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Neuro-Ophthalmology

The Effects of Glare on the Perception of Visual Motion as a Function of Age

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Purpose: The purpose of this study was to determine the impact of glare, that simulated the effects of oncoming vehicle headlights, and age on different aspects of motion perception in central and peripheral vision.

Methods: Twenty younger (mean age = 25 years, range = 20–32 years) and 20 older (mean age = 70 years, range = 60–79 years) visually healthy adults completed four visual motion tasks. Stimuli were presented centrally and at 15 degrees horizontal eccentricity for 2 viewing conditions: glare (continuous, off-axis) versus no glare. Motion tasks included minimum Gabor contrast required to discriminate direction of motion, translational global motion coherence, minimum duration of a Gabor to determine direction of motion (2 different size Gabors to determine spatial surround suppression), and biological motion detection in noise. Intraocular straylight was also measured (C-Quant).

Results: Older adults had increased intraocular straylight compared with younger adults ($P < 0.001$). There was no significant effect of glare on motion thresholds in either group for motion contrast ($P = 0.47$), translational global motion ($P = 0.13$), biological motion ($P = 0.18$), or spatial surround suppression of motion ($P = 0.29$). Older adults had elevated thresholds for motion contrast ($P < 0.001$), biological motion ($P < 0.001$), and differences in surround suppression of motion ($P = 0.04$), relative to the younger group, for both the glare and no-glare conditions.

Conclusions: Although older adults had elevated thresholds for some motion perception tasks, glare from a continuous off-axis light source did not further elevate these thresholds either in central or peripheral vision.

Translational Relevance: A glare source that simulated the effect of oncoming headlights, did not impact motion perception measures relevant to driving.

Introduction

Older adults commonly complain of problems with glare from oncoming headlights when driving on nighttime roads.[1] The presence of a bright light source results in a reduction in the visibility of objects, known as disability glare,[2] which is mainly due to retinal straylight from intraocular light scatter.[3] The levels of ocular straylight increase with normal aging,[4,5] especially in the presence of media opacities, such as cataracts.[5,6] In the context of driving, there is evidence that disability glare produced by oncoming vehicle headlights reduces the distance at which visual stimuli can be recognized,[7] including recognizing pedestrians[8–13] and road signs and signals.[10,11]

Motion perception has been shown to be relevant for safe operation of a vehicle.[10,14–19] Both the driver and the environment are in motion, providing important cues regarding potential hazards in the visual scene. Motion perception is a hierarchical process involving numerous regions of the brain that process different aspects of motion in the visual world. For instance, area V1 is able to detect small local motion signals[20] that are subsequently integrated in area MT/V5, particularly translational patterns.[21] The superior temporal sulcus[22] is involved in processing biological motion, which enables the perception of patterns of motion to be recognized as living forms.[23] The processing of biological motion requires correct interpretation of motion signals, as well as form and orientation.[23,24]

Previous studies have demonstrated that some of these aspects of motion perception decline with aging, even in visually healthy older adults.[25–29] Furthermore, there is evidence that reduced motion sensitivity is related to impaired on-road driving performance under both day and night-time conditions,[10,18,19,30] including reduced ability to recognize pedestrians and traffic signs, and to maintain accurate lane positioning. Therefore, studying the direct effects of a glare source on these aspects of motion perception in older adults may highlight deficits that are relevant in the context of road safety.

To our knowledge, only one study has explored the effects of glare resulting from oncoming headlights on motion perception.[31] This study showed that, in the presence of real vehicle headlights under night-time conditions, the minimum contrast required to identify the direction of moving sine gratings increased. However, only two younger observers were assessed. There are also no reports of the effects of glare on motion perception in the peripheral vision of either young or older adults, despite the fact that peripheral vision is relevant for driving, particularly for maintaining lane position[32] and hazard detection.[33]

Therefore, the current study aimed to explore the effect of a continuous glare source on the perception of different types of motion in visually healthy adults in both central and peripheral vision. We assessed two age groups, one of whom were older, as this age group has increased levels of intraocular straylight, even when media opacities are not present,[4,5] and commonly complain of driving difficulties in the presence of oncoming headlight glare.[10] Our experimental design specifically included older adults with normal healthy vision, as this is representative of the majority of older drivers, yet still captures individuals with some mild age-related impairments of motion perception.[25–29] Based on the results of Andersen and Holiday,[31] we hypothesized that motion contrast thresholds would be elevated under glare conditions and that these effects would be greater for older than younger adults.

