

THE EFFECT OF AUTOMOBILE WINDOW TINTS ON CONTRAST SENSITIVITY  
AND COLOR DISCRIMINATION UNDER PHOTOPIC AND MESOPIC  
CONDITIONS

by

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requirements for the degree of

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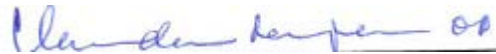
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APPROVED:



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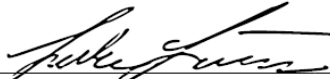
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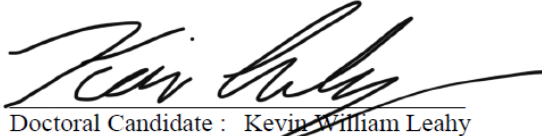
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## ABSTRACT

*Background:* The objective of this study is to determine if tinted windshields and windows impact the contrast sensitivity function (CSF) and color vision in drivers under Photopic (high luminance) and Mesopic (lower luminance) conditions. *Methods:* A sample of subjects (N=21) in the age range 21-30 years with good visual acuity and no known history of color vision defects were included. The Vistech Contrast Sensitivity Chart and Hardy Rand Rittler (HRR) Color Vision tests were used to measure subject Contrast Sensitivity and Color Vision, respectively. Measurements were made through filters that closely approximate the transmittance levels of commercial automobile windshields and windows. Measurements were repeated under mesopic light levels. Mesopic conditions were simulated by using neutral density filters of 1.0 log units. *Analysis & Results:* Contrast sensitivity data were plotted as a function of the following spatial frequencies 1.5, 3.0, 6, 12, and 18 cycles per degree for three tint densities and a baseline condition under photopic and a simulated mesopic condition. Under mesopic conditions, there was a significant drop in contrast sensitivity across all spatial frequencies. Under photopic conditions, there was a drop in contrast for the higher spatial frequencies. Results from this pilot study could have potential implications for optometrists and other eye care providers that are solicited by patients for letters that permit the use of tinted windows as a medical necessity.

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## CHAPTER 1

### INTRODUCTION OF THE EFFECT OF AUTOMOBILE WINDOW TINTS ON CONTRAST SENSITIVITY AND COLOR DISCRIMINATION UNDER PHOTOPIC AND MESOPIC CONDITIONS

Optometrists and ophthalmologists have been combating a dichotomous medical and ethical dilemma for decades – when is it appropriate to prescribe automotive window tint? What levels of photophobia exceed the threshold for a comfortable and safe driving experience? Are sunglasses also sufficient? Who is truly responsible when their patient is involved in a motor vehicle accident? These are questions that run through an eye care professional's mind when relinquishing their unguarded signature.

Although many patients find both functional and cosmetic advantages when applying a filter to their windshield, many drawbacks coexist and are often overlooked. Two of the most apparent disadvantages would include the potential for reduced visibility, and the distortion of color perception. Additionally, the benefits of window tinting are often solely considered when referencing daytime – photopic – driving conditions. When a patient with aftermarket automotive window tint chooses to drive under low light – mesopic or scotopic – conditions, the reduction in visibility and chromatic distortion of targets may play a more significant role. If the latter is true, eye

care professionals should also be mindful of their influence on hazardous driving conditions.

Furthermore, from a legal and ethical standpoint, one has to factor in the degree of restricted access to the tinted vehicle. In other words, when a prescription filter is applied to an automotive windshield, many patients disregard their legal obligation to restrict friends and family members from using the selected vehicle. To be clear, the window tint prescription is *only* written for the patient with an appropriately diagnosed medical condition.

