BASIC CONCEPTS IN SCIENTIFIC EVIDENCE ON NIGHT VISION[1]

Introduction

Most people have never heard of the terms "fovea", "ocular accommodation", or "senile miosis". While the typical driver has a general awareness that it is harder to see at night, and it is not uncommon to hear that people have more problems with night vision as they age, the physiological and psychological reasons why remain unknown to most individuals. For the plaintiff's attorney handling a nighttime accident, auto or otherwise, he or she will not be surprised to find that scientific evidence bears out these basic notions of nighttime difficulty and the effects of age, but they may be surprised to find the dramatic extent to which vision is lost at night. In the myriad fact situations that can involve a nighttime injury (i.e. the defendant whose vehicle has broken tail lights or is towing an unlit trailer, the motorist or trucker whose vehicle is off the road but partially obstructing it, or the defendant who failed to adequately light a work area) a working knowledge of the basic principles that affect nighttime vision is essential.

Statistics have long shown that serious traffic accidents are far more common at night than during daylight hours. Statistics from the National Safety Council for the years 1980 through 1998 show an average of more than three times the rate of fatalities at night than for daytime. (For example, in 1998, the nighttime rate was 4.6 fatalities per one hundred million miles, compared with 1.1 for daytime.)[2] Extensive research and experimental psychology involving the science of nighttime vision, combined with the study of human factors, has helped to understand the Awhy@ of this dramatically higher rate, and the answer is far more complex

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[1]This article was written with the valuable assistance of Dr. D. Alfred Owens, Professor of Psychology at Whitley Psychology Laboratories, Franklin and Marshall College, Lancaster, PA, 17604-3003.

than the simple notion that it is "dark out."[3]

The extensively researched subject of nighttime vision is important not just to determine what the individual defendant in an injury case saw, when they should have seen it, and what steps they should have taken to avoid the collision, but often may focus on what knowledge a business or corporation (such as the defendant driver's employer) should have gained through reasonable inquiry and basic knowledge of nighttime vision factors. For example, the trucking company that fails to educate its employee driver about the essential dangers of nighttime vision, and further fails to provide adequate training and adequate equipment to properly warn the public of a stalled vehicle blocking part of the roadway, must be charged with this basic knowledge.

The Physiology and Psychology of Nighttime Vision

An essential element of avoiding any accident is, of course, a person's ability to perceive the danger in time for them to take actions to avoid the danger. Under reduced light circumstances, one's ability to recognize and localize the danger is seriously impaired for a number of physiological reasons. The most important basic functions in recognizing an object are "acuity" and "contrast sensitivity". Yet, at the dark limit of civil twilight (defined as the period between sunset or sunrise and the point at which the sun is six degrees below the horizon, which is generally about 30 minutes before sunrise and after sunset in the northern United States), the functions of acuity and contrast sensitivity are reduced to less than 10 percent of normal daytime levels.[4] As night falls and light dims, physiologically the eye transitions from

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[2]National Safety Council (1999), Injury Facts, Itasca: Illinois, p. 90.

[3]Owens, D. A. (1996) Differentiation of Visibility and Alcohol as Contributors to Twilight Road Fatalities, Human Factors 1996, 38 (4), 680-689.

[4]Leibowitz, H. W., and Owens, D. A. (1991) Can Normal Outdoor Activities be Carried Out in Civil Twilight? Applied Optics, 30, 3501-3503.

photopic (cone receptors) to scotopic (rod receptors) vision, during which the visual recognition capabilities of the eye change dramatically.

At the same time that the receptors of light change within the eye, the eye's ability to focus, called "ocular accommodation", loses its normal efficiency, giving rise to a common problem called "night myopia". [5] In addition, all persons, as they age, will suffer a gradual reduction in their maximum pupillary dilation, a process sometimes referred to as senile miosis, which in fact begins in the early teens. While there are wide individual differences at all ages in the maximum pupil dilation, the trend toward smaller pupils with age is universal.[6] Because retinal illuminance is proportional to the area of the pupil, a reduction in pupil diameter from eight millimeters to four millimeters, which is typical of changes from age 20 and 60 years, corresponds to a fourfold reduction of light in the retina. While this change alone would produce a substantial decrement in visual acuity and contrast sensitivity in twilight and nighttime circumstances, another important factor is that the density of the eye's lens increases over the life span of a person, which increases both the absorption and scatter of light that passes through the pupils. These ocular changes progressively limit dark adaptation, absolute sensitivity, glare recovery, and contrast sensitivity. Experiments by Professor Owens helped demonstrate the extent to which these age related changes contribute towards accidents.[7]

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[5]Owens, D.A., and Leibowitz, H.W. (1976) Night Myopia: Cause and a Possible Basis for Amelioration. American Journal of Optometry & Physiological Optics, Vo. 3, p. 709-717; Andre, J. T. and Owens, D.A. (1999). Predicting Optimal Accommodation Performance from Measures of the Dark Focus of Accommodation. *Human Factors*, 41 (1), 139-145.