Methods

Participants

Participants included 20 younger (mean age = 25 years, range = 20–32 years) and 20 older (mean age = 70 years, range = 60–79 years) visually healthy adults. Participants were recruited via advertisements placed around The University of Melbourne, local newspapers, University online portals, and from a database of participants previously tested in our laboratory. The study followed the tenets of the Declaration of Helsinki and was approved by The University of Melbourne Human Research Ethics Committee (HREC 1749806). Participants were given a full explanation of the study and experimental procedures and their possible consequences, and written informed consent was obtained from each participant. We provided a $20 (AUD) gift voucher per session to help offset any expenses incurred in attending the experimental sessions.

Participants underwent a vision screening and ophthalmic examination to verify they met the inclusion criteria. This screening consisted of the measurement of visual acuity and subjective refraction using a standard wall-mounted, high-contrast Early Treatment Diabetic Retinopathy Study (ETDRS) chart at a 3 meter viewing distance, a slit lamp examination of ocular media clarity, a macular optical coherence tomography (OCT) scan of each eye using the Spectralis OCT (Heidelberg Engineering GmbH, Heidelberg, Germany), and a monocular visual field screening of each eye using the O600 screening test[34] using the Octopus 600 perimeter (Haag-Streit, Berne, Switzerland). Additionally, participants performed the Mini-Mental State Examination (MMSE).

Inclusion and Exclusion Criteria

Inclusion criteria were distance binocular visual acuity equal to or better than 6/9.5 with the participant's habitual distance refractive correction, spherical equivalent refraction within ±6 diopters (D; with equal to or less than 2.5 D astigmatism), lens opacities less than NO3, C3, or P2 with the LOCS III grading system,[35] no macular defect visible on the OCT within the central 10 degrees, and no more than 3 missed contiguous points within the visual field, with no missed points located immediately within the tested region (15 degrees of eccentricity). In addition, participants were required to have a MMSE score of 24 or higher.[36]

Testing Procedure

Participants completed a series of motion perception tests under both the glare and no glare conditions during two testing sessions on separate days. Each testing session, excluding preliminary testing and C-Quant measurement (approximately 30 minutes), was less than 90 minutes in duration, including regular scheduled breaks and any additional breaks initiated by the participant. Testing was performed binocularly in a dark room illuminated by the computer monitor (maximum luminance of the monitor was 200 cd/m^2). Participants were not required to dark adapt prior to the experiment. The monitor provided maximum illuminance of 32 lux at the eye. We tested two eccentricities: central (stimulus center located at 0 degrees eccentricity) or peripheral (stimulus center located at 15 degrees to the right and 5 degrees upward from the fixation marker in the screen center). The peripheral stimulus location was the same as that used in a previous study,[26] with the upward shift in target location chosen to avoid the physiological blind spot.

Test order for baseline (no glare) and glare conditions, as well as central and peripheral vision, was randomized between participants. Therefore, the combination of viewing condition and eccentricity was approximately counterbalanced between participants. The order of presentation of motion tasks was also randomized for each participant. Experiments were developed in Python using the coder module of Psychopy version 1.85.2.[37] Stimuli were displayed on a calibrated 32-inch Display++ monitor (Cambridge Research Systems, Ltd., Rochester, UK), with a refresh rate of 120 Hz, a spatial resolution of 1920 × 1080 pixels and a pixel size of 0.36 mm. Viewing distance was 100 cm, which was maintained using a chinrest. Participants wore their full optical correction for this viewing distance using trial lenses.

Simulated Glare Condition

For the glare condition, we simulated the effect of the headlights of an oncoming vehicle at 25 meters away from a driver (Fig. 1). This was based on the closed road night-time study of Kimlin and colleagues[10] who used an LED light source on the bonnet of the vehicle driven by the participant to simulate oncoming headlight glare. In our design, we mounted a conventional 12 Watt white LED luminaire (luminance = 10,000 cd/m^2) on a frame at 57 centimeters from the participant. At 25 meters, a typical headlight of 20 centimeters diameter subtends 0.5 degrees of visual angle. At this distance, the headlight of an oncoming car would be located approximately 3 meters horizontally from the driver (rightward in the case of Australia), which is at a visual angle of 7 degrees. Our glare source was presented through an aperture 0.5 degrees in diameter and located 10 degrees to the right of the center of the screen. This horizontal separation avoided direct occlusion of any of the test stimuli. This off-axis light source provided an illuminance of 3.4 lux at the participant's eye, which exceeds the maximum limit permitted for the B50L testing point (0.5 to 1.1 lux) by a factor of three.[38,39] The illuminance values were increased by a factor of three relative to the standard to simulate the glare effects of misaligned headlights. Pilot testing demonstrated that changing the axis of our glare source did not affect the illuminance levels at the plane of the participant's eye. During the glare condition, the main researcher (author J.A.S.) observed the participant's gaze at regular intervals to ensure that they fixated the correct location (either the central stimuli or the eccentric fixation spot).

