IMPROVING ANALYTICAL APPROACHES FOR EVALUATING VISIBILITY

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Over the last 12 years, the Safety Research Department at Ford has been working more or less continuously on the development of analytical methods for describing driver vision with automobile headlamps in a traffic systems context. These models are based on field-validated versions of Blackwell's laboratory contrast sensitivity curves. The present seeing distance model can deal with a wide range of parameters including headlamp configuration and misaim, target type, size, location and reflectance, road geometry, disability glare effects and backlighting from opposing lamps, ambient illumination, driver attention, driver age and percentile contrast sensitivity level and the reflectance characteristics of wet and dry roads and shoulders. The Ford CHESS (Comprehensive Headlamp Environmental Simulation System) program is a further development of the analystical approach. CHESS uses the Ford seeing distance model to perform a great number of discomfort glare calculations and seeing distance "tests" on pedestrian and delineation targets under a wide range of traffic and driving conditions.

The major benefits of these models are that (1) they make it possible to test and compare beam patterns while they're still in the "drawing board" stage, (2) they can eliminate or reduce the need for field tests and (3) they permit comparisons and evaluations of headlamps under a much wider range of conditions than is feasible even in the most extensive field testing. CHESS also provides a flexible context for incorporating and integrating new research results in highway vision, and for this reason it has a heuristic character.

CHESS's major limitations arise from the fact that the underlying visibility computation is essentially a simulation of a seeing distance test. That is, it is based on narrowly defined and highly simplified contrast detection criteria. CHESS does not deal at all with higher order visual processes and the night driving problems that these processes underlie. These considerations also apply to analytical methods for evaluating fixed lighting or delineation treatments that are based on laboratory contrast detection pardigms. There are two broad problem areas. First, none of our deterministic models deal adequately with the problem of driver attention and how objects of varying conspicuity are "noticed" (as opposed to being detected in the psychophysical sense). The Ford models do incorporate an attention factor in the algorithms that calculate seeing distance to obstacles. But this is based on a single, small scale study performed more than 40 years ago. It would be very useful to have a formulation for estimating the fraction of real world drivers who will notice an obstacle or signal at a given level of conspicuity under various driving conditions. This is a problem that surfaces frequently in applied human factors traffic research. The necessary research is expensive and time consuming, however, because it requires a "one-trial-per-subject" design to insure realistic alertness states. Nevertheless, this is a sufficiently important and general issue to warrant a dedicated research effort.

The second problem area has to do with the higher order visual processes that allow the driver to extract path information and orienting cues from the larger visual context. Under good visibility conditions, these processes are reasonably well explained by contrast detection models applied to the formal delineation elements. However, under more difficult visibility conditions, involving high background complexity, this approach does not suffice. Drivers begin to rely on secondary, informal cues that may be very subtle. Also, orienting cues that are actually well above threshold may go undetected because there is not enough effective "signal" to overcome the background "noise". A useful way to think about this problem is in terms of the influence of background complexity on the delineation conspicuity required for adequate visibility of orientation and path following cues. Although the definitions of conspicuity and background complexity present real problems, they reduce ultimately to physical measurement schemes, and the difficulties are more of a practical nature. Defining what constitutes "adequate" visibility, however, is a less tractable problem.

Simple contrast detection mechanisms are not sufficient to define visual quality. We experience a powerful sense of unease when driving under poor visibility conditions because we find it difficult to organize the visual elements of the scene into orientation and guidance cues. Unfortunately, understanding of the higher order visual processes that underlie this subjective response has not advanced to the point of practical application in a real-world research problem. There is no simple behavioral measure -- such as contrast detection -- that can be applied to measure visual quality in the sense discussed above.

A practical solution to the problem of determining what constitutes adequate visibility is to develop a scale based on driver judgments of visual quality, as determined by conspicuity and background complexity. The advantage of this approach is that it utilizes the driver as a direct sensor, tapping his strong cautionary response to poor visibility without the need to analyze the underlying higher order processes. The research problem is thus to determine the relationship between the objective measures of visual complexity and path cue conspicuity (i.e., the signal to noise ratio) and the resulting judgments of visual quality. This basic approach of relating driver judgments to physical lighting parameters was used by deBoer to develop a scheme for scaling discomfort glare.

Given such a relationship, it would be possible to incorporate it into analytical models such as CHESS to provide a more powerful figure of merit for expressing visual quality in night driving.

VISIBILITY ASPECTS OF ROAD LIGHTING

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Road traffic requires the user to participate by means of his own actions and decisions made on line and based on visual information collected in situ. At night, artificial lighting is essential in order to acquire the necessary visual information. The lighting function is to enable the traffic to function "more or less" as during the day.

