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Effect of Increasing Road Light Luminance on Night Driving Performance of Older Adults

Said M. Easa, Maureen J. Reed, Frank Russo, Essam Dabbour, Atif Mehmood, and Kathryn Curtis

Abstract**—**The main objective of this study was to determine if a minimal increase in road light level (luminance) could lead to improved driving performance among older adults. Older, middle-aged and younger adults were tested in a driving simulator following vision and cognitive screening. Comparisons were made for the performance of simulated night driving under two road light conditions (0.6 and 2.5 cd/m^2). At each light level, the effects of self reported night driving avoidance were examined along with the vision/cognitive performance. It was found that increasing road light level from 0.6 cd/m^2 to 2.5 cd/m^2 resulted in improved recognition of signage on straight highway segments. The improvement depends on different driver-related factors such as vision and cognitive abilities, and confidence. On curved road sections, the results showed that driver's performance worsened. It is concluded that while increasing road lighting may be helpful to older adults especially for sign recognition, it may also result in increased driving confidence and thus reduced attention in some driving situations.

Keywords**—**Driving, older adults, night-time, road lighting, attention, simulation, curves, signs.

I. INTRODUCTION

NIGHT driving represents a considerable challenge for older adults due to age-related losses in vision and cognition [1-7]. The declined visual abilities include acuity, contrast, depth and visual attention and cognitive abilities such as processing speed. Age-related losses in those abilities are linked to some difficulties in *daytime* driving for older adults [8] and given that older drivers represent one of the fastest growing groups of drivers [8,9], it is also important to understand the impact of aging on night driving where visual abilities further decline with reductions in luminance.

The visual abilities of older adults' are taxed at low luminance due to loss of retinal rod sensitivity, slower dark adaptation and slower glare recovery [10,11]. Older drivers have more difficulties at night with sign recognition, road edge excursions, maintaining appropriate driving speeds, steering accuracy and object recognition when compared to their younger counterparts [12,13]. The majority of older drivers seem to recognize these difficulties and often choose to avoid night driving [14, 15], which may reduce driver confidence and driving ability when night driving cannot be avoided [16]. Older drivers cite their own decline in driving performance and vision loss as their reason for self-restriction of night driving [17–19]. One possible way to mitigate night-time driving difficulties due to vision loss for older drivers may be to increase road lighting.

Increases in road light levels reduce collision rates and mild decreases in road lighting ($\leq$ 1.5 cd/m^2) increase collision rates [20–23]. However, little is known about the effects of those mild changes in lighting on night time driving behaviours beyond collisions, especially for older adults. Thus, it is possible that direct comparisons between simulator driving performances at varying night time light levels could lead to insights that relate back to recommendations on road lighting for seniors. The main objective of this study is to determine if a minimal increase in road light level could lead to improved driving performance in older adults.

The following sections describe the experimental design (participants, vision and cognitive tests, and simulation driving scenario design), the analysis results of the simulation driving performance, and discussion and conclusions.

II. EXPERIMENTAL DESIGN

A. Participants

The participants included 25 younger (19–27 years), 23 middle-aged (37–56 years) and 27 older (63–84 years) drivers who volunteered to participate in this study. Younger participants were undergraduate and graduate students studying at Ryerson University in Toronto, Ontario, middle-aged participants were Ryerson community members who answered on-campus calls for participation and the older adults were members of Ryerson's LIFE (Learning is For Ever) Institute, a continuing education program for older adults. Overall, 49% of these respondents were male (young = 48%, middle = 57%, and older = 44%) and 51% female (young = 52%, middle = 43%, and older = 56%). All participants were licensed to drive in Ontario and 31% reported that they avoid night driving (young = 24%, middle = 17%, older = 48%).

