Task Analysis: Relating Visual, Cognitive and Attentional Capabilities to Driving Performance (Knowledge, Skills and Abilities)

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How does one determine the importance of visual functions for everyday tasks such as driving?

a. Historical overview
b. Clinical ophthalmic assessment
c. Expert opinion – individual or a panel of experts
d. Correlational or association studies
e. Risk factor analysis
f. Simulation studies
g. Task analysis
h. All of the above

Comprehensive Evaluation

a. Background
   i. Historical perspective on current vision standards
   ii. Review of previous investigations
   iii. Review of visual functions to assess
   iv. Formal Job Descriptions
b. Subject Matter Experts
   i. Field Advisory Panel (FAP) – Incumbents with extensive experience.
   ii. Management Advisory Panel (MAP) – Administrative staff
c. Job Analysis
   i. Visits to representative facilities (find common and unique settings, jobs)
   ii. Interviews with incumbents
   iii. Formal task analysis (knowledge, skills and abilities – KSAs)
      1. Frequency, required at entry, importance for safety
   iv. Review of critical incidents
   v. Review of appeals and challenges.
vi. On-site evaluations of job conditions and performance of incumbents at various job sites.

d. Development and implementation of vision simulations
   i. Accurate, valid depictions of occupational activities, evaluated, modified and approved by FAP and MAP
   ii. Analysis of results
   iii. Linkage of vision simulation findings with job analysis
   iv. Final Recommendations for vision requirements

b. Post-hoc evaluation of individuals who fail to meet the vision requirements and are appealing the outcome
   i. Follow-up support for subsequent appeals, adjustments to recommended vision standards due to changes in the job specification or the occupational environment, etc.

A study of vision requirements for Drivers License Examiners in the California Department of Motor Vehicles (DMV) will be used as an example of this type of project. (Johnson CA. Vision Requirements for Driver’s License Examiners, Optometry and Vision Science, 2005, 82: 779-789).

Rationale: In accordance with the Americans with Disabilities Act (“… if certain criteria are used to screen out an employee or employees with disabilities as a result of such an examination or inquiry, the exclusionary criteria must be job-related and consistent with business necessity, and performance of the essential job functions cannot be accomplished with reasonable accommodation”), the California State Personnel Board issued a mandate that any physical or mental requirements for specific occupations had to be validated through a comprehensive investigation that addressed the issues raised by the Americans with Disabilities Act or they must be dropped as a requirement for the job.

At the time of the study, the current vision requirements for Licensing and Registration Examiners (LREs) was a best-corrected visual acuity of 20/25 or better using both eyes, and 20/30 or better in the poorest eye. There were no other vision requirements.

A review of the literature revealed many studies related to various visual functions and driving, that every state in the USA had different vision standard for driving, and that there had been no previous formal study of driver’s license examiners that had been published in the past.
A questionnaire was provided to all LREs within the state of California with a response rate of more than 54%. The average length of service was 5.6 years (range = 3-27 years) and the average number of accidents they were involved with was 2.7 (range = 0 to 20). Accidents were more frequent for younger and older LREs.

A field advisory panel of incumbent LREs with extensive experience on the job and at various offices was organized, along with a management advisory panel of administrative personnel within the DMV. LRE job descriptions were provided and discussion with the two panels was initiated to determine critical, frequent and unique issues related to this occupation. Both panels were utilized to provide information for deriving inquiries to be included on the questionnaire regarding job conditions and performance, and for identification of topics for consideration as part of this investigation.

The job analysis consisted of administration of the questionnaire, interviews with incumbent LREs, visits to representative and unique DMV offices, ride-alongs for standard drivers license examinations, and extended drivers license examinations (e.g. commercial vehicle operators, individuals with physical and/or mental disabilities, evaluation of high risk drivers with multiple previous offenses, etc). The combination of findings from all these sources was used to determine specific visual functions to evaluate and establish job-related simulation studies that could assess performance quantitatively.

The questionnaire, in addition to acquiring demographic information, contained 60 questions pertaining to job activities and tasks that were reviewed by the field advisory panel and the management advisory panel. The purpose of the questionnaire was to determine whether the task was required upon entry to the job, its importance and its frequency, using a five points scale as noted below:

<table>
<thead>
<tr>
<th>When Required</th>
<th>Importance</th>
<th>Frequency of task</th>
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<tbody>
<tr>
<td>0 = does not apply</td>
<td>0 = does not apply</td>
<td>0 = does not apply</td>
</tr>
<tr>
<td>1 = not necessary at entry</td>
<td>1 = slightly important</td>
<td>1 = few times/year</td>
</tr>
<tr>
<td>2 = helpful at entry</td>
<td>2 = moderately important</td>
<td>2 = 1-3 times/mo.</td>
</tr>
<tr>
<td>3 = some needed at entry</td>
<td>3 = very important</td>
<td>3 = 1-3 times/week</td>
</tr>
<tr>
<td>4 = full needed at entry</td>
<td>4 = critical</td>
<td>4 = few times/day</td>
</tr>
<tr>
<td>NR = no response</td>
<td>NR = no response</td>
<td>NR = no response</td>
</tr>
</tbody>
</table>
Additionally, the questionnaire was used to determine the knowledge, skills and abilities necessary for successfully performing the job, and for designing the job-related simulation studies.

The top ten (highest score) items on the questionnaire for when required (R), importance (I) and frequency of task (F) are listed below (some items appeared as top selections for two or three of the ratings, so each is marked accordingly with R, I, and/or F).

- Visually check mirrors, side windows and rear windows to look for undetected vehicles during turns, lane changes and intersection crossings – R, I, F
- Ability to react and take control of vehicle during dangerous situations – R, I
- Observe examinee’s ability to detect and properly respond to potential hazards (pedestrians, bicyclists, poor road conditions, etc.) – I, F
- Visually detect and identify traffic signs and road markings – R
- Knowledge of traffic signs and road markings – R
- Ability to detect potentially dangerous situations – R
- Observe examinee’s ability to detect and appropriately respond to oncoming or intersection traffic – I
- Visually scan for potential roadside hazards, other vehicle traffic or other conditions that may create a potentially unsafe situation during a drive test – I
- Visually inspect tires, lights, turn signals emergency brakes and other safety equipment on vehicle to be used for drive test. – F
- Observe examinee’s steering smoothness and ability to use driving lanes properly. – F
- Observe examinee’s head and eye scanning behavior and use of mirrors in traffic, when approaching intersections, during lane changes and backing up or turning – F

Following the questionnaire analysis, a linkage assessment was conducted to relate specific task activities to particular visual functions to establish the job-relatedness of individual vision requirements. This was then used to establish a series of job-related simulations in which performance (speed, accuracy) and individual confidence ratings could be obtained. The simulations were performed under controlled conditions (closed road scenario). The prior literature indicated that normal or near-normal color vision (ability to pass the D-15 color vision test) was necessary to be able to properly recognize traffic lights, hazard warnings, tail lights
at night, etc). Therefore no simulation involving color vision performance was initiated. The five simulations were directed towards evaluation of visual acuity, peripheral vision (visual fields), and attention (multitasking). A small group of LREs with normal eye examinations in both eyes, less than one year of experience (to be similar to entry level applicants were selected. The participants were selected to provide a reasonable distribution of age, gender, race and other attributes typical for the applicant population. All participants were initially tested with their best visual function to establish a baseline for their performance and to provide their top confidence for their ratings (10 on a scale of 0 to 10). Following this, they were then tested with degraded visual acuity (use of plus lenses to blur their vision) and peripheral vision (goggles with restrictions of the visual field) to determine any changes in performance and confidence level. For the multitasking attention component, participants had to perform several activities simultaneously.

Simulation 1 consisted of identification of road signs to assess the importance of best-corrected visual acuity. Participants sat as a passenger in a vehicle travelling at a rate of 2-3 miles per hour, beginning at a distance of 800 feet, and were asked when they could read the sign that said “ROAD CONSTRUCTION AHEAD”. The examiner recorded the distance at which the sign could be read and received confidence ratings (0 to 10) for visual acuity levels of 20/20, 20/40, 20/60 and 20/100. There was a systematic reduction in the distance needed to recognize the road sign and lower confidence ratings as visual acuity was reduced from 20/20 to 20/100. The reductions were generally consistent with what would be expected from lower visual acuity levels.

Simulation 2 was a similar study of best-corrected visual acuity that evaluated the distance at which road hazards could be identified. Two of six road hazards were placed on the roadway at the same distance as the road sign, but were on the road surface. The road hazards consisted of a green cloth, a gray briefcase, a piece of truck tire, a tire jack, a piece of wood and a fan belt (some items were dangerous to run over and some were not). All participants were shown the objects beforehand. The distance at which the object could be identified decreased and confidence ratings were lower for poorer levels of visual acuity, similar to the road sign study. Except for the 20/100 visual acuity level (which was better than the 20/60 acuity level), there was also a decrease in the ability to correctly identify the objects in the roadway. Also, participants had to be much closer to successfully perform this task in comparison to reading the road sign.

Simulations 3 and 4 consisted of participants performing a typical routine drive test (seated in the passenger side of the vehicle) for various levels of visual acuity
(20/20 to 20/100 – simulation 3) and restricted peripheral vision (full binocular visual field, and 140, 70, 30 and 10 degrees of horizontal extent – simulation 4). Participants gave a confidence rating of their level of comfort in performing a drive test under these conditions. Reductions in visual acuity and visual field extent produced systematic decreases in confidence ratings. Participants did not feel comfortable performing a drive test with visual acuity levels of 20/60 and 20/100 and felt tentative for a 20/40 visual acuity level. Similarly, participants did not feel comfortable performing drive tests with visual field constrictions of 70 degrees or lower.

Simulation 5 consisted of a multitasking investigation on a closed road track where they were asked to scan the environment for potential road hazards and dangerous situations, evaluate the driver’s ability to maintain control of the vehicle and maintain proper driving reactions to situations while periodically checking the left and right side view mirrors (participants were asked to count them), and to make notes and grade driving skills on a standardized score sheet. The road hazards were orange cones (participants were asked to count them) and dangerous situations were a basketball or softball being rolled across the street from between parked vehicles. The same visual field restrictions that were used for simulation 4 were employed for this simulation. There was a reduction in the percentage of correct cone counts and eye movements identified (left and right mirror checking) with reductions in the visual field extent, as well as dramatic decreases in confidence ratings.