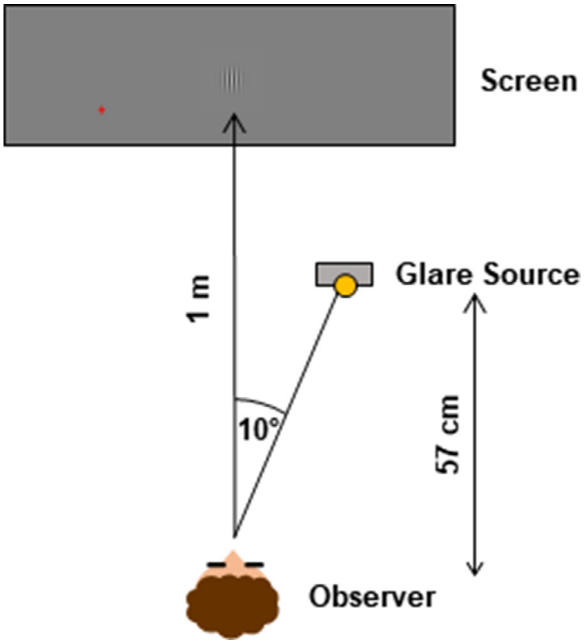

Figure 1. Schematic illustration of the experimental setup. For the peripheral testing condition, participants fixated a red cross located in the left corner of the screen.

Measurement of Light Scatter in the Eye: C-Quant

During the first session, before starting the psychophysical experiments, we measured intraocular straylight levels using the commercially available C-Quant device (Oculus Optikgeräte GmbH, Wetzlar, Germany), which uses the method of compensation comparison to estimate straylight levels in the eyes.[40] This test required participants to compare the intensity of two halves of a central flickering circle, and to respond via a button press to indicate which half of the circle appeared to be flickering more intensely. The resultant straylight parameter, referred to as “s,” is reported as log (straylight).[41] This “s” parameter refers to the intensity required for an external compensatory light to make the flickering effect disappear. For C-Quant measurements, participants were optically corrected using the spherical trial lens (provided with the device) that was closest to the participant's spherical equivalent refraction. The device also reports 2

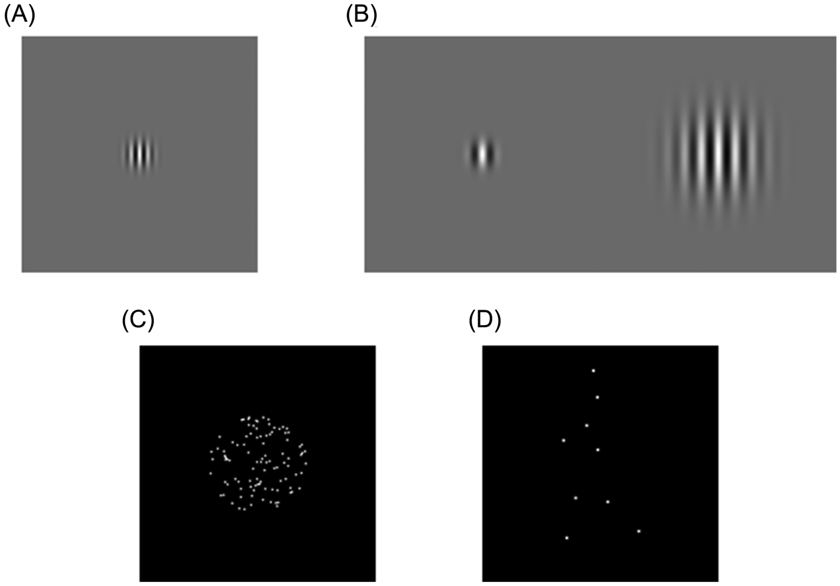

Figure 2. Representation of the stimuli used for the experiment. (**A**) High contrast Gabor patch for motion contrast task. (**B**) Small and big Gabor patches to explore surround suppression of motion. (**C**) Circular random dot kinematogram (RDK) for global motion coherence task. (**D**) Single frame of the point light walker pattern depicting a leftward human walker.