S. M. Easa is Professor with the Civil Engineering Department, Ryerson University, Toronto, Canada (phone: 416-979-5000; fax: 416-979-5122; e-mail: seasa@ryerson.ca).
M. J. Reed is Associate Professor with the Department of Psychology, Ryerson University, Toronto, Canada (e-mail: mreed@ryerson.ca)
F. Russo is Associate Professor with the Department of Psychology, Ryerson University, Toronto, Canada (e-mail: russo@ryerson.ca)
E. Dabbour is Assistant Professor with the Civil Engineering Department, Abu Dhabi University, United Arab Emirates (e-mail: essam.dabbour@adu.ac.ae)
A. Mehmood is a PhD candidate with the Civil Engineering Department, Ryerson University, Toronto, Canada (e-mail: amehmood@ryerson.ca).
K. Curtis is a Master's candidate with the Department of Psychology, York University, Toronto, Canada (email: kjbc@yorku.ca)

B. Vision and Cognitive Tests

Static Visual Acuity (96% contrast) and Low Contrast Acuity (25% and 11% contrast) Tests. These tests were measured by the Regan Contrast Letter Charts (Paragon Services Inc.). Binocular far acuity was measured under optimal lighting (100 cd/m^2; typical optometric levels) and again at low luminance (0.6 cd/m^2; typical highway road light levels in Ontario).

Stereo-acuity (depth) Test. This test was performed using the Stereo Fly Test/Graded circle test (SO-001-Stereo Optical Co.). This test measures the stereo ability between 40 (best performance) to 800 seconds of arc.

Dynamic (in motion) Acuity Test. This was performed using the high Contrast (96%) Regan Letter Chart during controlled head motion. The participants moved their head laterally at 80 degrees/second (entrained by the beat of a metronome) while reading the eye chart. Every participant practiced this head motion prior to conducting the experiment and once the participant was able to comfortably move his/her head laterally at the required speed he/she was asked to read the eye chart under optimal lighting (100 cd/m^2) and again at low luminance (0.6 cd/m^2). Banks et al. [24] suggest that studies using head motion vs. target motion show similar results. The selected speed of head motion was chosen because it results in retinal motion that is typical in every day driving situations [25].

Visual Attention Test. This test was performed using the Useful Field of View test [26]. In the computerized UFOV test participants were given three sub-tests: processing speed (target identification alone), divided attention (identification while performing a secondary task), and selective attention (identification while performing a secondary task in the presence of distracters). In this test participants must identify a target. The fastest presentation time (in milliseconds) leading to a correct response is recorded.

Processing Speed Test. This was performed using three processing speed tasks: Digit Symbol Substitution test [27], Letter Comparison test [28], and Trails test [29]. The first task measures the participants' ability to quickly switch attention as they substitute as many symbols as possible with the corresponding digits within a 90-second time limit. The Letter Comparison task measures participants' ability to process two sources of information at once. In the task the participants identify whether letter strings (3-letter, 6-letter, and 9-letter strings) on the left are identical to those on the right to decide if they are the same or different. The number correctly compared within a 20 second period per string size is measured. In the Trails task the participants' ability to scan a page where numbers are printed in a random fashion on different parts of the paper is measured. The participant must start at the number 1 and draw a line connecting 13 numbers in order. Trails B is similar except that the participant must connect both numbers and letters in an ordered fashion (i.e. 1-A-2-B-3-C), thus they must not only scan but also switch attention from numbers to letters during the task. The time in seconds it takes to complete the task is measured.

C. Simulation Driving Scenario Design

The STISIM Driving Simulator (Systems Technology Inc.) was used to create the driving scenarios. Participants sat in an experimental passenger car where the throttle, steering wheel and brakes are connected to the driving simulator system. The system measures driver's response to the computer generated scenario events which are projected on a wall screen. Further, a button located on the steering wheel allowed participants to respond when they recognized roadside signs. Drivers were asked to drive as they normally do, obeying driving rules.

Driver performance was measured at two levels of lighting (0.6 and 2.5 cd/m^2). The lower light level was chosen because it is typical of Ontario highways and the higher light level was chosen because it is minimally higher than the maximum luminance in most jurisdictions. Typically the maximum luminance varies between 1.2 and 2 cd/m^2 [23, 30]. The light levels were achieved in the simulation environment with the use of neutral density filters (Rosco Cinigel Filters). The light measurements were taken from the road pavement as is the standard in light measurements on Ontario highways.