[6]Loewenfeld, I. E. (1979), Pupillary Changes Related to Age. Inn H. S. Thompson, R. Daroff, L. Frisen, J.S. Glaser, and M. D. Saunders. (EDS.), Topics in Neuro-Opthamology (p 124-150). Baltimore: Williams and Wilkins.

[7]Owens, D. A. and Tyrrell, R. A., Effects of Illuminates, Blur and Age on Nighttime Visual Guidance: A Test of the Selective Degradation Hypothesis, *Journal of Experimental*

Psychology: Applied, 5 (2), 1 - 14.

Before discussing what all of this means, it is important to deal with the basic concepts of acuity and contrast sensitivity.

Visual Acuity

Virtually everyone who has ever read the standard wall chart used to test vision has been part of a test of visual acuity, and the concept is a very basic one, namely how small of a letter (or object) can the person see and focus on. Yet, what is almost universally unknown is the incredibly small portion of the visual field within which a person can focus at any one time. This portion of the visual field, called the "fovea", makes up only one to two degrees of a person's visual field, about the size of a person's thumbnail with his arm extended in front of him. This field of clear central vision is so small that when a person is focusing on the smallest line of the eye chart, he will not be able to read the larger lines just above it. Visual acuity becomes quite poor once the image is off from the center of the visual field into peripheral vision (namely anything out of the fovea). Acuity becomes progressively worse as one moves further into the periphery.

People are not generally aware of this limitation because they are constantly moving the focus of their eyes without realizing it. The practical effect of this very limited field of acuity, and not being able to clearly see an object in the periphery until one has a reason to look to it, is that people "see what they look for." The purpose of the flashing lights of an emergency vehicle, or the bright red of an emergency roadside flare, is to tell the person that there is a danger to perceive, and to lead them to look for this danger, and to bring it into focus. If there is no reason to direct the focus, the danger becomes dramatically harder to see. Absent special conspicuous warnings, people generally look for what they expect based on past experiences.

Contrast Sensitivity

Contrast sensitivity refers to a person's ability to recognize an object regardless of its size by virtue of the differences in brightness compared to its surroundings. In low light circumstances, contrast sensitivity becomes even more important than visual acuity. By way of example, a dark semi-tractor and trailer lacking any markings or lights may be multiple times larger than the person standing next to it wearing retro-reflective clothing (e.g., a runner's vest), but at a distance, the huge dark object may be invisible and the high contrast retro-reflective marking may be easily seen.

Finally, the effects of glare must be considered at night, which significantly interfere with contrast sensitivity.

The serious degradation of nighttime vision by virtue of the effects of darkness on visual acuity and nighttime contrast sensitivity ultimately can contribute to an accident by interfering with a person's ability to perceive the danger in time to react. Psychologists have studied extensively the factors affecting the time needed to perceive and respond, which in general will increase with ambiguity and uncertainty. Where a person expects an event, either because it is conspicuous or predictable, and normally requires a predetermined response, the response time will be short. If, on the other hand, it takes several seconds to recognize the danger because of a very weak visual stimulus (i.e., there is little contrast and the person's attention was not directed to the danger by such things as warning flares or reflective triangles on the road), the additional reaction time can be dramatic, adding seconds to the perception time that may not be enough to avoid the accident. (At 60 miles per hour, a driver covers the length of a football field in just 3.3 seconds).

What, then, is the practical significance of this information in a nighttime accident. Trucking companies that place fleets of drivers on the road without properly educating them to

the limits of nighttime vision, and without taking the steps to provide high visual contrast to their vehicles and proper safety equipment to ensure that attention is focused on the vehicles that may present a danger, must be charged with this knowledge. Professional drivers similarly have this obligation. Trucking companies and professional drivers must be charged with the knowledge of the effects of age on the degradation of nighttime vision and the steps that accordingly must be taken to accommodate this serious reduction in one's ability to see and perceive at night. Hard scientific evidence exists to back up the commonly understood concept that it becomes harder to see at night as one ages, placing the correspondingly higher burden on that driver to take steps to reduce their speed and increase their attention to accommodate these increased risks.

In short, the hard scientific evidence is there for use in the appropriate case to demonstrate how and why the defendant failed to take reasonable steps and avoid the accident in question.

CONCLUSION

Scientific literature on the serious degradation of vision at night is vast and extensive, and far beyond the scope of this article. What this article will hopefully have demonstrated is the existence of this literature, the basic concepts, and a direction to follow when one is faced with this issue.