The effectiveness of road lighting is expressed in the reduction of the nighttime accidents. For important urban roads, the installation of "good" road lighting will result in a reduction of some 30% of the nighttime injury accidents when compared with no or very poor lighting. Accident studies have generally shown that the relative nighttime danger is reduced when the lighting is improved.

The efficiency of road lighting is expressed in terms of supply-and-demand. Both the supply and the demand can be expressed in conspicuity. It is possible to measure the supplied conspicuity of a lighting installation, and the conspicuity required by road users.

The go-no-go limit for road lighting quality, however, cannot be found in this way. Taking part in traffic, as a driver of a car, involves much more than visual activities alone. Driving is not primarily a visual task: in the first instance, it is a decision-making task. Reaching the destination is the first aspect of the driving task. Avoiding accidents represents the second aspect of the task.

For Task I (reaching the destination), route selection and control, speed and position selection and control are relevant. In many cases, disturbances represent conflicts or dangers. Some conflicts or dangers might develop into accidents if no avoiding maneuvers are executed. In all cases, the disturbances are sudden, unpredicted and unwanted, involving situations where information is inadequate.

Collision-avoiding maneuvers include:

- coming to a stop
- avoidance by leaving the traffic lane
- avoidance by swerving within the traffic lane
- adjusting (reducing) speed
- simply going on

The required advance viewing time for coming to a stop is the greatest, for simply going on the smallest.

The specific (or critical) visual object must be known. While it is not necessary to stop for a stone of 20 x 20 cm dimensions, it is necessary to stop for a stationary truck on a two-lane, two-way road when opposing traffic is present. And it is necessary to swerve around the stone, but not around a newspaper or a matchbox. It is difficult to set up an inventory of the critical objects. However, the 20 x 20 cm obstacles are not frequent. In the first place, it seems that the curves in roads and other traffic participants are important. This is in accord with the restricted information that can be deduced from the accident statistics. All this relates to the "demand" side; the picture can be completed only when we know more about the different specific or critical visual objects.

As regards the "supply" side, the picture is nearer to completion. The system built by Blackwell and accepted by CIE provides the possibilities to assess the relation between the photometric and geometric aspects of lighting installations and the degree in which specific objects may be seen.

VISUALLY CRITICAL ELEMENTS IN NIGHT DRIVING, IN RELATION TO PUBLIC LIGHTING

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Purpose of Paper

This presentation focuses upon car driving at night outside built-up areas. In order to apply public lighting selectively and efficiently it is necessary to know which elements in the task environment of a car driver are insufficiently visible for safe and smooth driving, using (dipped) vehicle lighting. The visibility of these "visually critical elements" is amenable to improvement, in particular by public lighting. Until now, the visibility of the so-called "critical object" (something like a brick at 100 m distance on the road surface) has been used as an important criterion for the quality of public lighting. However, the relation between seeing such an object and traffic safety is not very clear.

The results of two exploratory studies on the nature of visually critical elements, done by order of the Netherlands' Roadway Authorities, will be briefly presented. For more information, see Walraven (1980) and Padmos (1981).

Methods

In the first study, nine subjects drove a car along a 112 km trajectory, consisting of various road types in non-built-up areas. Each driver had one nighttime run (with dipped headlights) and one daytime run as a control. Driver's reports of visually critical elements were taken during the runs. Moderate intensities of motorized traffic were present; road surfaces were dry.

In the second study, a representative sample of 1,200 car drivers was interviewed (home-interview) for experiences during driving in non-built-up areas. There were questions about the most important problems encountered during night driving, about character and cause of recently experienced near-accidents and about the appraisal of public lighting.

Results

Visually Critical Elements

The most frequently reported nighttime visually critical elements belonged, in both studies, to the category "course of the road and other geometric road characteristics." The visibility of obstacles on the road surface was never mentioned as a problem. Rarely mentioned was the problem of seeing other cars; somewhat more mentioned was the visibility of bicyclists and pedestrians (interview study only). Glare from oncoming cars' headlights was often mentioned as a problematic circumstance.

From the first study it appeared that most visual problems occurred on unlit local roads, and fewer on unlit main roads. On express highways very few problems were mentioned; here the presence of public lighting did not markedly influence the frequency of problems.

Near-Accidents

Two-hundred twenty-three near-accidents were reported; they were about equally distributed between day and night. Eighty-five percent were with another moving car. However, "not seeing a motor vehicle in time" was mentioned as a cause in only 9% of the cases. In about half of those, this related to the limited scope of the side-mirror. Actually, visual causes as a whole did not constitute more than 27% of the total. Beside