The driving scenario included three segments: freeway segment, transition segment, and rural segment (Fig. 1). In the freeway segment, the posted speed was 100 km/h. The freeway segment had two lanes in one direction and included four letter signs, each with a single letter and one of the letters (target letter) was to be visually identified by the participants. The letter sequence in the low light level was F, B, E, and P and that in the higher light level was B, E, F, and P. During this segment the drivers were asked to hit a button attached to the steering wheel when they identified the target letter (E in the low light condition and F in the higher light condition). Note that the sign to be identified was always the third sign

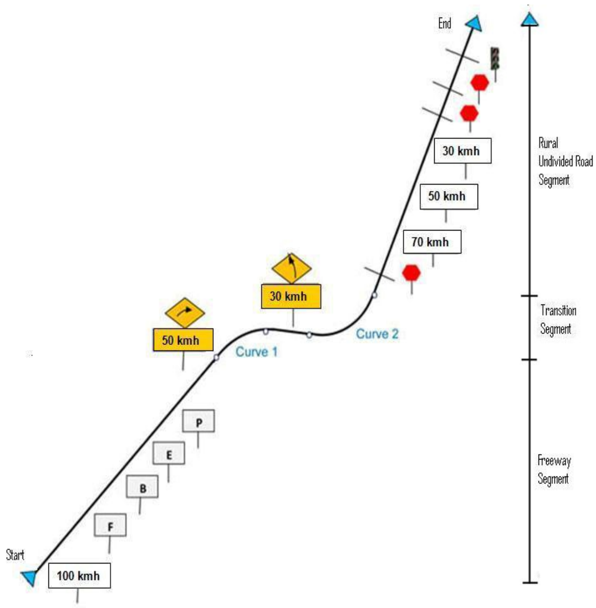

Fig. 1 Geometry of the driving simulator scenarios

(unknown to participants) to ensure consistency in both light conditions. The posted speed signs were typical of those on Ontario highways, having a white background and black lettering. In the lower light condition, the luminance of the letter signs and speed signs (for all parts of the scenario) was 1.2 cd/m^2, which is the typical recommended luminance for road signs [31]. In the higher road light conditions, the luminance was 4.6 cd/m^2. In this segment, vehicle speed and the distance to the identified sign were measured.

The transition segment between the freeway and rural segments was accomplished through a reverse horizontal curve, a right circular curve (radius = 95 m) followed by a left circular curve (radius = 110 m) with an intermediate tangent, and was intended to represent a typical interchange off ramp. In the transition segment, the participants were required to reduce their speeds from 100 km/h to 50 km/h (the design speed of the right circular curve) by following a series of yellow advisory speed signs. The sign luminance for the advisory speed signs was 0.76 cd/m^2 in the lower light scenario and 2.2 cd/m^2 in the higher light scenario. The measures taken in that segment included driver's mean curve position (accuracy) and individual variability in curve position (precision) at different time intervals, mean speed, distance from the posted speed sign at which the participants began to slow, and reaction time to brake (RTB). The RTB is defined as the time taken for the driver to move his/her foot from the accelerator to the brake. On the circular curve to the left, the participants were required to slow to 30 km/h. The measures taken were the same as those of the right circular curve.

The rural segment had a four-lane undivided road (two lanes in each direction) with a series of stop signs and posted speed signs with varying speed limits. In that segment, the drivers changed the speed after coming to a stop sign, where the posted speed signs change from 70 km/h to 50 km/h and then to 30km/h. Two measures were taken. First the distance from the sign where the driver removes the foot from the accelerator was measured and second the difference in time between the removal of the foot from the accelerator to the brake was taken as a measure of reaction time to brake. The number of stop signs missed was also recorded. The scenario ended with a traffic signal.

The number of times the driver exceeded the posted speed limit was recorded throughout the entire scenario along with the number of times the driver crossed the lane edge marking to the pavement shoulder. Originally the number of centre line excursions was also recorded; however, that type of excursion was found to occur infrequently among older adults (less than 5% of trials). The road lighting was counterbalanced between participants, where some participants started with the low light scenario followed by the high level scenario, and vice versa for the others.