Summary and Take Home Messages

Drivers should have the ability to detect, recognize and identify road signs, hazards and potential dangerous situations, indicating a best corrected visual acuity of at least 20/40. The peripheral visual field extent should extend to at least 100 degrees horizontally and 70 degrees vertically, with the absence of areas of non-seeing (scotomas) produced by ocular or neurologic diseases. Color vision should be sufficient to be able to recognize traffic lights, road hazard indicators, taillights and related color-coded items (the ability to pass the Farnsworth D-15 test is a good procedure to assure this capability. Multitasking, a common occurrence while driving, requires appropriate division of attention and decision making to maximize safety.

There are wide variations in how much individuals can compensate for visual, cognitive or attentional deficits. Some tests (e.g., the useful field of view) and eye care specialists (e.g., low vision experts, occupational therapists) can be helpful in
deciding whether a person is able to drive safely and under what conditions. Additionally, there are some technologic devices that can be used to assist drivers who have some physical or mental impairment.

Providing proper training can be helpful to individuals who experience driving difficulties, and a standardized system adopted by all states within the USA would be beneficial as well.

Determinations of the suitability to drive for individuals with physical or mental impairments should be done by specialists with expertise in these areas.

References:

FEATURE ARTICLE ON LINE

Occupational Psychophysics to Establish Vision Requirements

Chris A. Johnson*

ABSTRACT

Purpose. To develop and implement a comprehensive procedure for determining vision requirements for different vocational and occupational tasks.

Methods. Evaluations performed for more than 10 state agencies and businesses were conducted over a period of approximately 9 years. The procedure included a literature review, an assessment of potential visual functions to address, a formal job analysis, interviews with incumbent workers, obtaining advice and recommendations from subject matter experts (experienced incumbents and administrators), development of job-related simulation studies, linkage of simulation results to the job analysis, a review of appeals and critical incidents, a thorough assessment of work environments and conditions, and final recommendations.

Results. Examples of occupational simulations for quantitative job-related task performance for best-corrected visual acuity, uncorrected visual acuity, color vision, peripheral vision, the use of one vs. two eyes, naïve vs. experienced incumbents, and impoverished visual conditions are presented. Changes in task performance and confidence ratings were obtained for various levels of degraded vision.

Discussion. This procedure, referred to as “occupational psychophysics,” provides a quantitative systematic method of defining the vision requirements for various essential job functions. In conjunction with the frequency of performance, requirements at entry to the job, safety, reasonable accommodation, alteration of the work environment, and administrative issues, this approach provides a quantitative, rational basis for establishing job-related vision requirements.

Key Words: vision, psychophysics, occupation, essential job functions, vision requirements, visual acuity, peripheral vision, color vision, job analysis

What level of visual function is necessary for performing various job-related (vocational/occupational) activities? This is a question that is frequently posed to eye care specialists, but unfortunately there are only a few formal investigations of this type that have been published. Many studies are now emerging on vision and driving, which is a task that is required of many occupations. Determination of the physical, mental, and cognitive entry level requirements for various occupations continues to be a perplexing enigma. Historically, many of the eligibility requirements for various work-related activities have either been developed through expert opinion, modification of military standards, or some other form of qualitative evaluation, with little or no consideration of evidence-based recommendations. In this view, the majority of investigations that have addressed this problem have not measured how changes in visual performance affect the accuracy and efficiency of specific job tasks. Many groups have attempted to adapt or completely transfer standards from prior studies, even when the occupational demands, work environment, basic job functions, and related issues for the job under review are considerably different from those encountered in the previous investigations. The Americans with Disabilities Act provided additional significance to job-related selection procedures and training devices that do not discriminate against individuals, by identifying the physical abilities and requirements that are necessary for performing essential job functions. Section 1630.14, Subsection (b) (3) of the Americans with Disabilities Act (which governs Medical Examinations) states in part: "...if certain criteria are used to screen out an employee or employees with disabilities as a result of such an examination or inquiry, the exclusionary criteria must be job-related and consistent with business necessity, and performance of the essential job functions cannot be accomplished with reasonable accommodation." In this view, it is important to establish that employment

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selection criteria are necessary to perform essential job functions and to verify that it is not possible to provide reasonable accommodations to perform the job without jeopardizing the quality or safety of the work. It is, therefore, essential to conduct investigations of employment standards for job-related physical abilities that are valid, reliable, and easy to implement.

The primary purpose of this investigation was to develop and implement a comprehensive procedure for determining vision requirements for different vocational and occupational tasks. To accomplish this, it was necessary to develop a plan for identifying vision abilities and skills that are necessary for conducting essential job functions. How does one establish a rational evidence-based method of determining occupational requirements for vision? One can achieve this by using a multi-factorial approach to job-related task performance that incorporates, (1) applying a comprehensive evaluation that includes a literature review and background of prior research; (2) the use of incumbents and experienced occupational personnel (a Field Advisory Panel [incumbents] and a Management Advisory Panel [administrative]); (3) a formal job analysis, job-related performance simulation studies; (4) assessment of successful and unsuccessful cases (progress, critical incidents, reasonable accommodations, challenges, appeals); and (5) follow-up, modification, and refinement of recommendations. In most instances, this work cannot be done quickly and it requires a multidisciplinary approach involving specialists with expertise, in particular areas who are willing to collaborate with each other. A critical aspect of this type of work is to establish a strong, direct linkage between the formal job analysis and the job-related performance simulation studies. It should be noted that this article is not intended to present a comprehensive evaluation of all occupations or visual functions, but rather to demonstrate an approach that can be used to establish visual function guidelines for different occupations. The remainder of this article will provide descriptions and justifications of procedures that have been utilized for establishing job-related vision requirements for many different occupations, with illustrative examples provided to demonstrate the feasibility and usefulness of this process. Table 1 presents an outline of this general approach.

It should also be noted that evaluations of this type can be performed using either a within subjects (repeated measures) or a between subjects design. In most of the studies reported in this article, a within subjects design was used because it is then possible to have each participant serve as his/her own control and changes in performance can be measured as a function of changes in visual function. This reduces the variability that can be present in this type of investigation and can also decrease the number of participants needed for the evaluation. However, there are some circumstances that are not compatible with this type of approach (e.g., “simulation” of color vision deficiencies). In this instance, it is best to use a between subjects design such as the one just reported. This emphasizes the importance of using an appropriate design for each investigation. However, it should also be kept in mind (as was done in these studies) that it is important to properly characterize the demographics (age, gender, race, etc.) of the incumbent work force when selecting participants for these types of simulations.

Although this review represents the cumulative experience from a long-standing interest in the application of basic and clinical visual science findings to real-world problems, the main findings are based upon consulting activities performed for various agencies within the state of California, including the California State Personnel Board, the California Highway Patrol, the California Department of Corrections, the California Department of the Youth Authority, the California Department of Motor Vehicles, the California Department of Transportation, the California Department of Fish and Game, the California Department of Forestry, the California Commission on Peace Officer Standards and Training, the California Department of Parks and Recreation, and the California State Attorney General’s Office.7–9–19

**METHODS**

**Job Analysis**

Initiation of the job analysis endeavor should focus on the development of a comprehensive job evaluation. Such an evaluation should include, (1) an assessment of the official job description, including occupational duties and responsibilities, entry level requirements, and other related items; (2) an overview of the concepts and rationale underlying the job; (3) a description of the composition of the current work force; (4) an assessment of the job applicant selection process; and (5) a review of prior history and literature related to the job. Also, (6) interviews with incumbents and supervisors, (7) job audits, (8) an evaluation of critical incident reports, (9) a thorough assessment of the work environment and conditions (weather, lighting, hazardous, or dangerous areas, etc.), and (10) a detailed series of visits to the work facilities. Additional-
ally, (11) a thorough analysis of the knowledge, skills, and abilities (KSA) associated with the occupation by human factors and industrial psychology specialists (development of a detailed questionnaire), (12) input from surveys of incumbents, (13) health and safety issues, (14) reasonable workplace accommodations and the Americans with Disabilities Act, and (15) any other factors that are relevant to the specific job activities must be considered. Finally, (16) the consequences of performance failures, in terms of their frequency, how critical they are to safety issues and whether they are required on entry must be given careful attention.

A critical part of the job analysis is a survey of incumbent workers. Typically, this survey consists of approximately 100 to 200 questions that are directed towards the KSAs that are associated with the job. The survey should provide a comprehensive overview of activities associated with the occupation and allow incumbents to rate the frequency, importance, and necessity for performing the task upon entry to the job. In most instances, a rating scale is used to obtain responses, ranging from a score of 0 (not at all) to 5 (very high) for frequency, importance and requirement at job entry. In this manner, it is possible to determine the most common, the most important (performance and safety), and the most critical tasks upon entry to the job, which is invaluable in establishing appropriate occupational simulation studies, to be described later in this article. A thorough and careful job analysis is a vital part of successfully designing job-relevant performance measures.

**Visual Functions**

There are a number of visual functions that should be considered for various occupations. In addition to their importance for performing specific tasks, there are other factors that must also be considered. These include whether the test of visual function can be performed by personnel who are not eye care specialists, the procedure must be evaluated under standardized conditions in an eye clinic, the test is quick and easy to perform and evaluate, is robust to various conditions present at the testing site, there are established decision criteria for interpretation of results, and many other issues. This limits the possible visual functions that can be considered for testing. The following visual functions that appear to be viable candidates include but are not limited to: visual acuity (corrected and uncorrected), contrast sensitivity, glare disability, peripheral visual fields, color vision, stereovision and other depth perception cues, vernier acuity, dark adaptation and performance under low illumination and contrast, flicker and motion sensitivity, dynamic visual acuity, and the useful field of view. Complex cognitive tasks (attention, vigilance, etc.) are not included in this listing of visual functions, although they are critical for properly interpreting situations (e.g., environmental characteristics, safety, accuracy, and efficiency), making rapid decisions, and responding to emergencies. It should be kept in mind that not all of these visual functions may be relevant for some occupations; therefore, a careful assessment of the job functions and work environment for each job is necessary. Listed below is a brief description of the aforementioned measures of visual function and the types of tasks that they may be useful for performing as part of the job.