Although most eye care providers would instinctively state that automotive window tint is *not* the most appropriate management option for most patients, doctors oftentimes struggle to find objective rationale for their instinct. In part, the issue may be that scientific literature provides evidence for both sides of the argument. Some evidence emphasizes the detrimental effects of window tint on driving performance<sup>1</sup>, while other scientific articles outline the putative benefits of window tints including glare reduction, heat reduction, and protection from harmful UV rays<sup>2,3</sup>. The purpose of this study was to determine if automotive window tints impact the contrast sensitivity function and chromatic discrimination of drivers under simulated conditions photopic (daytime) and mesopic (evening) illumination.



## CHAPTER 2

### METHODS OF THE EFFECT OF AUTOMOBILE WINDOW TINTS ON CONTRAST SENSITIVITY AND COLOR DISCRIMINATION UNDER PHOTOPIC AND MESOPIC CONDITIONS

A sample of subjects (N=21) in the age range 21-30 years with good visual acuity and no history of color vision defects were included. Measurements were made through filters (50%, 35% and 15% transmittance) that approximated the percent transmittance of light, medium and dark automobile window tints, respectively. Measurements were repeated under a Mesopic condition, simulated by using Neutral Density filters of a 1.0 log unit density strength. Under the simulated Photopic and Mesopic conditions, the overhead lights in the testing room were kept at an estimated 250 lux based on recommended lighting levels for a classroom<sup>4</sup>.

The Vistech Contrast Sensitivity Chart was used to measure the Contrast Sensitivity Function (CSF) at a standard 3-meter test distance. The Hardy Rand Rittler (HRR) Pseudoisochromatic Plate Test was used to measure color vision with the Macbeth lamp as the primary illumination source.

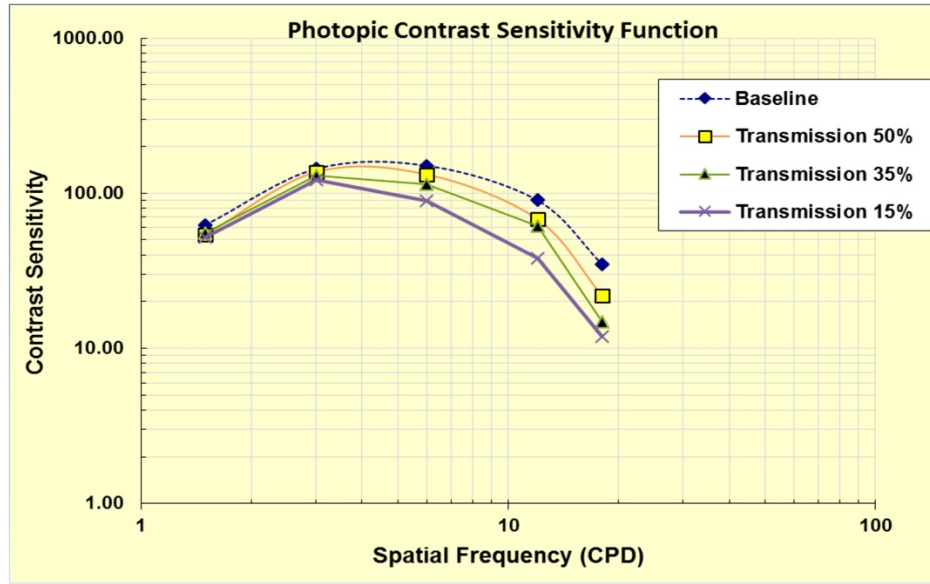
Test subjects with refractive error wore appropriate contact lens correction, enabling them to use a standard trial frame while testing. Plano lenses were cut to match

the size of a trial lens and tinted to match the three transmittance values. All lens transmittance values were verified with a spectrometer.