III ANALYSIS RESULTS

All collected data were statistically analyzed using the analysis of variance procedures to determine whether driving performance is affected by the increase in light level, cognitive and vision performance, or driving avoidance. Only the variables that were affected by the changes in the road light level are reported here. The Alpha parameter was set at 0.05, while Bonferoni corrections were used when multiple analyses of the same variable were conducted. Thus, for the mean curve position and individual variability in curve position, speed exceedances and speed during sign searches, alpha was set at 0.025. For those variables, the incidents (trends) where the alpha levels varied between 0.025 and 0.05 are also reported. Both correlation analyses and standard regression techniques (backward) were used to examine the relationships between driving performance and vision/cognitive performance.

A. Simulation Driving Performance

In four situations the change in road lighting impacted the driving behaviour including mean curve position during the left curve of the transition segment, mean distance to roadside sign identification, mean number of times the driver exceeded speed limits, and the mean number of incidents where the driver crossed the lane markings to the pavement shoulder.

Mean Curve Position. The accuracy of the mean curve position was calculated as a difference score using the mean driving curvature of the vehicle relative to the actual road curvature, given by (1/*R*), where *R* is the curve radius. For convenience, difference scores (difference between vehicle curve and road curve) are converted into meters as shown in Fig. 2 (the error bars are also shown). Overall, road lighting affected the accuracy of driver's curve position. The lower light level resulted in smaller differences between the actual and mean vehicle curve (greater accuracy) ($F(1,72) = 5.62$, $P = 0.020$). Figure 2 illustrates that the effect is due to the older age group and shows a trend between age groups and light where the difference in accuracy at the two light levels is larger for older than younger participants (who show little difference) ($F(1,72) = 3.35$, $P = 0.040$; Bonferoni Correction). A significant group effect reveals that older

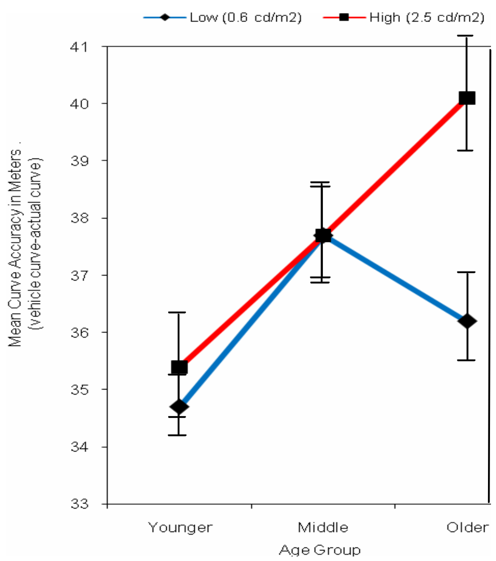

Fig. 2 Mean curve position relative to actual curve position for younger, middle aged and older adults

adults show less accuracy in curve position than younger adults ($F(2,72) = 6.62$, $P = 0.002$).

To explore the effect of vision and cognition on curve accuracy, both vision and cognitive variables were correlated with the mean curve position. Under the higher light level, small and moderate correlations were found to exist between mean curve position and all types of acuity (static, dynamic and contrast), ranging between -0.292 and -0.527. This suggests that people with the poorest acuity had the least accurate curve position in higher light conditions. On the other hand, acuity did not have a significant effect on accuracy under the lower light level. The correlation results for older adults alone were consistent with those reported above for the entire sample. However, a trend between road lighting and contrast acuity for older adults was found for *individual lane precision* (variability) when driving on the road curved segments ($F(1,25) = 4.70$, $P = 0.040$; Bonferoni Correction). This shows that in the higher light condition, those with poor acuity were more precise than those with better acuity. In the lower road light condition those with poor acuity were less precise than those with better acuity and less precise than in the higher light condition. These results suggest that higher road lighting benefits those with poor contrast acuity but for those with better acuity, higher road lighting does not lead to improved precision.

Significant correlations were also found for the entire sample, under the higher light condition, between the mean curve position and the cognitive variables (visual attention and processing speed), and ranged from -0.26 to -0.54. Those with the poorest cognitive performance showed the poorest accuracy in curve position. This result was also representative of the older group. Among all cognition measures, only processing speed for scanning was significantly correlated with mean vehicle curve position for the lower light condition ($r = -0.26$). Those who were fastest to process during scanning were also the most accurate in curve position. This correlation was not significant when considering the older adults alone.