1. **Best-corrected visual acuity**—The ability to resolve fine spatial detail with the use of a refractive correction. This is useful for reading, face identification, distinguishing one object from another (e.g., weapon vs. non-weapon), and many other tasks.22,26,47

2. **Uncorrected visual acuity**—The ability to resolve fine spatial detail without the use of a refractive correction.21,23–25,48,49 This is useful for similar tasks as #1 above, but may be required at a closer distance (such as direct physical threats, combative situations, and other procedures to maximize safety), under time-demanding stressful conditions or unexpected situations where a rapid response is required.

3. **Contrast sensitivity**—The ability to detect the presence of an object from the background environment on the basis of their luminance or reflective differences.50,51 This is particularly important for conditions where visibility is limited such as smoke, fog, snow, and rain.

4. **Glare disability**—The degradation in visual capabilities in the presence of a glare source (glare sensitivity), or the time required to return to normal performance after exposure to a glare source (glare recovery).52 Veiling glare, glare disability, and glare recovery all must be considered. This is important for tasks such as going from a dark inside environment to bright sunlight, driving at night, and viewing across bodies of water.

5. **Peripheral visual function** (visual fields)—The ability to detect objects that are present in the peripheral field of view.53–57 For tasks involving surveillance, mobility, object detection and identification, and other situations good peripheral vision is essential.

6. **Color vision**—The ability to detect an object on the basis of its hue (color detection) and the ability to distinguish one object from another on the basis of hue differences (color discrimination).27,28,58,59 This is important for tasks such as describing identification of persons or vehicles, examining contraband materials, distinguishing badges or identification tags, or identifying chemicals.

7. **Stereovision and depth perception**—The ability to appreciate a difference in the apparent depth of objects on the basis of retinal disparity (differences in the angle subtended in the two eyes (stereovision) and the ability to detect differences in the apparent distance of objects using all available cues (depth perception).60,61 This is important for properly determining terrain and mobility pathways, judging relative distances, and performing near tasks within 1 meter. It is important to note that there are many cues to depth, and stereoacuity is, but, one of many depth cues that are utilized by observers and is most useful for tasks within a 1 meter distance.

8. **Vernier acuity**—The ability to distinguish small positional offsets among objects.62 The ability to determine whether two reference marks are aligned or misaligned is important for tasks such as properly reading dials and meters, or evaluating the relationship between two objects in space.

9. **Dark adaptation and performance under degraded viewing**—The ability to perform visual functions under conditions of low luminance, low contrast, fog, haze, and other conditions where visibility is limited.63 This is an important capability for task performance under these conditions and is particularly important for ensuring proper safety conditions are maintained.
10. Flicker sensitivity—The ability to distinguish temporal variations in the luminance of an object.\textsuperscript{64–66} Flicker is an important feature to attract an observer’s attention, particularly for peripheral viewing. It is often used as a method of conveying a warning of potentially dangerous situations.

11. Motion sensitivity—The ability to determine changes in the position of an object over a short period of time.\textsuperscript{64} Movement of objects is also an important visual cue for attracting attention, both from the standpoint of safety (collision avoidance) and in judging the best method of intercepting an object that is changing position.

12. Dynamic visual acuity—The ability to appreciate fine spatial detail of an object as it is moving.\textsuperscript{67} Often tasks requiring identification of objects in motion (e.g., birds in flight, signs on vehicles) are important for rapid decision making.

13. Useful field of view—The ability to localize objects in the field of view, attend to more than one item at once and make distinctions, and react to objects that appear in the visual field.\textsuperscript{68} Many tasks or occupations require an individual to attend to more than one item at a time, or to attend to different portions of the field of view, which makes this issue of crucial importance under these conditions.

To date, the visual functions that have been repeatedly shown to have value for essential job functions, are easy to test and interpret, and have practical importance and validity are uncorrected visual acuity, best-corrected visual acuity, peripheral visual function, color vision, and dark adaptation, and viewing under degraded conditions. This does not necessarily imply that all of these tests are critical for all occupational demands, nor does it rule out the possibility of other visual functions having a vital role for effective performance and safety in other occupations.

A particularly important feature of establishing vision requirements for specific occupation is the use of simulations. The simulations should recreate the conditions of the work environment as accurately as possible, yet provide a means of obtaining quantitative data concerning task performance and the participant’s confidence and comfort in performing the task. In some instances, challenging situations (poor lighting, bad weather, cluttered environments, etc) must be considered. In this view, it is vital to get feedback and suggestions from experienced incumbents and administrators pertaining to the accuracy and validity of the simulation. Examples are presented in the Results section of this article.

RESULTS

For all the investigations reported in this article, all participants provided written informed consent in accordance with the Declarations of Helsinki.

Examples of Evaluating Visual Function

The determination of appropriate vision requirements for performing essential job functions can be accomplished in a variety of ways. One method has been to adopt the standards that have been used by other institutions (military, corporate, government), although another approach has been to obtain expert opinions. Unfortunately, these two approaches usually do not consider the variety of environmental conditions (e.g., weather, lighting), the uniqueness of each occupational endeavor, or the specific decision-making characteristics of each job when determining the impact of vision on task performance. For this reason, we felt that both performance-based tasks and the confidence of the employee were crucial to establishing evidence-based standards. To measure performance, it was felt that the time to complete the task and the frequency of correct task performances could provide this information. By examining task performance with good to excellent vision (within normal limits) and then degrading some aspect of visual function, it would be possible to measure changes in performance related to variations in visual function. This can be accomplished by designing a job-relevant simulation in which task performance can be measured within a period of several minutes or less. This process provides a strong indication of the dependence of the task on visual function, allows testing to be performed with a smaller number of subjects (because each participant serves as his/her own control), and provides an empirical linkage between vision and task performance. The confidence of the participant can be evaluated by using a rating scale for each of the test conditions. We have used a rating scale in which 0 represents no confidence in being able to perform the task, 10 represents maximum confidence in being able to perform the task (characteristic of routine job activities) and intermediate value representing in-between confidence ratings. It is useful to provide instruction and feedback to participants to make sure that they are familiar with the use of the confidence rating scale. The following topics and figures are presented as examples of how this approach can be used to establish rational guidelines for various visual functions needed for different occupations. It should be noted that in these cases, the emphasis was placed on entry level requirements that would be applicable to inexperienced applicants, although the effects of experience were examined for some of the investigations. Also, the examples presented are but a subset of all possible visual functions and occupational tasks, and is not intended to be fully comprehensive.

Uncorrected Visual Acuity

Vision requirements for uncorrected visual acuity levels are typically addressed when a task must be performed when employees are not able to wear their normal optical correction (e.g., emergency situations, assaults, accidents). Additionally, optical corrections may become fogged or dirty as a result of conducting routine job activities. Included in this analysis is a determination of whether the optical correction should be spectacles, contact lenses, or either type of correction, with the likelihood of dislodgement being the main issue of concern. The first example was a simulation performed in the dining hall of a correctional facility. Briefly, the scenario consisted of a busy, crowded dining hall where a fight broke out between several inmates. In the process of restoring order in a noisy setting, the optical correction of the correctional officer (spectacles or contact lenses) became dislodged. The officers’ task was to seek help by safely and rapidly going to a “safe” exit of the dining hall without their correction in place. There were three
exits, with two of them being secured by inmates and one having a fully uniformed correctional officer at the entrance.

Fig. 1A presents the average amount of time (eight participants) required to find the safe exit as a function of uncorrected binocular visual acuity. Incumbent workers whose experience was 6 months or less (to provide a reasonable match to entry level employees) were selected. In this instance, visual acuity was degraded by plus lenses (individually determined) in a trial frame worn by the participant. It can be observed that there is essentially no change in performance for visual acuity levels between 20/20 and 20/200, after which there was a systematic increase in the time to find the exit with greater levels of visual acuity reduction. At the 20/1600 visual acuity level, some participants were “feeling” their way along the wall of the dining hall to find the appropriate exit. By contrast, the average confidence ratings of the participants fell systematically with reductions in visual acuity below 20/20, as indicated in Fig. 1B.

A second example of the importance of uncorrected visual acuity consists of a youth authority group supervisor breaking up an altercation between several wards in dim illumination in a housing unit at close distance (7 feet). With a group of wards surrounding the supervisor, the task was to detect which one was holding an object (detection) and whether the object was a weapon or not (identification). Before the simulation, each participant was shown two weapons (knife and screwdriver) and two safe items (toothbrush and comb).

Figure 2A demonstrates that for a 20/20 visual acuity level, object detection is 100% and object identification is quite good (about 70%). With reduced visual acuity levels, there is a gradual reduction in detection abilities, and a dramatic decrease in correct object identification. Average confidence ratings (Fig. 2B) showed
a steady decrease with reduced visual acuity levels. Note that the performance measures for detection and identification are different, and that they do not correspond exactly with the confidence ratings.

These two examples illustrate how uncorrected visual acuity can affect a person’s performance and confidence for some essential job functions. However, it should also be noted that the uncorrected visual acuity level depends on environmental conditions, the task, and the frequency and consequences of performance errors.

Best-Corrected Visual Acuity

Tasks that require the use of fine spatial detail vision (object identification, reading, face recognition, etc.) may have a requirement for best-corrected visual acuity. Fig. 3A presents the average percentage of correct responses as a function of best-corrected binocular visual acuity level for Correctional Officers performing surveillance of the day room of a typical housing facility for inmates. Fig. 3B shows the average confidence ratings. Twenty volunteers acting as inmates were seated at five tables (135° horizontal field of view) playing cards or dominos in front of an observation station. During each 1 min scenario, an event occurred at one of the five tables (passing a weapon [screwdriver], passing cigarettes, throwing a punch, a “high five” or nothing). The time at which the event occurred, the inmate performing the event, and the table where it occurred were all randomized and counterbalanced for the five participants (Correctional Officers). The Correctional Officers task was to determine which table and inmate performed the event and what activity was performed. It can be observed that the task was difficult because performance was at an average of about 50% correct with the participant’s (Correctional Officer’s) normal visual function. There was a decrease in performance for the 20/40 to 20/100 visual acuity level and a more dramatic decrease in performance for visual acuity worse than 20/100.