quality parameters (Q and esd), which, according to the device instruction manual, should be higher than 0.5 and lower than 0.08, respectively.[42]

Motion Tasks

At each session, participants completed four motion perception tasks of differing complexities. This section will briefly summarize the experimental procedures, that have been described elsewhere[28] and which were common for all the tasks: a two alternative forced choice staircase with participants reporting the direction of motion of the pattern (rightward or leftward). The staircase procedure was three up one down with six reversals for all tasks except for biological motion that was three down one up. Responses were collected via button presses on a computer keyboard. Figure 2 illustrates the stimuli used. In order of motion processing complexity, the tasks were:

A) **Motion contrast**: This task determined the minimum contrast required to identify the direction of motion of a drifting sine wave grating (see Fig. 2A). Sine wave gratings are widely used to assess early stages of motion processing,[43] including area V1.[44] For this experiment, we used a vertically oriented Gabor patch of $\sigma = 1.35$ degrees with the size truncated at $\pm 3\ \sigma$, with a spatial frequency of 3 c/degrees, a duration of 250 msec and a drift rate of 2 degrees/s (see Fig. 2A). The Gabor patch was presented against a uniform grey background of 94 cd/m^2. This background luminance was the same for all tasks involving the use of Gabor stimuli. The staircase procedure modified the grating contrast, with contrast decreasing after three correct responses and increasing after each incorrect response.

B) **Duration thresholds for identifying the direction of motion**: One property exhibited by many visual neurons is surround suppression, which refers to the decrease in the neural response to a suprathreshold stimulus when surrounded by a pattern with similar characteristics.[45] Based on the work of Tadin and colleagues,[46] our task measured the minimum duration to identify the direction of motion of high contrast Gabor patches (92% Michelson contrast) with a spatial frequency of 1 c/degrees, a drift rate of 2 degrees/s, and of 2 sizes: $\pm 3\ \sigma = 4.05$ degrees and 15 degrees (see Fig. 2B). We calculated a suppression index (SI) by subtracting the log duration threshold of the larger stimulus from the log duration threshold of the smaller stimulus. Therefore, a larger SI indicates that the participant required the stimulus duration to be longer in order to determine the direction of motion for the larger patch, as compared to the smaller patch (i.e. more suppression was present). Tadin and colleagues[46] suggested that the stimulus size at which suppression was most strongly observed was consistent with the size of MT/V5 neuron's receptive fields. The staircase modified the duration of the Gabor, with stimulus duration decreasing after three correct responses and increasing after each incorrect response.

C) **Translational global motion coherence**: This task determined the lowest percentage of signal dots required to detect translational motion of a random dot kinematogram (RDK; see Fig. 2C). The test stimuli consisted of a circular 10 degrees diameter RDK which contained 100 white dots of 5 × 5 pixels moving rightward/leftward at a speed of 2 degrees/s and with a stimulus duration of 420 msec. Individual dot luminance was 200 cd/m^2 and the dots were presented against a black background of 1.74 cd/m^2. The same dot and background luminances were used for the biological motion task, detailed below. The staircase modified the number of noise dots, with an increase in noise dots after three correct responses and a reduction after each incorrect response.

D) **Biological motion**: A more complex pattern of motion is biological motion, which is the pattern of motion of living creatures. Biological motion can be studied using a point light walker[47] (see Fig. 2D). Our paradigm required the observer to identify the direction of motion of a point light walker embedded in visual noise. The point light walker was adapted from Shipley and Brumberg[47] and consisted of 13 animated dots of 5 × 5 pixels that were configured in a rectangular array of approximately 4 degrees wide and 7.4 degrees high, with one full stride occurring in 900 msec. The staircase increased the number of noise dots after three correct responses and decreased them after one incorrect response. The noise dots adopted a similar pattern of motion as that representing the joints of the point light walker but at random locations.

In addition to motion perception testing, we assessed static contrast sensitivity using a customized program developed in PsychoPy. Participants were required to detect the orientation (45 degrees or 135 degrees) of a 3 c/degrees static Gabor patch presented for 250 msec and truncated at $\pm 3\,\sigma = 4.05$ degrees. The selection of the spatial frequency, stimulus size, and duration were consistent with the motion contrast task. Contrast thresholds were determined by a three-down, one-up staircase with six reversals (initial Michelson contrast of 92%, decreasing logarithmically in step sizes of 0.5 for the first reversal, 0.3 for the second, and 0.1 for the final four). Final contrast thresholds were calculated from the final four reversals of two staircases.

