tasks identified by the Human Resources Research Organization (16) in order to identify and define for each task, subtask, and individual driving behavior, the basic visual requirements, without regard to either feasibility of testing or "face validity." Independently of the analytical effort, the contractor experimentally investigated the interrelations among visual functions important to driving for which tests are readily available. Unlike most research studies of this type, which have used essentially normally sighted individuals, this study used a heterogeneous population whose corrected visual acuity ranged from 20/20 to 20/200. Major findings obtained in the first phase of this study are reported by Henderson et al. (14). Among the conclusions reached by the authors are the following:

1. Based on the results of a comprehensive literature survey and a detailed and systematic analysis of the visual requirements of the driving task, the visual functions judged to be most important to driving and which should be included in the Integrated Vision Testing Device are as follows: perception of movement in depth; perception of angular movement; visual field (useful peripheral vision); saccadic, pursuit, and steady fixations; static acuity; and dynamic visual acuity.
2. Night driving creates environmental conditions that are generally detrimental to visual performance, particularly of older drivers. Any realistic visual screening program must evaluate the effects of glare and low illumination level on all visual functions important to driving. Thus, provisions for testing under glare and low illumination should be included in the Integrated Vision Testing Device.
3. Only limited information is currently available concerning basic human capabilities on many of the visual functions judged most important to driving, such as movement in depth and angular movement. Information is urgently needed concerning the range of normal human variability in capability and the degree to which perceptual training can be used to improve performance.

The second phase of the study, now under way, involves construction of a prototype screening device and the conduct of a rigorous field evaluation to determine whether performance on the device relates sufficiently well to driving record to justify its use for screening driver license applicants.

Three of the prototype devices have been built and are currently undergoing field evaluation. The device provides the following performance measures:

1. Static acuity, i.e., the ability to resolve a stationary target;

2. Ability to perceive movement in depth, measured both centrally and peripherally;
3. Ability to perceive angular movement, measured both centrally and peripherally;
4. Useful peripheral vision, measuring the ability to detect, acquire (by head and/or eye movement), and identify acuity targets appearing briefly at random locations within a 180- by 20-deg field; and
5. Dynamic visual acuity, i.e., the ability to track and resolve a moving acuity target.

The device provides the capability for performance measurements under both normal and low levels of illumination as well as under conditions of either spot or veiling glare. In the field evaluation, the devices are being used to gather performance scores on a large random sample of licensed California drivers as well as on smaller samples of novice drivers, drivers with poor records, and commercial (bus and truck) drivers. The performance scores obtained will be correlated with driving record information (accidents and traffic violations) made available by the California Department of Motor Vehicles.

CONCLUSIONS AND RECOMMENDATIONS

There does not exist at the present time a sufficient body of scientific data to provide appropriate authorities with the guidance they require to establish vision test requirements and cutoff scores for screening driver license applicants. There are, however, sufficient data available to warrant continued use by all of the states of a test for static acuity and, for those states now utilizing it, a visual field test. Additional research and/or further analysis of existing data is required in a number of areas to produce the type of factual information needed for development of effective vision-screening procedures. Some of these areas are as follows:

1. Detailed evaluation of significant vision-driving relations is required to specify cutoff scores for those vision tests that appear potentially valuable.
2. A longitudinal study (of at least 5 years duration) is necessary to study further the deterioration with age of performance on vision tests in use or those being considered for driver license screening. Such a study is necessary to determine the desirability of differential frequency of reexamination for various age groups.
3. A systematic and detailed analysis of the visual requirements for driving should be conducted. In addition to identifying individual visual functions important to driving, consideration should be given to the complex psychological judgments involved in driving that require the dynamic interpretation, as well as the sensing, of visual information. This analytical effort, if extended to include the total driver-vehicle-roadway complex, may also yield criteria for evaluating visual performance requirements that may be used to supplement the traditional criterion of the driving record. (A start in this direction has been made in the aforementioned study currently being supported by DOT.)
4. A compact, reliable, and not-too-expensive multipurpose visual tester should be developed that can be used as a standardized test device to measure static acuity, one or more measures of dynamic visual performance, and some aspects of night vision. Once developed, this device should be subjected to a rigorous evaluation and validation program. (As indicated earlier, this activity is currently under way.)
5. All states should be urged to make a permanent record of all visual performance data collected on all applicants. These data should be maintained in a form readily accessible to those concerned with establishing the relation between visual performance and driving record and with making decisions regarding useful tests and cutoff scores.
6. A complete and detailed driver record file should be established at the federal level, containing data on accidents and convictions for traffic violations reported to any governmental or private organization or agency. Such records should be kept as long as is economically feasible because the reliability of such information increases as its period of accumulation increases. This recommendation is made under the assumption that driving record will remain the prime indicator of driving performance for some time to come and, thus, should be made as valid as possible.