There was a systematic decrease in confidence ratings as visual acuity levels were reduced (Fig. 3B). These results provide a basis for determining the progressive change in performance as a consequence of systematic reductions in visual function, thereby providing a direct linkage between these factors. However, in making a final recommendation concerning vision requirements for a particular occupation, one must also consider the cognitive and decision making components of the situation, the results of the job analysis (KSA, frequency of performance, importance, safety, and other issues), weather and visibility conditions, administrative issues, and many other aspects of the work environment. The significance of each of these components must be considered in rendering a final recommendation.

A more dramatic example of the way in which best-corrected visual acuity influences performance is depicted in Fig. 4, which show the percentage of correct responses for identifying a fully uniformed Correctional Officer and detection of a weapon from among eight inmates during the day and at night. The task was performed from an observation tower overlooking the yard from a distance of approximately 200 yards. For the day task, normal outdoor lighting was employed (average luminance of approximately 50 to 100 cd/m²), and the participants were asked to identify which individual was the officer and which inmate was holding a weapon (screwdriver). For the night task, only identification of the officer was required. The average luminance of the night yard was approximately 4 cd/m² and the lighting was provided by sodium vapor lamps (narrow band yellow illumination). It can be observed that for both the day and night yard tasks, average performance was 100% with 20/20 visual acuity, but fell to about 15% correct with 20/30 visual acuity, and could not be performed at all for visual acuity levels of 20/40 or worse (Fig. 4A).

Confidence ratings also fell for reduced visual acuity levels, especially for the night yard task (Fig. 4B). This example illustrates the importance of excellent best-corrected visual acuity for some occupational tasks. For this particular task, it is vital for safety and maintaining control of the situation to be able to properly identify the location of a correctional officer in a night yard. The combination of a long observation distance, low illumination, limited chromatic cues, and small details makes this visual task especially
challenging, with dramatic consequences when visual function is only slightly below expected normal values.

A third example pertaining to best-corrected visual acuity is presented in Fig. 5, for parole agents required to identify an individual from a photograph under night lighting conditions from a distance of approximately 30 feet. Sixteen parolees were placed in a recreational area and the Parole Agent’s task was to identify a specific parolee from a Polaroid photograph. Fig. 5A presents the average percentage (based on six participants) of correct responses for identifying the parolee in question as a function of best-corrected visual acuity level, and Fig. 5B presents the average confidence ratings. With normal vision, average performance is better than 90% correct and confidence is high, but there is a dramatic reduction in both performance and confidence for visual acuity levels below 20/20.

Peripheral Visual Function (Visual Field)

Peripheral visual function (visual field performance) is important for tasks involving surveillance, detection of items, and tasks involving complex, multiple activities where attention must be distributed across several areas.

Figs. 6A and 6B present the average percentage of correct responses and the average confidence ratings, respectively for group supervisors in the youth authority monitoring day room activities in a housing unit although they were using different amounts of peripheral visual field. For this simulation, an individual group
supervisor was seated at a desk facing the day room (subtending approximately 120° of horizontal visual field extent) where 25 wards were seated watching television and conducting other activities. To the left and right of the day room (180°) were two hallways leading to individual housing units where wards and group supervisors could travel. Each simulation lasted 90 s, during which three events would occur at different times: (1) a ward would walk down the right hallway and would touch several housing doors to the left and right of the hallway (touch); (2) several wards would change their seating position at different times (movement of wards); (3) several wards would raise their hand at different times (hand raising). The participant’s task was to call out when a doorway was touched by a ward (door touching), and at the end of the trial indicate which wards had moved and which had raised their hand for binocular horizontal visual field extents of 180° or more (full visual field), 120, 60, 30, and 10°. No instructions were given as to which task was more or less important or should take priority over the other tasks. The horizontal and vertical visual field was restricted from a full binocular visual field to 120° by using a pair of safety goggles with the lenses removed and the exterior fitted with occluding material and compressible foam. The 60, 30, and 10° binocular visual fields were created by using customized trial frames with occluder lenses modified with different sized apertures. For each observer, the effective field of view was verified before testing, with adjustments to vertex distance and trial frame positioning used to produce a consistent visual field size for all participants. Fig. 6A shows that the most noticeable activity (movement of wards) remained fairly constant for all peripheral visual field extents, whereas the more subtle activity (hand raising) systematically decreased with reductions in visual field extent, and the most peripheral task (door touching) was the most greatly affected by decreases in peripheral visual field size. Confidence ratings decreased progressively with reductions in visual field size (Fig. 6B).

A second example of the importance of peripheral visual field extent was observed for parole agents who were interviewing a parolee in the living room of his/her place of residence. A 1 minute interview of the parolee was conducted according to standard procedures. During that time, several events could occur. The parolee could be holding sunglasses, look out the window, hide a syringe in the couch, manipulate a pack of cigarettes, or put hands in trouser pockets. The observer was instructed to indicate if any of these events occurred (central tasks). Additionally, another person could quickly walk from the kitchen to the dining area, a person could peek into the living room window, a person could walk from one bedroom to another, or a person could peek around a corner in the hallway (peripheral tasks). The observer was instructed to recount each of these events for central and peripheral tasks being conducted during the interview, and to rate their confidence in being able to perform these tasks for different peripheral visual field extents (full field of 180 or more, 120, 60, 30, or 10° of binocular horizontal visual field extent). Central and peripheral tasks were randomly interspersed between the first and last 30 s of the interview. Fig. 7A presents the average percentage of incidents correctly detected for central and peripheral tasks as a function of peripheral visual field size, and Fig. 7B shows the average confidence ratings. It can be observed that there was a slight reduction in detection of central visual tasks with decreases in peripheral visual field size and a dramatic decrease in correct detection of peripheral tasks. Confidence ratings (Fig. 7B) decreased systematically with reductions in visual field size.

Both of these examples demonstrate the importance of the peripheral visual field for all jobs in which multitasking is being conducted; the field of view is large, and brief, infrequent events must be detected. Note also that the performance measures and confidence rating results are similar but not identical. In some instances, task performance appears to be more affected by reductions in visual function than an individual’s confidence in performing the task, and in other instances the opposite is observed. This illustrates the importance of obtaining both sources of information to provide a more comprehensive assessment of the influence of degraded visual function on occupational task performance.
Color Vision

The ability to distinguish one object from another on the basis of the chromatic content (color) of the light can be a significant factor for some occupations, especially if the lighting conditions are not typical. For example, the night yards at correctional facilities often use low level yellow lighting (sodium vapor lamps), game wardens must identify specific markings on birds and other animals under a variety of environmental conditions, and some items on-the-job are color-coded (display panels, warning systems, signal lights). Fig. 8A presents the average percentage of correct responses for identifying a fully uniformed officer from among eight inmates in a yard under night lighting conditions (4 cd/m² with sodium vapor lamps) from an observation tower. Fig. 8B presents the confidence ratings for (a) two observers with normal color vision and normal visual acuity (20/20 or better), (b) the same normal observers with binocular visual acuity reduced by spherical blurring lenses to 20/40, and (c) a group of six observers with normal visual acuity (20/20 or better) but with congenital color vision deficiencies. One observer was a mild deutan (green) who could pass the Farnsworth panel D-15 test and had a score of 107 on the Farnsworth Munsell 100 Hues test, three observers were moderate to severe deutos, and two were moderate to severe protans (red) who failed the D-15 test and scored worse than 175 on the 100 Hues test. Fig. 8A demonstrates that the color normal observers were able to perform the test with 100% accuracy, the blurred (20/40) color normals...
were not able to perform the test at all, and the color-deficient participants had substantially reduced performance. Fig. 8B shows that the confidence ratings were in accordance with the performance measures.

It is clear that for tasks of this type, normal color vision is important. In this and many other investigations, measurements of the Commission Internationale de l’Eclairage chromaticity coordinates of various objects were obtained under various types of lighting. These measurements can be quite helpful because congenital color vision deficiencies are highly similar, and color combinations that can be confused by such individuals can be readily identified.

One Eye vs. Two Eyes

There are some environmental circumstances (bad weather, low lighting, low contrast, etc.) in which the use of both eyes may provide an advantage over one eye alone, or occupational situations (assaults, attacks, etc.) during which the use of one eye becomes temporarily impaired. For some tasks, stereo acuity or stereopsis is important, but these are mostly confined to near vision tasks (<4 feet of observation distance) requiring accurate depth perception and are negligible for tasks involving long observation distances.61

Fig. 9A presents the average distance at which a pedestrian can be detected by a drawbridge operator using one or both eyes while observing the drawbridge on a foggy day for different visual acuity levels. The pedestrian was wearing a dark trenchcoat and a dark hat, and the distance of the pedestrian from the drawbridge observation booth entrance was measured with a tape measure after each trial. Because fog can be difficult to standardize and control, a simulation of foggy conditions was produced by passing a small electrical current over a liquid crystal window and having the observer view through this display. The drawbridge operators were asked to adjust the liquid crystal window to a translucency similar to a typical foggy day. Multiple measurements of the setting were quite close, both within and between different participants. It can be observed that there was a 15 to 20% improvement in detection of the pedestrian using both eyes in comparison to using only one eye, except at the poorest visual acuity level, where visibility was very limited for both conditions. Confidence ratings (Fig. 9B) were better for both eyes than for one eye under clear and foggy conditions. This example illustrates the importance of having both eyes functioning properly for some types of tasks, a factor that has also been presented by other investigators.69–73