To better understand the relationship between driver performances, curve design, and vision/cognitive variables in the *older* group a standard regression analysis was performed. For this analysis, the mean vehicle curve accuracy difference was calculated as the difference between mean curve position for driving in lower light from the mean curve position for driving in higher light for each circular curve segment. Overall, 31.3% of the variance in these data could be predicted by night contrast acuity and the curve radius. The relationship is given by

$$\Delta_C = 0.041\, LCA + 3.54\, I - 4.72 \quad (1)$$

where $\Delta_C =$ mean vehicle curve accuracy difference, LCA = low contrast acuity taken at night light levels, I is a dummy variable representing the reverse curve transition segments (0 for the right circular curve and 1 for the left circular curve). The measured acuity ranged from 20–30 (normal acuity) to 40–160 (poor acuity).

Unlike the correlations presented above, it was possible to examine performance across both light levels for both highway curve segments. This regression suggests that on the right circular curve (radius = 95 m), older adults who have normal to poor contrast vision (e.g. 20–100), show curve positions that are slightly more accurate in higher light than lower light or are similar at both light levels, while in the left circular curve (radius = 110 m), those with normal acuity show curve positions that are equal at both light levels while those with poorer acuities tend to show more accuracy at lower light levels.

Mean Distance to Identify Road Signs. A significant effect of the road light level was found when individuals were asked to identify a road sign along the road segment with 100 km/hr posted speed. In the higher light condition, the identification of the sign took place further away (54.5 m) than in the lower light conditions where the identification took place at 41.3 m ($F(1,60) = 9.45$, $P = 0.003$). However, there was no effect of age group on this identification.

The identification distance was not correlated with any vision or cognitive variable in the higher light condition. However, the analysis showed that acuity (static, contrast and dynamic) and visual attention variables (processing speed and selective attention) were related to road sign identification, where correlation coefficient, r, varied from -0.25 to -0.47, under the lower light condition. Those with the poorest acuity needed to be closer to the road sign for identification. In addition, those with slower visual attention needed to be closer to the sign to identify it. Because these correlations with visual attention were only evident under low light condition, the scope of this research also included the examination of the effect of the contrast acuity on the correlations with visual attention, while controlling for the contrast vision. However, these partial correlations between distance to recognize signage and visual attention were not significant.

Compliance with Posted Speeds. The number of times a participant exceeded the posted speed limit was recorded. Speed was exceeded more in the higher light condition than in the lower light condition ($F(1,72) = 5.52$, $P = 0.022$). A significant interaction suggested that drivers in the older group were more affected by the light changes than those in the younger group ($F(1,72) = 4.48$, $P = 0.015$), as shown in Fig. 3. Similarly, by analyzing the data collected from the older adults group, it was found that drivers in that group exceeded the posted speed fewer times under the lower light condition than under the higher light condition ($F(1,26) = 19.62$, $P < 0.001$).

No significant correlations were found between the number of times a driver exceeded the posted speed and any vision or cognitive variable under either the higher or the lower light condition, except for a small but significant correlation that was found between the number of times a driver exceeded the posted speed and visual scanning processing speed under the lower light condition ($r = -0.26$).

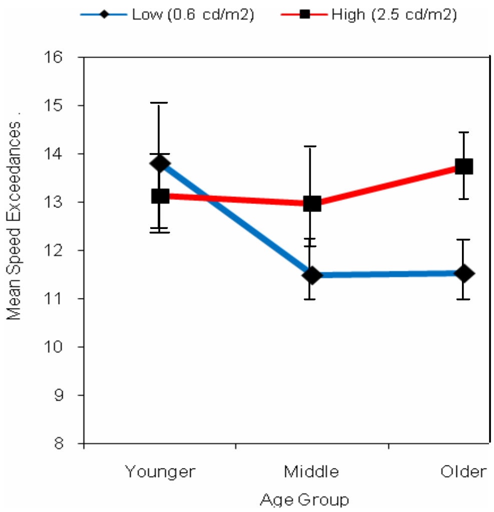

Fig. 3 The mean number of speed exceedances during the driving scenario by younger, middle-aged and older adults

Those with the fastest completion time exceeded the speed limits more often. When this correlation was re-run while controlling for contrast acuity, the correlation remained significant.