Statistical Analysis

We performed our primary statistical analyses in IBM SPSS Statistics for Windows, version 26.0.0.0[48] and plotted figures with R Studio version 1.1.456.[49] We used a repeated measures multifactorial analysis of variance (ANOVA) considering two conditions (no glare and glare), two age groups (younger and older), and two eccentricities (central and peripheral). We transformed raw threshold values into log values to allow the use of parametric statistical tests and also to be consistent in terms of the units included in our previous research.[28] An additional 2-way ANOVA was performed to explore the effects of age and eccentricity on contrast sensitivity. R Studio was used for additional data analysis, including independent samples *t*-tests to compare visual parameters between age groups (i.e. visual acuity, contrast sensitivity, and intraocular light scatter) as well as Pearson correlations between the C-Quant results and motion tasks under glare. Bootstrapped confidence intervals for the correlations (2.5% and 97.5% limits), based on a thousand resampled correlations, were calculated using a customized r function. Cohen's d for effect sizes was calculated using the R package "effsize."[50]

Results

Figure 3 shows baseline visual parameters as a function of the age group, and Table 1 shows the characteristics of our sample (see Supplementary Material S1 for the complete data set). All participants had scores of 27 or higher on the MMSE. As expected, the older participants had significantly higher levels of intraocular light scatter measured by the C-Quant than the younger participants. C-Quant data from five older individuals were removed from the analysis because their values did not meet the quality parameters. In addition, binocular logMAR values and contrast thresholds were significantly elevated in the older compared to the younger participants (see Figs. 3B, 3C, 3D). The results of the independent *t*-tests between groups are provided in Figure 3. A 2-way ANOVA showed a main effect of age on contrast sensitivity: $F(1,76) = 31.00$, $P < 0.001$ and eccentricity: $F(1,76) = 77.95$, $P < 0.001$ but no significant interaction between age and eccentricity: $F(1,76) = 0.23$, $P = 0.63$.