Impoverished Visual Conditions

Low lighting and low contrast conditions have already been described, but there are other circumstances (due to poor weather, smoke or other visual impairments) where visibility becomes compromised. If essential job functions are being performed under these conditions, then it is important to evaluate these conditions and their impact on visual function. Fig. 10A presents the average percentage of correct responses for detecting the presence or absence of a pedestrian (wearing a dark trenchcoat and a dark hat) on a drawbridge at night under night lighting, using one or both eyes for different visual acuity levels, whereas Fig. 10B presents the average confidence ratings associated with this task. Once again, it can be observed that performance is better using two eyes, than with one eye at intermediate visual acuity levels, and the confidence ratings are moderately higher. The improvement in performance with two eyes appears to be better than what one might expect on the basis of probability summation (approximately a 40% improvement).73 However, it is well known that oculomotor adjustments (accommodation and convergence) are compromised under degraded viewing conditions74–77 and impaired performance of accommodation and vergence under the night viewing conditions may have also contributed to the difference in monocular and binocular viewing performance. In addition to providing information about the performance using one or two eyes, this investigation also indicates that visual performance can be dramatically influenced by lighting and other environmental conditions.
Experienced vs. Naïve Observers

It is well known that for many tasks, even repetitive ones such as hand-rolling cigars, practice, and training can improve performance after many years of experience. For many occupations, it is important to determine whether improvements in performance should be considered, or whether the KSA should be required upon entry to the job. Figs. 11 and 12 present the percentage of correct performance of five experienced (8 or more years of experience) and five inexperienced (<6 months of experience) game wardens. Two simulations are presented. In the first, participants were asked to identify five items (wooden stick, golf club, shotgun, rifle, fishing pole) being removed from the back of a jeep and placed on the ground at an observation distance of 100 feet. Fig. 11A presents the average percentage of correct responses as a function of visual acuity level for experienced and inexperienced game wardens, and Fig. 11B denotes the confidence ratings.

As expected, both groups show reduced performance and lower confidence ratings with poorer visual acuity levels, but it can readily be observed that there is very little difference in task performance or confidence ratings among the two groups of game wardens. A related simulation was conducted for detecting the presence or absence of antlers on a deer from an observation distance of 100 feet. The deer was a decoy with movable parts (neck, tail) and removable antlers that was being used to capture game poachers. The deer was placed in a grove of trees surrounded by brush and game wardens were asked to make their determination after 20 s of observation. Fig. 12A presents the average percentage of correct responses and Fig. 12B the average confidence ratings for experienced and inexperienced game wardens performing the task.
Again, there are decreases in performance and confidence for both groups as visual acuity is decreased. Between groups, there are small differences noted, but nothing that consistently demonstrates better performance and confidence ratings for one group over another at all visual acuity conditions. The studies suggest that visual function is a primary determinant of task performance, that it is applicable to both entry level and experienced individuals, and that visual function is the limiting factor for these skills.

CONCLUSIONS

Visual performance guidelines can be established once all the aforementioned steps have been completed. However, it is imperative that a multidisciplinary approach is used to assure that all aspects of the performance of specific tasks are of sufficient quality. If the eye care practitioner is to serve as a knowledgeable consultant then he/she must be properly apprised of the vision-related components of the job. However, I have omitted many other factors in this area of inquiry. For example, driving a vehicle is an important part of many occupations,19,24–44 and so driving should be given due consideration in the job description of these activities.

It is also important to recognize that the vision requirements for different occupations will vary, as will the vision requirements for the same occupation in different settings. This can be due to the risk/benefit characteristics of the situation, official policies and procedures of the agency, or inconsistencies between standard occupational procedures and properties of the vision requirements validation study. The vision requirement for one situation may be quite different for another situation. In some instances, recommendations can seem surprising until a more detailed analysis of the basis for this result is uncovered.

Task performance, as measured by accuracy (percent correct) or speed (time to completion) and subjective confidence ratings are both very helpful in establishing occupational vision requirement recommendations. In many instances, task performance and confidence ratings may be highly correlated, but they can also be somewhat independent at other times. An individual may be highly confident despite low performance measures or, conversely, may feel tentative even though they are sufficiently able to perform the task. In either case, this can have an influence on the employees' skills, abilities, and judgment.

As pointed out in the Americans with Disabilities Act recommendations, it is also necessary to consider the issue of “reasonable accommodation.” Can the job be performed in a different manner that minimizes the impact of visual performance, frequency of activity, or threats to safety? Alternatively, are there changes to the person’s vision that can be performed? For example, refractive surgery might be conducted as a reasonable accommodation for uncorrected refractive error. Here, the critical issues would be the accuracy of the refractive surgery procedure, its long-term stability, its safety, and its side effects profile. Similarly, hazards related to falls and missed-step accidents related to the use of bifocal and varifocal spectacles must be considered in terms of their use, reasonable accommodations, alterations of the work environment, and implementation of appropriate safety precautions.79 The implications of these factors for different occupations and environmental situations can vary considerably. To summarize, each occupational situation should be evaluated as a unique case rather than as a similar subset of a general category. A law enforcement officer in a high-crime area of a major city is not the same as a patrolman in a rural farming community. A myriad of other circumstances may be applicable to specific occupations and work environments.

It is important to make sure that all test procedures, methods of interpreting results, and testing conditions are well documented and that personnel who will be administering these procedures are highly trained. In addition, it is important to have a process identified to evaluate individuals who do not meet the vision requirements but feel that they are able to perform the job. In this view, it is desirable to have a series of essential job functions that can be administered to the individual to determine whether or not they are able to perform effec-
tively. Appeals and challenges to the existing standards also will help to establish and refine the final guidelines. Finally, it is important to keep in mind that there are individual variations in task performance that may also influence an individual’s ability to perform certain activities safely and effectively. In some instances, an individual may not meet the vision requirements for a specific occupation, but may feel confident that they can still perform essential job functions. For these circumstances, a method of having an individualized assessment of task performance under job-related conditions may be informative and of value. Several agencies have such individualized assessment programs included as part of their application process.

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Vision Requirements for Driver’s License Examiners

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ABSTRACT: Purpose. The purpose of this study was to determine the vision requirements for licensing and registration examiners (LREs) of motor vehicle drivers in the state of California. Methods. A comprehensive investigation was conducted that included a literature review, consideration of the Americans with Disabilities Act, analysis of materials with a subject matter expert panel, an overview of visual function tests, a formal job analysis, job audits and site visits to licensing offices, analysis of accidents and critical incidents, performance of simulation studies, and a review and evaluation of all materials collected during the study. Results. Based on this analysis, three visual functions (best-corrected visual acuity, peripheral visual field extent, and color vision) were determined to be important for performing the essential job functions of an LRE. It was recommended that LREs demonstrate a best-corrected visual acuity of at least 20/20 in each eye, a peripheral visual field of at least 100° diameter of horizontal and vertical extent in each eye (with no evidence of scotomas or pathologic areas of nonseeing within the visual field), and color vision capabilities that permit a passing score on the Farnsworth Panel D-15 color vision test. Discussion. The findings of this investigation provide a strong basis for specifying and justifying vision requirements for performing essential job functions for an LRE in the state of California. (Optom Vis Sci 2005;82:779-789)

Key Words: visual function, driving, driver’s license examiners

A number of investigations have examined the importance of visual performance, aging, and related factors for driving an automobile.1-44 Visual acuity, contrast sensitivity, color vision, peripheral visual field sensitivity, and other factors have been proposed as important visual functions associated with driving behavior.1-44 However, in the United States, each state has different vision requirements for obtaining a valid driver’s license,17-19 and commercial vehicle operators have more demanding vision requirements than those for conventional motor vehicle operators.11,15,29 In contrast to the extensive research that has been performed on vision and aging and their influence on driving performance, there is relatively little research information available for the visual requirements for examiners responsible for evaluating individuals to determine whether or not they are suitable for obtaining a license to drive a standard motor vehicle or a commercial motor vehicle.

Licensing and registration examiners (LREs) in the State of California perform a variety of tasks in their occupation, including vehicle inspection, dissemination of public service driving information, administration of written, oral, visual and practical driving performance tests, and related activities. At least 50% of their time is spent on practical driving performance tests, the vast majority of which are basic driver’s license examinations. These practical tests usually take approximately 20 to 30 min to complete and involve the evaluation of more than 40 basic driving skills (turns, backing, braking, and so on) for which a score (0 to 100) is issued. Some LREs are also trained to perform special driving tests (45 to 60 min) for individuals with physical or mental disabilities that do not meet the standard driver’s license requirements and commercial vehicle license examinations (45 to 60 min) for individuals seeking a class C driver’s license. Monocularity was not included as a visual condition in this evaluation of LREs because commercial vehicle operators are not allowed to be monocular in most states. Commercial vehicle operators also have a color vision requirement for employment, and this was also considered in this investigation, although no simulations were conducted to evaluate this visual function. The special driving tests are more rigorous than standard driver’s license examinations. In addition to evaluating driving competence, LREs are expected to maintain a high level of driving safety during the drive tests, which are performed on urban and rural streets and interstate highways.

The purpose of this investigation was to determine the vision requirements for LREs for the Department of Motor Vehicles (DMV) in the state of California by using a multifaceted approach. Before this investigation, the vision requirements for LREs was a best-corrected visual acuity of 20/25 or better using both eyes and
Vision Requirements for Driver's License Examiners—Johnson

20/30 or better in the worst eye, although validation of these requirements was not based on empirical studies. Many vision requirements that have been established for this and other occupations in the past have been determined by the opinion of a specialist or consensus from an expert panel. This investigation represents a somewhat novel and unique approach to establish and validate job-related vision requirements for LREs.

**METHODS**

The primary aim of this investigation was to provide a thorough investigation of vision requirements for LREs performing various job-related tasks. To achieve this goal, a comprehensive study was conducted by performing a literature review, consideration of the Americans with Disabilities Act, the continual assistance of a subject matter expert panel, an overview of visual function tests, a formal job analysis, job audits, site visits to driver’s licensing offices, and a review of accidents and critical incidents. This provided a framework for designing a series of vision-simulation studies. All aspects of the investigation listed here were considered as part of the final analysis and derivation of recommendations. A detailed description of the procedures used for this 2-year investigation is beyond the scope of this article. The methods used for this study are therefore described briefly in this article, although a full account of the procedures may be found in the Technical Report for this project, available on request from the author of this article.