REFERENCES

1. Algea, C. W. Licensing of Motor Vehicle Operators. Eng. Exp. Sta., Ohio State Univ., Columbus, Rept. 177-1, 1961.
2. Allen, M. J. Night Vision Performance Tester, Laboratory Model. Division of Optometry, Indiana Univ., Bloomington, 1966.
3. Burg, A. An Investigation of Some Relationships Between Dynamic Visual Acuity, Static Visual Acuity and Driving Record. Dept. of Eng., Univ. of California, Los Angeles, Rept. 64-18, April 1964.
4. Burg, A. Apparatus for Measurement of Dynamic Visual Acuity. Perceptual and Motor Skills, Vol. 20, 1965, pp. 231-234.
5. Burg, A. Visual Acuity as Measured by Dynamic and Static Tests: A Comparative Evaluation. Jour. Applied Psychology, Vol. 50, No. 6, 1966, pp. 460-466.
6. Burg, A. Light Sensitivity as Related to Age and Sex. Perceptual and Motor Skills, Vol. 24, 1967a, pp. 1279-1288.
7. Burg, A. The Relationship Between Vision Test Scores and Driving Record: General Findings. Dept. of Eng., Univ. of California, Rept. 67-24, June 1967b.
8. Burg, A. Vision Test Scores and Driving Record: Additional Findings. Dept. of Eng., Univ. of California, Rept. 68-27, Dec. 1968.
9. Burg, A. Vision and Driving: A Report on Research. Human Factors, Vol. 13, No. 1, 1971, pp. 79-87.
10. Committee on Medical Aspects of Automotive Safety. Visual Factors in Automobile Driving, and Provisional Standards. Archives of Ophthalmology, Vol. 81, 1969, pp. 865-871.
11. Crancer, A., Jr., and O'Neall, P. A. Comprehensive Vision Tests and Driving Record. Division of Research, Washington Dept. of Motor Vehicles, Olympia, Rept. 028, Dec. 1969.
12. Crinigan, O. D. Survey of Motorists' Vision Requirements. Jour. American Optometric Assn., Vol. 32, No. 3, 1960, pp. 209-210.
13. Goldstein, L. G. Human Variables in Traffic Accidents: A Digest of Research and Selected Bibliography. Highway Research Board Bibliography 31, 1962.
14. Henderson, R. L., Burg, A., and Brazelton, F. A. Development of an Integrated Vision Testing Device: Phase I Final Report. System Development Corp., Santa Monica, Rept. TM-(L)-4848/000/00, Dec. 1971.
15. Highway Safety Program Manual: Vol. 5, Driver Licensing. National Highway Safety Bureau, Dept. of Transportation, Washington, D.C., Jan. 1969.
16. McKnight, A. J., et al. Driver Education Task Analysis, Vol. 1, Task Descriptions. HumRRO Division No. 1, Alexandria, Va., Aug. 1970.
17. Michaels, R. M. Systems Research in Safety. Paper presented at 71st Annual Meeting of American Psychological Assn., Philadelphia, 1963.
18. Richards, O. W. Vision at Levels of Night Road Illumination: Literature 1967-1969. Highway Research Record 336, 1970, pp. 63-75.
19. The State of the Art of Traffic Safety. Arthur D. Little, Inc., Cambridge, Mass., June 1966.
20. 1969 Survey of State Requirements for Motor Vehicle Operators. American Optical Corp., Southbridge, Mass., 1969.

DISCUSSION

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Henderson and Burg summarized the variety of driver licensing tests and the lack of agreement among them with regard to passing standards. They emphasized that there are no tests or requirements for night vision, nor is any consideration given to the dynamic aspects of visual performance. The study shows some relation between static visual acuity and greater correlation between dynamic visual acuity and driving record. A vision test for driver license screening should be valid, reliable, standardized, cost-effective, and commercially available. Currently used tests fail these requirements. The authors propose research toward understanding the role of vision in driving.

I agree with Henderson and Burg and again call attention to the need for standardized tests. Color vision testing is unnecessary beyond recognition of signals revealed during the road test, and I doubt that stereopsis is of enough importance in driving to justify testing time. I do believe that cerebral response patterns, gradually built up with experience, determine driving skill and could be another approach to driver certification. On the question of retesting, I suggest 30, 50, and 70 years of age when changes occur in the visual system of human beings.