Older adults also were significantly affected by road lighting when reducing speed (from 50 to 30 km/hr) during the curved segments of the scenario. Under both light conditions older adults did not begin adjusting speed until they have already passed the posted sign; however, under the higher light condition they began adjusting speed one meter beyond the sign, while under the lower light condition they did not adjust their speed until 35.7 m beyond the sign ($F(1,17) = 4.45$, $P = 0.050$). This speed adjustment was correlated with processing speed for visual scanning ($r = 0.50$). Those with the slowest scanning were poorest at making speed adjustments (adjusting beyond the sign). Further, older adults showed less variability in their speed during the curved segment of the scenario under the lower light condition than under the higher light condition ($F(1,26) = 6.89$, $P = 0.014$). This variability was correlated with visual attention and processing speed under both light conditions ($r = 0.40$ to 0.64). Those with the slowest visual attention scores and the slowest processing speeds had the most variability in their speed.

Number of Road Edge Excursions. Under both light levels, those with the poorest contrast acuity also showed the most road excursions (ranges from 0.28 to 0.49). Visual attention processing speed was also correlated with road edge excursion under both light conditions ($r = 0.31$ and 0.42 for low and high light levels, respectively). Those with the poorest processing speed had the most road excursions. Finally, under the higher light condition, processing speed for visual scanning and attention switching was correlated with road excursions ($r = 0.27$). Those with the poorest processing speed (for scanning and attention switching) had the most road excursions.

B. Self-Reported Avoidance and Driving Performance

The results for the difficulties related to driving on curves are shown in Fig. 4. As noted, drivers who avoid driving at night showed poorer accuracy in their curve position than those who do not ($F(1,73) = 11.42$, $P < 0.001$). A trend between the light level and night driving avoidance revealed that those who avoid driving show less accuracy under the higher light condition than they do under the lower light condition, where accuracy in those who do not avoid night driving is relatively unaffected by road lighting ($F(1,73) = 3.97$, $P = 0.050$; Bonferoni correction). The analyses on individual precision of driver curve performance revealed that those who avoid driving are less precise in driving during curve highway segments than those who do not ($F(1,73) = 5.72$, $P = 0.019$).

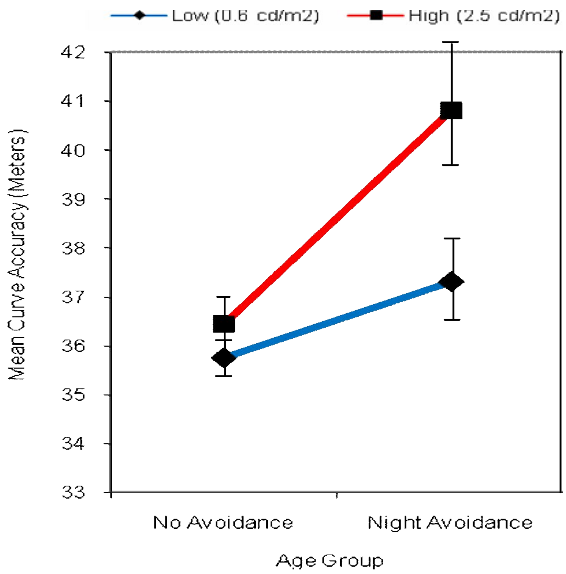

Fig. 4 The mean curve position relative to actual curve position (accuracy) for those who avoid/do not avoid night driving

In addition to curve position difficulties reported above, older adults who reported that they avoid driving at night were found to be faster to react to speed changes during curved road segments than those who do not avoid driving ($F(1,16) = 6.31$, $P = 0.023$). While initially this finding may seem counterintuitive, it was not unexpected. The reaction time here is measured as the time for the participant to move the foot from the accelerator pedal and start pressing the brake pedal. The results suggest that those who do not avoid night driving anticipate the speed change better and thus begin that process of accelerator release so as to smoothly brake. Those who avoid night driving take quick brake actions, suggesting that they are not anticipating the changes as well.

IV. Discussion And Conclusions

The main finding of this study is that road lighting has different effects on night-time driving behaviours depending on the type of behaviour and the age of the participant. The increase in road luminance was helpful for drivers in some situations and had a negative impact in others. Further, some outcomes were mediated by age.