Before this investigation, the vision requirements for LREs in the State of California consisted of a best-corrected visual acuity of 20/25 or better using both eyes and 20/30 or better visual acuity in the poorer eye. No other vision requirements were specified. Throughout this study, the author maintained continual interaction with a subject matter expert (SME) and administrative panel to obtain advice and recommendations for this project. The panel consisted of incumbent LREs (different gender, age, race, and years of experience) from a variety of locations throughout California and administrative staff. In addition to providing occupational information pertaining to LREs, the panel also offered information pertaining to the Americans with Disabilities Act, accident and conviction reports, critical incidents, and other pertinent details.

A formal job analysis was also conducted as part of this study consisting of two primary components. The first factor included job audits at selected DMV offices throughout California that encompassed a variety of driving situations, weather conditions, and traffic patterns. The job audits incorporated interviews with incumbent LREs and drive test ride-alongs (standard drive tests, limited term drive tests, special drive tests, and commercial vehicle drive tests). This portion of the job audit allowed the author to become familiar with the daily activities of LREs and provided valuable information for designing the simulation studies (described later) as well as offering an opportunity to produce the second aspect of the job audit, a job analysis questionnaire. A total of 60 job-related task descriptions were included in the questionnaire, and participants were asked to indicate the requirements (1 = not needed at job entry to 4 = full performance needed at job entry), importance (1 = slightly important to 4 = critical), and frequency (1 = a few times per year to 4 = several times each day) of each task. The questionnaire was distributed to 500 LREs at 130 California DMV offices, and 271 responses were received. Those tasks that were rated to be of high requirements, importance, or frequency were determined for each of the vision simulations (described later).

The primary visual function measures considered for this project included visual acuity, contrast sensitivity, glare disability, peripheral vision (visual fields), stereopsis, color vision, vernier acuity, dark adaptation and night vision, flicker and temporal visual processing, and dynamic visual acuity. Secondary visual performance measures such as the useful field of view, motion sensitivity, accommodation and vergence facility, low luminance acuity, ocular dominance, movement in depth, eye movements, fusional abilities, and other tests were also considered. It was determined that best-corrected static visual acuity and peripheral vision were the primary visual functions to evaluate for this project based on a literature review, importance for LRE task performance, interviews with incumbent LREs, and ease of implementation at DMV offices. Several visual simulation studies were designed to evaluate the impact of these visual functions on performing the essential job functions of an LRE. A secondary consideration of the role of color vision on driving performance was also addressed, although it was not felt that a simulation study was needed for this visual function.

Five vision simulation studies were developed, three of which evaluated the influence of best-corrected visual acuity on job performance for an LRE and two of which examined the role of peripheral vision on the essential job functions of an LRE. The selection of vision simulations was based on all aspects of the review of materials previously described, extensive input from the SME panel, and other related aspects of the study. Each of the vision simulations had one or more tasks or KSAs (knowledge, skills, and abilities) that had an importance rating of important to critical (importance [I]), some to full performance required at entry to the job position (when required [WR]), and/or a frequency of performance amounting to one or more times per week (frequency of task [F]) for LREs. To produce these data, each parameter (when required, importance, and frequency of task) was evaluated by incumbents using a 0 to 4 scale plus a “no-response” option, as illustrated in Table 1. A total of 500 questionnaires were sent out to 130 DMV offices throughout California, and 271 LREs responded. Table 2 presents the characteristics of the LREs who responded.*

All of the simulation studies were conducted at or near a California DMV office that had a variety of industrial, urban, rural, residential, freeway, and other driving environments and that were amenable to the performance of vision simulation studies. For all simulations, a highly experienced LRE served as the driver’s license applicant. Two measures were obtained for the simulations: 1) job performance measures and 2) confidence ratings. Job performance measures consisted of an LRE’s ability to perform certain tasks or skills associated with the job and varied somewhat from one simulation to the other. Confidence ratings were based on a 0 to 10 scale (0 = no confidence, 10 = complete confidence) relative to performance under normal vision conditions. For all simulations and test conditions, each participant was asked to provide a confidence rating based on a reference value of 10 for their typical visual function during employment activities. A brief description of the vision simulations, and the corresponding tasks and KSAs associated with them is presented subsequently. Average ratings for WR
TABLE 1.
Categories of responses for the job analysis questionnaire for licensing and registration examiners

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<th>Category</th>
<th>When required</th>
<th>Importance</th>
<th>Frequency of task</th>
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<tr>
<td>0</td>
<td>Does not apply</td>
<td>Does not apply</td>
<td>Does not apply</td>
</tr>
<tr>
<td>1</td>
<td>Not necessarily at entry</td>
<td>Slightly important</td>
<td>A few times a year</td>
</tr>
<tr>
<td>2</td>
<td>Helpful at entry</td>
<td>Moderately important</td>
<td>One to three times a month</td>
</tr>
<tr>
<td>3</td>
<td>Some performance needed at entry</td>
<td>Very important</td>
<td>One to three times a week</td>
</tr>
<tr>
<td>4</td>
<td>Full performance needed at entry</td>
<td>Critical</td>
<td>One or more times a day</td>
</tr>
<tr>
<td>NR</td>
<td>No response</td>
<td>No response</td>
<td>No response</td>
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TABLE 2.
Characteristics of the licensing and registration examiner respondents for the job analysis questionnaire

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</tr>
<tr>
<td>Years as an LRE</td>
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</tr>
<tr>
<td>Number of offices worked</td>
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<td>1-11</td>
</tr>
<tr>
<td>Number of accidents</td>
<td>2.7</td>
<td>0-20</td>
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</table>

DMV, division of motor vehicles; LRE, licensing and registration examiner.

I, and F for these tasks and KSAs were all above a rating of 3.0 (see Table 1) and most were above 3.5.

Simulation studies are time-consuming and difficult to conduct. The primary purpose of these investigations was to evaluate the change in task performance as a function of variations in visual function capabilities. In this view, it is possible for each participant to serve as their own control, thereby minimizing the number of participants that were required for testing. As indicated in the simulation section, each participant was first tested using their typical vision capabilities followed by successive degradations in visual acuity (by increasing blur) or restrictions in visual field size (using goggles and apertures).

**SUBJECTS**

The six participants in this investigation were selected to represent a reasonable cross-section of age, gender, and race. Each participant took part in all five of the simulation studies, and the order of testing participants was the same for each simulation. All of the six participants were LRE applicants, and therefore had a proper amount of prior training, but had limited experience in performing actual drive tests. Table 3 presents the characteristics of the subject population participating in the vision simulation studies. All participants had normal eye examinations and no history of ocular or neurologic disorders other than spectacle or contact lens correction.
TABLE 3
Characteristics of the subject population participating in the vision simulation studies

<table>
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<tr>
<th>Subject no.</th>
<th>Gender</th>
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For the visual acuity studies, each participant wore a modified pediatric trial lens frame that was used to hold trial lenses that reduced their binocular visual acuity to the appropriate visual acuity testing levels. The lenses were determined individually for each participant viewing a standard eye chart under the lighting and environmental conditions used for the simulations. Although the use of trial lenses to induce blur was used to degrade visual acuity, it is also clear that other visual functions such as contrast sensitivity, depth perception, and other factors are also influenced by optical blur. The trial frames were worn throughout the visual acuity simulations, and the presentation order of conditions was always sequentially from better to worse visual acuity levels. Before testing, all participants were familiarized with the test frames used in the simulations. Full binocular visual field conditions were conducted without the use of any head-mounted device. Binocular visual field restrictions of approximately 120° and 60° diameter were produced by means of a modified set of safety goggles equipped with occlusion devices and restriction apertures. The visual field was restricted by a modified trial frame set (occlusion of viewing beyond the trial frame apertures) for the smaller visual fields (approximately 30° and 10° diameter). Again, the order of presentation of test conditions was from fuller to narrower visual field restrictions for all participants.

SIMULATION 1: IDENTIFICATION OF ROAD SIGNS
Visual Function: Best-Corrected Visual Acuity

Related tasks: Visually detect and identify traffic signs and road markings. Observe ability to read, identify, and respond to traffic signs.

Related KSAs: Knowledge of traffic signs and road markings. Ability to detect, identify traffic signs, markings at long distances.

Subjects were asked to identify and read a sign by the side of the road. All tests were performed in the morning on bright, sunny days with clear visibility. The sign was a diamond-shaped orange sign (46 inches by 46 inches) with black letters (7 inches high, 4 inches wide, 1.5 inches thick, and 2 inches separation between letters) that read "ROAD CONSTRUCTION AHEAD" with each word on a separate line. Subjects were seated in the passenger seat of a state vehicle and were asked to indicate when they could clearly read all three words on the sign. They began at a distance of 800 feet from the sign and were driven at a very slow rate of speed (approximately equivalent to an average pace of walking or to 2 to 3 miles per hour) down the street toward the sign until they indicated that they were able to read all three words on the sign. The experimenter in the back seat of the vehicle then recorded the distance for sign recognition by means of markers placed on the curb at 25-foot intervals.

After this, the experimenter asked the subject for a confidence rating concerning their ability to read and identify the road sign on a scale of 0 (no confidence) to 10 (complete confidence). Subjects were asked to base their ratings on the confidence they would have if they did not know what the sign said and the level of visual acuity they were currently experiencing was their "normal" level of vision for performing drive tests.

The sign recognition task was performed for 20/20, 20/40, 20/60, and 20/100 visual acuity levels using the predetermined blurring lenses for each subject. Each of the visual acuity levels were tested twice for each subject. All subjects began with 20/20 visual acuity and were subsequently tested at 20/40, 20/60, and 20/100, respectively. A second set of measures was performed in the same order. For each trial, subjects began at the starting distance of 800 feet, which preliminary trials revealed was an appropriate starting distance (participants with 20/20 or better visual acuity could not read the sign at this distance). Subjects were instructed to tell the driver to stop when they were first able to read all three words of the sign.

SIMULATION 2: IDENTIFICATION OF ROAD HAZARDS
Visual Function: Best-Corrected Visual Acuity

Related tasks: Visually scan for potential roadside hazards, other vehicle traffic or conditions that may create a potentially unsafe situation during a drive test.