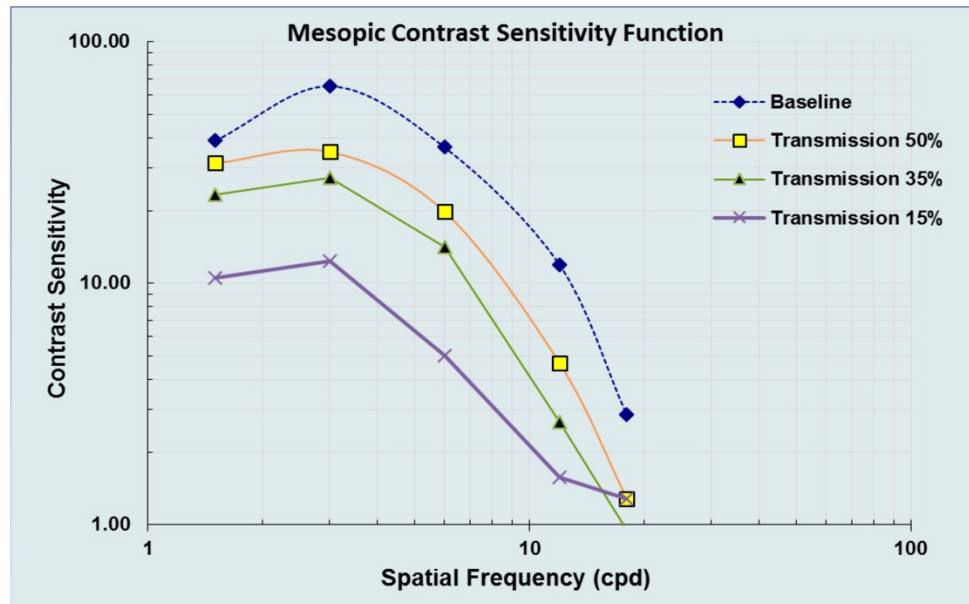
## CHAPTER 3

### RESULTS OF THE EFFECT OF AUTOMOBILE WINDOW TINTS ON CONTRAST SENSITIVITY AND COLOR DISCRIMINATION UNDER PHOTOPIC AND MESOPIC CONDITIONS

Contrast sensitivity data were plotted as a function of the following spatial frequencies 1.5, 3.0, 6, 12, and 18 cycles per degree for three filters with 50%, 35% and 15% transmittance and a 'no-filter' Baseline condition, under Photopic and Mesopic Illumination. For each condition, mean Threshold Contrast was analyzed using a Two-Factor Repeated Measures Analysis of Variance (ANOVA). The two factors were Spatial Frequency and Percent Transmittance. Under Mesopic conditions, the main effect of percent transmittance was significant ( $F(3,419) = 75.53, p < 0.001$ ). Under Photopic conditions the main effect of percent transmittance was non-significant ( $F(3,419) = 0.89, p < 0.44$ ). There was no significant change in chromatic discrimination with the tint, however, as expected color discrimination was significantly better under photopic conditions ( $p < 0.03$ ).



**Graph 1:** Contrast Sensitivity as a function of Spatial Frequency for Filters with 50%, 35% and 15% transmittance. Under Photopic conditions there was no significant difference in contrast sensitivity with decreasing transmittance



**Graph 2:** Contrast Sensitivity as a function of Spatial Frequency for Filters with 50%, 35% and 15% transmittance. Under Mesopic conditions there was a significant drop in contrast sensitivity with decreasing transmittance. Mesopic conditions were simulated with a 1.0 log unit ND filter

## CHAPTER 4

### DISCUSSION OF THE EFFECT OF AUTOMOBILE WINDOW TINTS ON CONTRAST SENSITIVITY AND COLOR DISCRIMINATION UNDER PHOTOPIC AND MESOPIC CONDITIONS

As stated earlier in this paper, although most eye care providers would instinctively state that an automotive window tint is *not* the most appropriate management option for their patients, they often struggle to find objective rationale for this instinct. The purpose of this study was to determine if automotive window tints impact the contrast sensitivity function and chromatic discrimination of drivers under simulated conditions of photopic and mesopic illumination.