Drivers of all ages could identify signs further away in higher road lighting luminance. In as much as sign reading and related decision-making processes require focused attention, the positive effects of increased lighting may provide additional time for the driver to make safe driving maneuvers. It was not surprising that mild increases in road lighting should benefit vision. While drivers of all ages are required to have reasonably good acuity (20/40 or better), losses in contrast recognition and target detection are striking at luminance levels below 1 cd/m^2, especially for older adults [32–34]. It may be that the minimal increase in lighting from 0.6 to 2.5 cd/m^2 was adequate to compensate for those losses. The findings of this study also show that in the low light condition (0.6 cd/m^2) acuity affected sign reading. Those with the poorest acuity (static, dynamic and contrast) had to be closer to the sign to read it. In contrast, acuity did not affect the outcome when road luminance was increased to 2.5 cd/m^2. This suggests that increased lighting helped to compensate for some acuity and contrast losses.

In addition to acuity, light might also assist with cognitive losses. In the lower luminance but not the higher luminance condition those with the poorest visual attention needed to be closer to the sign to recognize it. Zur and Shinar [19] suggest that older drivers may be aware of some losses and change driving habits to compensate**.** Here, we find support for that argument in that those with the most processing difficulties exceeded speed limits less often and were less variable in their driving speed under the lower light condition, suggesting that they were attempting to increase caution.

In contrast to the benefits of road lighting on sign recognition, the results of this study suggest that the increase in lighting luminance had an adverse effect on drivers of all ages in terms of exceeding the posted speed. In addition, older drivers showed less accuracy on following the lane centre line of the curved segments of the highway in the higher light condition. These results suggest that under the higher light condition, drivers adopt less cautious and attentive strategies. Assume et al. [20] examined driver concentration of more than 27,000 drivers on a highway before and after the installation of light standards. Overall, the authors found that in general drivers increased speed and decreased concentration after the instillation of road lighting. Based on questionnaire response, they theorized that individuals of different ages may be uniquely affected by changes in driving concentration.

Here we find support for this theory in that all drivers change behaviours under higher light condition by increasing speed and older drivers uniquely reduce vehicle curve accuracy. These results can be explained by the theoretical notion of target risk, where humans have a relatively stable level of risk tolerance and will modify behaviour in different settings in order to maximize benefits without compromising risk homeostasis [35]. Decreased attention may be thought of as a sort of cognitive benefit that is afforded by a less demanding driving scenario. Our finding that older drivers have less curve accuracy in the high light condition might suggest that they are using different strategies than younger adults in dealing with or perceiving risk.

The effect of acuity on driver performance was also found to be situation specific. First, drivers with poor acuity were less accurate in their curve position under the higher light condition, but acuity did not affect accuracy under the lower light condition. On the other hand, these drivers were more precise (less variability) in lane position during the curved segments of the highway under the higher light condition than in the lower light condition. In addition, those with poor acuity were more precise than those with better acuity in the higher light condition. This finding suggests that under the higher light condition, those with poor acuity have difficulty in accurately navigating curves but are benefited from the higher light as it allows them to increase their driving precision. Further, those with better acuity, while being more accurate than their lower acuity counterparts, do not benefit from more light in terms of precision.

Second, acuity was also predictive of sign recognition only in the lower but not higher light condition. The small increases in light may have aided those with poor acuity leveling their visual performance for sign recognition to that of those with better acuity. Third, road edge excursions were affected by acuity under both light levels, meaning that those with the poorest acuity had the most edge excursions. This suggests that the increase in light does not aid those with poor acuity with this type of driving behaviour. Previous authors have found acuity to be related to some driving behaviours such as road hazard identification and sign recognition and not to others such as crash involvement [36–38]. Here we uniquely find that the increase in lighting for night driving, which improves acuity, will have varying effects on driving behaviours. This implies that changes in lighting as an aid to vision loss for older drivers must consider the relationship between these behaviours and acuity.