Observe ability to properly react to adverse weather conditions (fog, rain, snow, and so on) and traffic conditions (construction, road repair, and so on).

Related KSAs: Ability to use scanning eye movements, head
movements, and peripheral vision to detect pedestrians, other vehicle traffic, and potential road hazards. Ability to visually detect potentially dangerous situations.

This simulation examined the role of visual acuity in detecting and identifying objects and potential hazards that are present in the roadway. The basic test procedure was similar to that used for simulation 1. However, instead of reading a road sign, subjects were asked to identify two objects that were placed in the roadway, one placed approximately 5 feet out from the curb and one in the middle of the driving lane. The same street that was used for simulation 1 was also used in simulation 2. The objects in the roadway were placed at the same distance as the "ROAD CONSTRUCTION AHEAD" sign.

A total of six potential road hazards and objects were used, each of which was an item commonly seen along the roadways. They consisted of a piece of green cloth, a gray briefcase, a piece of truck tire, a tire jack, a piece of wood, and a fan belt. Two of the six items were placed in the roadway for each trial. The location (near the curb or middle of the driving lane), pairing of items, and number of occurrences of items at each acuity level were counterbalanced across subjects and trials. Two trials were performed for each visual acuity level (20/20, 20/40, 20/60, and 20/100). The same roadway markings as in simulation 1 were used in this simulation to determine recognition distance.

Each trial began at a distance of 800 feet, well beyond the distance at which objects could be recognized with 20/20 visual acuity. Both the distance for object identification and the percentage of correct responses (i.e., correct identification of objects) was evaluated as an indicator of performance for each visual acuity condition. For each visual acuity level, a subjective determination was also made as to whether the subject was able to detect either or both of the items in the roadway at the 800-foot starting distance (although they could not be identified). Also, confidence ratings of subjects were requested for each trial in a manner similar to that used in simulation 1. Like with simulation 1, these determinations were made in the morning with bright sunny weather conditions and good visibility.

**SIMULATIONS 3 AND 4: SIMULATED DRIVE TEST**

**Visual function: Best-Corrected Visual Acuity (3) and Peripheral Visual Field (4)**

Related tasks:
- Visually scan for potential roadside hazards, other vehicle traffic, or other conditions that may create a potentially unsafe situation during drive test.
- Visually check mirrors, side windows, and rear windows to look for undetected vehicles during turns, lane changes, and intersection crossings.
- Visually inspect gauges, controls, speedometer, brake light, and parking brake during vehicle drive test.
- Visually determine the speed and distance of oncoming traffic.
- Visually detect and identify traffic signs and road markings.
- Visually notice potential vehicle problems (e.g., cracked windshield, inoperative defroster, smoking brakes) that may create a safety problem during the drive test.
- Observe examinee’s head and eye scanning behavior and use of mirrors in traffic when approaching intersections, during lane changes, and when backing up or turning.
- Observe examinee’s ability to detect and appropriately respond to oncoming or intersection traffic.
- Observe examinee’s ability to properly operate all equipment necessary to maintain control of the vehicle.
- Observe examinee’s ability to detect and properly respond to potential hazards (pedestrians, bicyclists, poor road conditions, and so on).
- Observe examinee’s ability to properly judge and respond to the speed and distance of other vehicles.
- Observe examinee’s ability to negotiate turns, yield right-of-way, exhibit caution at intersections, and maintain proper vehicle position at stops.
- Observe examinee’s steering smoothness and ability to use driving lanes properly.
- Observe and monitor examinee’s emotional state, mental alertness, and nervousness during drive test.

Related KSAs:
- Ability to quickly respond to emergency conditions or dangerous situations.
- Ability to react and take control of vehicle during dangerous situations.
- Knowledge of traffic signs and road markings.
- Ability to observe examinee’s driving behavior, scan for potential hazards, and fill out score sheet at the same time.
- Ability to detect and identify traffic signs and markings at long distances.
- Ability to use scanning eye movements, head movements, and peripheral vision to detect pedestrians, other vehicle traffic, and potential road hazards.
- Ability to visually detect potentially dangerous situations.
- Ability to detect and identify bicyclists, horseback riders, pedestrians, and motorists, especially under poor weather conditions.

This simulation was intended to provide a reasonable simulation of a standard drive test that would be conducted by an LRE. In this simulation, subjects were driven along an 8- to 10-min route that consisted of part of the drive route normally used for standard drive tests at the DMV site. The route included approximately one-half to two-thirds of the standard drive route (because of time and personnel constraints, the full drive route was not used). All of the testing for simulation 3 was conducted in the early to mid-afternoons on sunny days with good visibility.

Subjects were first driven along the route with 20/20 visual acuity. The route included busy streets and intersections, commercial and residential areas, lane changes, blind intersections, four-way stops, and many other characteristics that are part of a standard drive test. Subjects were instructed to observe traffic lights, road signs, pedestrians and bicycle traffic, oncoming and side traffic, judge the speed and distance of other vehicles, check side mirrors, observe the driver’s head and eye movement behavior, and other factors that would be important for them to attend to during a typical drive test.

Subjects were instructed to use the 20/20 drive test as a standard and assign it a value of 10 (highest confidence). After this, they were driven along the same route in the same manner, except that their visual acuity was degraded to 20/40, 20/60, and 20/100. On
completion of each drive, they were asked to compare their observations for their current vision with the 20/20 drive and assign it a confidence level relative to the standard of 10. The subjects were instructed to base their ratings on their confidence in being able to maintain safe conditions and provide a fair assessment of driving competence if this were an actual drive test. The order of presentation of visual acuity conditions was always 20/20, 20/40, 20/60, and 20/100.

The basic procedure for simulation 4 was essentially the same as that used in simulation 3, except that visual field size was varied by the use of several sets of goggles designed to restrict the binocular field of view to 120°, 60°, 30°, and 10° in diameter, respectively. Subjects were driven along the same minidrive route (8- to 10-min route) that was used in simulation 3. They were then driven along the route with good visual acuity and a full visual field and were asked to assign it a value of 10. This value then served as a standard by which to compare subsequent drives with restricted visual fields.

**SIMULATION 5: IDENTIFICATION OF ROAD HAZARDS AND DRIVER BEHAVIOR**

**Visual Function: Peripheral Vision**

**Related Tasks:**
- Visually check mirrors, side windows, and rear windows to look for undetected vehicles during turns, lane changes, and intersection crossings.
- Read and properly fill out road test score sheets, pretest inspection sheets, and other reports.
- Observe examinee's head and eye scanning behavior and use of mirrors in traffic, when approaching intersections, during lane changes, and when backing up or turning.
- Observe examinee's ability to detect and properly respond to potential hazards (pedestrians, bicyclists, poor road conditions, and so on).

**Related KSAs:**
- Ability to quickly respond to emergency conditions or dangerous situations.
- Ability to observe examinee's driving behavior, scan for potential hazards, and fill out score sheet at the same time.
- Ability to use scanning eye movements, head movements, and peripheral vision to detect pedestrians, other vehicle traffic, and potential road hazards.
- Ability to visually detect potentially dangerous situations.

Simulation 5 was intended to provide a more dynamic scenario that was typical of the activities that occur during drive tests and that would capture the tasks that are most demanding for peripheral vision. Based on interviews and job audits, ridealongs with incumbent LREs, results of the job analysis questionnaire, and input from the SME panel, it was clear that LREs must attend to at least three different tasks during drive tests: 1) scanning of the driving environment to look for road hazards and potentially dangerous situations; 2) evaluation of the drivers ability to maintain control of the vehicle, respond properly to different driving conditions, and make appropriate use of mirrors, scanning patterns, and so on; and 3) make notes and grade various driving skills using a standardized scoring sheet. This simulation was designed to provide an abbreviated, reproducible, and quantifiable emulation of these conditions.

The scenario consisted of a two-block section of a quiet street in a semicommercial area near the DMV field office (the exact location is the starting point for commercial drive test performed at this DMV office). Along the two-block section of the street, several tractor/trailer rigs and automobiles were parked on both sides of the street. During a trial, the designated driver approached the test area from a crossing street, turned the corner, and drove down the two-block test section at a constant rate of 25 miles per hour.

Road hazards, consisting of small orange cones, were randomly placed at various locations along the two-block section of the street. In addition, a minibasketball or a softball was intermittently rolled across the street in front of the vehicle as a distractor. Finally, the driver was given a predetermined number of times that he was to move his eyes and turn his head to check his left and right side mirrors while driving down the two-block test section. The subject was given a standardized score sheet and was instructed to make a checkmark in designated locations each time a road hazard was detected, make a checkmark in another part of the score sheet each time the driver checked the left side mirror, make a checkmark in a third designated area each time the driver checked the right side mirror, and to make a checkmark in a fourth area of the score sheet if a minibasketball or a softball rolled across the street in front of the vehicle. The intent of this simulation was to require the LRE to monitor the roadway and the driver while also using the score sheet. To perform all tasks simultaneously, like is typically done during drive tests, places significant demands on peripheral vision.

Testing was performed for full binocular visual fields, a 120° diameter visual field, a 60° diameter visual field, a 30° diameter visual field, and a 10° diameter visual field. Before each trial, the number of road hazards (cones) was varied between eight and 14, and their positions were changed along the two-block test route. The driver was given a predetermined number of mirror checks (at least four and no more than eight) for each trial with the number of left and right mirror checks varied for each trial. The presence of a minibasketball or softball or nothing crossing the road was also varied between trials to avoid any expectancies on the part of the subjects from one trial to another. After each trial, the subject gave a confidence rating (0 to 10 scale) and handed the scoring sheet to the experimenter.