Our findings indicate that contrast sensitivity is significantly compromised with tints, specifically under low luminance or mesopic conditions. This was true even with the lightest tint at 50% visible light transmittance (VLT). Color discrimination, however, remained unimpacted with tint. Since – in Michigan – prescription window tint is limited to all exterior windows, not including the front windshield<sup>5</sup>; one could argue that tinting car side windows will not interfere with central vision, and is therefore inconsequential to the task of driving. However, research suggests that safe driving requires operators to rapidly detect low contrast, often poorly illuminated peripheral targets through front side

windows<sup>3</sup>. Hence, tinting could significantly impact the speed of detection by further reducing the contrast of a low contrast target<sup>3</sup>, ultimately compromising driver performance and safety.

As with all research, our study results have some limitations. First, our cohort was comprised of young subjects with good ocular health and clear media. The prevalence of ocular conditions such as cataracts and macular degeneration is higher in the elderly, which undoubtedly compromise contrast sensitivity in this group<sup>6,7</sup>. Additionally, age-related neuronal and receptor loss decrease the contrast sensitivity function even further in this population<sup>8</sup>. Therefore as such, the detrimental effects of window tints on contrast sensitivity are presumably exacerbated in the elderly driving population.

The second limitation of our study relates to current automotive window tinting laws followed in the United States of America. As stated earlier, in most States – including Michigan – prescription window tint is limited to two or more side windows, but typically does not include the front windshield. Thus measuring *central* contrast sensitivity, as demonstrated in this study, may not be directly relevant to the putative functional compromise that drivers experience with tinted *side* windows.

Despite these limitations, our findings clearly imply that contrast sensitivity is significantly compromised with tints; even at 50% visible light transmittance with ambient light levels near mesopic or scotopic conditions. Future studies could investigate the effect of tints and ambient lighting on peripheral contrast sensitivity and target detection thresholds.

Overall, we contend that the risks associated while operating an automobile with tinted windows outweigh the benefits. We are hopeful that our results could incentivize eye care providers to recommend sunglasses or polarizers as an alternative to window tinting in confounding cases.

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APPENDIX A

IRB APPROVAL FORM

# FERRIS STATE UNIVERSITY

## Institutional Review Board for Human Subjects in Research

Office of Research & Sponsored Programs, 1010 Campus Drive FLITE 410G- Big Rapids, MI 49307

Date: April 21, 2017

To: Dr. Vandana Rajaram, Mr. Luke Lirones, and Mr. Kevin Leahy

From: Dr. Gregory Wellman, IRB Chair

Re: IRB Application #170109 (*Window Tint and its Effect on Contrast Sensitivity and Color Vision*)

The Ferris State University Institutional Review Board (IRB) has reviewed your application for using human subjects in the study, "*Window Tint and its Effect on Contrast Sensitivity and Color Vision*" (#170109) and determined that it meets Federal Regulations Expedited-category 2D. This approval has an expiration of one year from the date of this letter. **As such, you may collect data according to the procedures outlined in your application until April 21, 2018.** Should additional time be needed to conduct your approved study, a request for extension must be submitted to the IRB a month prior to its expiration.

Your protocol has been assigned project number (#170109), which you should refer to in future correspondence involving this same research procedure. Approval mandates that you follow all University policy and procedures, in addition to applicable governmental regulations. Approval applies only to the activities described in the protocol submission; should revisions need to be made, all materials must be approved by the IRB prior to initiation. In addition, the IRB must be made aware of any serious and unexpected and/or unanticipated adverse events as well as complaints and non-compliance issues.

Understand that informed consent is a process beginning with a description of the study and participant rights with assurance of participant understanding, followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document and investigators maintain consent records for a minimum of three years.

As mandated by Title 45 Code of Federal Regulations, Part 46 (45 CFR 46) the IRB requires submission of annual reviews during the life of the research project and a Final Report Form upon study completion. Thank you for your compliance with these guidelines and best wishes for a successful research endeavor. Please let us know if the IRB can be of any future assistance.

Regards,



Ferris State University Institutional Review Board  
Office of Research and Sponsored Programs