We also found small but significant correlations between some of the driving performance variables and cognitive performance. Richardson and Marottoli [39] reported that some driving maneuvers such as responding to traffic signals and other vehicles are predicted by visual attention and processing speed. Here we find that these relationships were dependent on the type of driving behaviour and the road light level. For example, curve accuracy, road edge excursion, and variability in driver speed (older adults only) were related to cognitive performance under both light levels. In general, drivers with better cognitive performance showed better road performance. However, older drivers with faster processing speeds exceeded the speed limits more often. These results suggest that driving performance is related in some ways to attentional control (as shown by visual attention and processing speed) and that drivers seem to have some ability to judge this control, given that those with poorer processing speeds compensate for this loss by driving more cautiously as evidenced by fewer speed exceedances.

Driver confidence was further examined by comparing those who do/do not avoid night driving. Overall, it was found that in some situations those who avoid night driving showed poorer accuracy in driving under the higher light condition than under the lower light condition, suggesting that they are attempting to compensate for the light conditions, while those who do not avoid driving at night were not affected by the light levels. Hakamies-Blomquist et al. [16] showed, based on driving statistics, that those who drive less than 3000 km/year were more at risk for collisions. Here, we find that while some compensation for the light level occurs, those who avoid driving at night show faster brake times and generally have less precision when navigating the road curved segments. This suggests that the loss of driving practice leads to poorer anticipation of road changes resulting in increased need for sudden braking and unsteady driving practices.

One of the limitations of this study was the small number of tested driving situations. While a number of driving situations has been examined, driving simulation scenarios were limited to rural and freeway driving. McPhee et al [40] suggests that driving performance in older adults is adversely affected by environmental clutter, such as clutter found in urban settings. Scenarios involving urban driving, turns, urban distractions, interaction with objects, traffic signals, and higher volume traffic might reveal further benefits and risks with changes in road lighting. Furthermore, only one group of older adults has been tested. Some recent data suggests that driving behaviours differ between older adults above 75 years of age and those younger than 75 [15]. Thus, it is also possible that changes in road lighting might offer different benefits/risks to these two older age groups and should be the focus of future research.

Clearly, a minimal increase in road light has both risks and benefits associated with it, given the complexities of driving behaviours. Such changes must consider driver's age, vision, cognition, and confidence.

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Said Easa is Professor in the Department of Civil Engineering at Ryerson University, Toronto, Ontario, Canada. He served as Department Chair during 2000–2006. He earned his B.Sc. from Cairo University, M.Eng. from McMaster University (Canada) and Ph.D. from University of California at Berkeley in 1982. His areas of research include highway geometric design, road safety, and human factors. He is Associate Editor of the Journal of Transportation Engineering, American Society of Civil Engineers (ASCE). He has published extensively in refereed journals and his work has received from ASCE the 2001 Frank M. Masters Transportation Engineering Award for outstanding contributions to the profession.

Maureen Reed is Associate Professor in the Department of Psychology at Ryerson University in Toronto Ontario. She earned her BA from Queen’s University in Kingston Ontario, and her MA and PhD. from York University in Toronto Ontario in 1991. Her research areas include visual perception, human development and human factors.

Frank Russo is Assistant Professor of Psychology and Director of Psychological Science Training at Ryerson University in Toronto, Canada. His current work focuses on music cognition, hearing science, assistive technology, and perceptual ergonomics. He has consulted for Canadian and U.S. Departments of Transportation on Locomotive Horn Effectiveness, and is co-inventor of a sensory-substitution technology enabling perception of music by the deaf and hard of hearing (Emoti-Chair). He is on the editorial board of Psychomusicology: Music, Mind and Brain and the board of directors of the Canadian Acoustical Association.

Essam Dabbour is Assistant Professor in the Department of Civil Engineering at Abu Dhabi University in Abu Dhabi, United Arab Emirates. He earned his B.Sc. from Alexandria University, and his M. A. Sc. and Ph. D. from Ryerson University (Canada). His areas of research include highway geometric design, road safety, human factors and intelligent transportation systems.

Atif Mehmood is a Ph.D. Candidate with the Department of Civil Engineering, Ryerson University, Toronto, Ontario, He earned his BSc. from Quaid-e-Awam Engineering University (Pakistan), M.A.Sc. from Ryerson University and has published five journal papers since the start of his doctoral studies in 2004. His interest lies in the area of traffic operations and highway geometric design.