**RESULTS**

**Visual Simulation 1 (Visual Acuity and Sign Recognition)**

Figure 1A presents the average distance (in feet) at which the highway construction sign could first be read as a function of visual acuity level for the six participants. Note that there is a statistically significant reduction in the distance at which the sign could be read as visual acuity was reduced from 20/20 to lower acuity levels (repeated-measures analysis of variance [ANOVA], F = 379.8, p < 0.0001). The data are generally consistent with theoretical expectations of reductions in recognition distance with degraded visual acuity, except that subjects did slightly better (5% to 10%) than one would predict on the basis of visual angle considerations for each acuity level. Average confidence ratings for the six subjects performing this task are shown in Figure 1B. Note that there is a very gradual but systematic decrease in the confidence ratings for visual acuity levels worse than 20/20. This result was not statisti-
FIGURE 1.
(A) Average distance needed to recognize a road sign as a function of visual acuity level. (B) Average confidence ratings for road sign recognition as a function of visual acuity.

FIGURE 2.
(A) Average distance needed to identify road hazards as a function of visual acuity level. (B) Average percentage of correct responses for identifying road hazards as a function of visual acuity level. (C) Average confidence ratings for identifying road hazards as a function of visual acuity level.

Visual Simulation 2 (Visual Acuity and Road Hazards)

Figure 2A presents the average distance at which the subjects were able to identify road hazards placed in the driving lane as a function of visual acuity level. Overall, the distances necessary to perform this task were approximately half as large as for reading road signs (simulation 1). The results, however, are quite similar in that one had to be approximately two times closer (relative to 20/20 recognition distances) to recognize road hazards with 20/40 visual acuity, three times closer at 20/60 visual acuity levels, and approximately five times closer at 20/100 visual acuity levels. This result was statistically significant (repeated-measures ANOVA, \( F = 62.10, p < 0.0001 \)).

With shorter distances overall, reaction time and driving speed become more critical factors in determining whether corrective actions can be taken to avoid a road hazard. This places greater demands on good visual acuity, because a 20/20 visual acuity level provides twice as much distance (or time) than 20/40 acuity to properly react to a road hazard. Although quantitative data was not obtained for object detection, all subjects reported that at the 800-foot starting distance, they were always able to detect the presence of objects with 20/20 visual acuity, at 20/40 they were able to detect both objects 83% of the time, and with 20/60 and 20/100 vision, they were never able to detect the presence of objects in the roadway at the 800-foot starting distance.

Figure 2B presents the average percentage of correct identifications of road hazards as a function of visual acuity level. At 20/20 visual acuity levels, there was a 100% correct identification of road...
hazards. This was reduced to approximately 80% correct at 20/40 visual acuity levels and approximately 65% correct at 20/60 visual acuity levels. At 20/100 visual acuity levels, the percentage of correct identifications improved to approximately 90%. It is likely that this improvement in road hazard identification for the 20/100 visual acuity level was related to the availability of additional visual cues at the close observation distances, although this possibility was not directly evaluated. The overall effect of percentage of correct identification as a function of visual acuity level was statistically significant (repeated-measures ANOVA, $F = 3.365$, $p < 0.047$).

Average confidence ratings for identification of road hazards as a function of visual acuity are shown in Figure 2C. There is a gradual but consistent reduction in confidence for visual acuity levels worse than 20/20, but this effect was not statistically significant (repeated-measures ANOVA, $F = 2.290$, $p = 0.12$).

Visual Simulation 3 (Drive Test Simulations—Visual Acuity)

Figure 3A presents the average confidence rating for the six subjects as a function of visual acuity level for the drive test simulation. From a rating of 10 at the 20/20 visual acuity level, there is a systematic decrease in confidence ratings to approximately 8 at a 20/40 visual acuity level, approximately 6 at a 20/60 visual acuity level, and approximately 4 at a 20/100 visual acuity level. This result was statistically significant (repeated-measures ANOVA, $F = 67.02$, $p < 0.0001$). In addition to the ratings provided by the subjects, anecdotal comments during the drive test simulation indicated that they were completely uncomfortable with performing a drive test with either 20/60 or 20/100 visual acuity and felt partially impaired or tentative in their abilities at the 20/40 visual acuity level.

Visual Simulation 4 (Drive Test Simulations—Peripheral Vision)

Figure 3B presents the average confidence ratings for each of the peripheral visual field conditions. From a confidence rating of 10 with full peripheral visual fields, ratings fell to approximately 6.5 for 120° diameter visual fields, approximately 2.5 for 60° diameter visual fields, and <1 for both the 30° diameter and 10° diameter peripheral visual fields. This result was statistically significant (repeated-measures ANOVA, $F = 102.5$, $p < 0.0001$). Not only did the confidence ratings show rather significant drops in confidence as visual field size was reduced, but subjects also demonstrated a much higher frequency and magnitude of head movements as visual field size was restricted. These increased head movements were more likely a response initiated to compensate for the restricted visual field.

Subjective anecdotes by the subjects indicated that they felt very uncomfortable in being able to conduct a drive test with the visual field restricted to <120°. Compared with the effects of visual acuity degradation, subjects seemed to be bothered to a greater extent by peripheral visual field restriction than by reduced visual acuity. This is reflected in the rather rapid drop in confidence ratings with systematic reductions in visual field size.

Visual Simulation 5 (Road Hazards and Driver Behavior)

Figure 4A presents the average percentage of correctly detected road hazards (cones on roadway - striped bars in Figure 4A and left and right mirror checks by the driver (eye movements—solid dark bars in Fig. 4A) as a function of binocular visual field size. In general, both tasks demonstrated reduced performance as visual field size became constricted, and these effects were statistically significant (two-way ANOVA, $F = 15.60$, $p < 0.011$ for road hazard detection and mirror checks, and $F = 51.50$, $p < 0.002$ for visual field size). In addition to the performance decrements, there was a distinct change in the behavior of the subjects during the test procedure as visual field size was reduced. Below 120° of visual field diameter, subjects made a greater number of head movements. As visual field size was progressively decreased, both the frequency and the amplitude of the head movements increased. The accuracy of the markings on the scoring sheet also decreased as visual field size was progressively decreased. Subjects also reported that they were not able to attend to both the road hazard task and the driver's eye and head movements at the same time for visual field sizes below 120° in diameter. Figure 4B presents the average confidence ratings for the various visual field sizes used in simulation 5. The results indicate a small drop in confidence ratings between a full visual field and a 120° diameter visual field and a dramatic drop in confidence ratings for visual field sizes below 120° in diameter. This result was statis-
Vision Requirements for Driver's License Examiners—Johnson

FIGURE 4.
(A) Average percentage of correctly detected road hazards (stippled histograms) and driver eye/head movements (solid histograms) as a function of peripheral visual field size. (B) Average confidence ratings for detection of road hazards and driver head/eye movements as a function of peripheral visual field size.

DISCUSSION

This vision standards validation project for LREs in the California DMV began with a background review of several areas, including 1) an assessment of the Americans with Disabilities Act (ADA) and related legislation and their impact on entry level LRE vision standards; 2) a review of the literature pertaining to vision and driving; 3) a review of vision standards and validation studies for other occupations, because there have been no prior vision standards validation studies for LREs; 4) a review of a representative sample of accidents and critical incidents; and 5) a review of the most salient visual functions, their relevance to driving and their ease of being tested. These factors and the basic purpose, methodology, and design of the project were evaluated in conjunction with the SME panel members.

The second phase of this project entailed job audits to representative DMV field offices and those with unique environments or drive test conditions, interviews with incumbent LREs, ridealongs (standard, limited term, commercial and special drive tests), and discussions with SME panel members. From this information, a questionnaire was developed with extensive input from the SME panel and was sent to all incumbent LREs in California. Approximately 55% of the questionnaires were returned, representing a large number of DMV field offices throughout California. The results of the questionnaire and job audits reinforced and documented the importance of good vision, especially visual acuity and peripheral vision, for performing the essential job functions of an LRE. These findings were discussed with the SME panel and were felt to be a valid and appropriate assessment of the job activities and the role of vision.

The final phase of this project consisted of the vision simulation studies in which the relationship between task performance (for essential job functions) and visual function were directly linked. Both objective performance measures and subjective confidence ratings were obtained for various job activities with varying levels of visual function in five simulations. The final recommendations are based on the combined assessment of all aspects of this project and are briefly described subsequently. The technical report fully documents all aspects of the project leading up to the final recommendations for entry-level vision standards for LREs.

It should be noted that there are clearly limitations to this type of approach for establishing vision requirements for specific occupations such as an LRE. First, the use of simulations to evaluate job task performance imposes restrictions that may not be completely representative of "real-world" situations for on-the-job activities of LREs. However, this multifaceted approach was designed to provide the closest possible method of capturing these events in a manner that could be readily controlled and repeatable as well as to provide viable, realistic scenarios that could produce quantitative performance results. Continuous feedback from incumbents and SMEs were essential to achieve these goals. Also, learning, experience, the presentation order of conditions, and other factors limit the generalizability of these findings. In this investigation, there was a mandate to establish vision requirements for entry-level employees with little or no prior experience with the expectation that the individual would be able to perform essential job functions with minimal training on visual functional capabilities. For these reasons, experience, presentation order, the ability to compensate for visual disabilities, and related issues were not considered as part of this investigation. Finally, the number of visual functions that were evaluated is limited to visual acuity and peripheral vision. Other visual functions were considered but were not included in this investigation because they: 1) did not have a strong relationship to driving performance in the literature, (2) were too expensive or time-consuming to consider for large population testing, (3) were not standardized or validated, or (4) could not be justified as an important component of the occupational requirements for an LRE.

The final recommendations for vision requirements for LREs are based on the combined assessment of job requirements, task analysis findings, simulation results, consultation from incumbents and SMEs, and related issues. Based on these factors, the final recommendations include a best-corrected visual acuity of 20/20 or better in each eye, a peripheral field of view of at least 100° of horizontal extent, and 100° of vertical extent in each eye, with no evidence of scotomas (nonseeing areas) resulting from pathology to the visual system and normal color vision or only mild-to-moderate color vision loss (ability to pass the Farnsworth D-15 color...
vision test). Although the color vision component was not empirically evaluated in simulation studies, the requirements for commercial motor vehicle operators include a color vision requirement. For this reason, it was felt that this visual function must be considered in the visual requirements for LRsIs. These recommendations are based on an assessment of all aspects of the investigation.

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Vision Requirements for Driver's License Examiners—Johnson 789


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