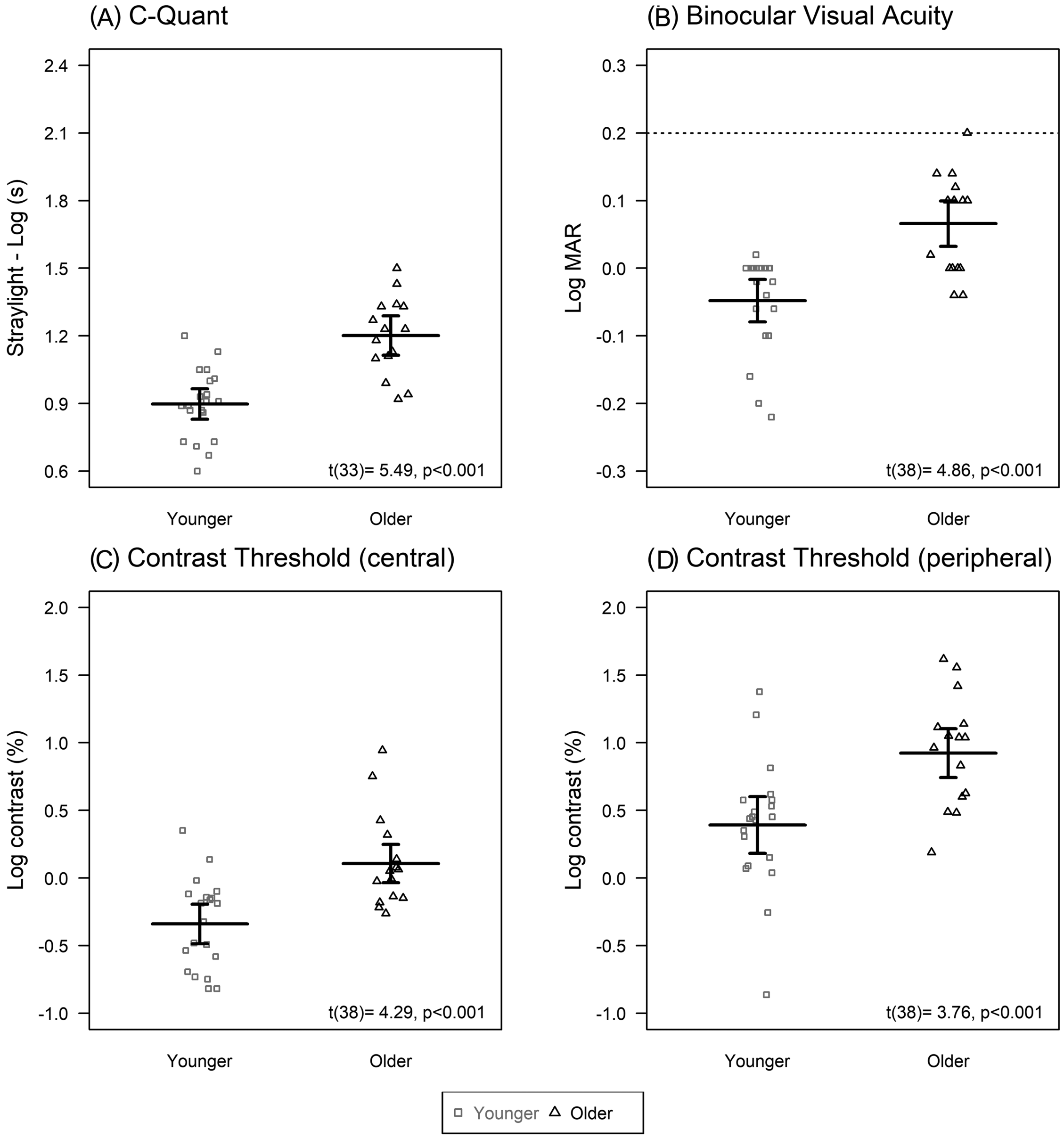

Figure 3. Between group comparison for non-motion perceptual tasks. (**A**) Light scatter measured by C-Quant. (**B**) Best corrected binocular visual acuity. The segmented line represents inclusion criteria cutoff (6/9.5). Panels (**C**) and (**D**) show contrast sensitivity in central and peripheral vision, respectively.

As illustrated in Figure 4, there was no main effect of glare for any of the motion tasks (motion contrast: $F(1,76) = 0.53$, $P = 0.47$; translational global motion: $F(1,76) = 2.33$, $P = 0.13$; and biological motion: $F(1,76) = 1.86$, $P = 0.18$), nor for the levels of suppression (no main effect of glare on SI: $F(1,76) = 1.16$, $P = 0.29$). There was also no significant interaction between age and glare for motion contrast ($F(1,76) = 0.16$, $P = 0.69$) or biological motion ($F(1,76) = 1.05$, $P = 0.31$), nor for the levels of suppression (no significant interaction between age and glare for the SI: $F(1,76) = 0.09$, $P = 0.77$).

Regarding eccentricity, motion thresholds were elevated in peripheral vision (main effect of eccentricity on motion contrast: $F(1,76) = 141.32$, $P < 0.001$; translational global motion: $F(1,76) = 10.72$, $P < 0.01$, and biological motion: $F(1,76) = 294.81$, $P < 0.001$). There was a main effect of eccentricity on the SI ($F(1,76) = 9.23$, $P < 0.01$), and this effect varied with age group. Specifically, compared with younger adults, older adults exhibited reduced SIs centrally but increased peripherally ($F(1,76) = 29.05$, $P < 0.001$). The presence of glare did not exacerbate these eccentricity effects (no significant interactions between glare

Table 1. Summary of Participant's Characteristics

	Younger		Older			
General parameters	Mean (*SD*)	Range	Mean (*SD*)	Range		
Age, y	25.5 (3.2)	20–32	69.9 (5.3)	60–79		
MMSE score	29.9 (0.5)	28–30	29.3 (0.9)	27–30		
	Younger		Older			
Visual parameters	Mean	*SE*	Mean	*SE*	Difference	Cohen's *d*
Spherical equivalent, D	−0.57	0.32	0.45	0.34	$t(38) = 2.17, P = 0.04$	0.68
C-Quant (best eye), Log(s)	0.90	0.03	1.20	0.04	$t(33) = 5.49, P < 0.001$	1.88
Visual acuity, LogMAR	−0.05	0.02	0.07	0.02	$t(38) = 4.86, P < 0.001$	1.54
Contrast threshold (central), Log contrast (%)	−0.34	0.07	0.11	0.07	$t(38) = 4.29, P < 0.001$	1.36
Contrast threshold (peripheral), Log contrast (%)	0.39	0.11	0.92	0.09	$t(38) = 3.76, P < 0.001$	1.19

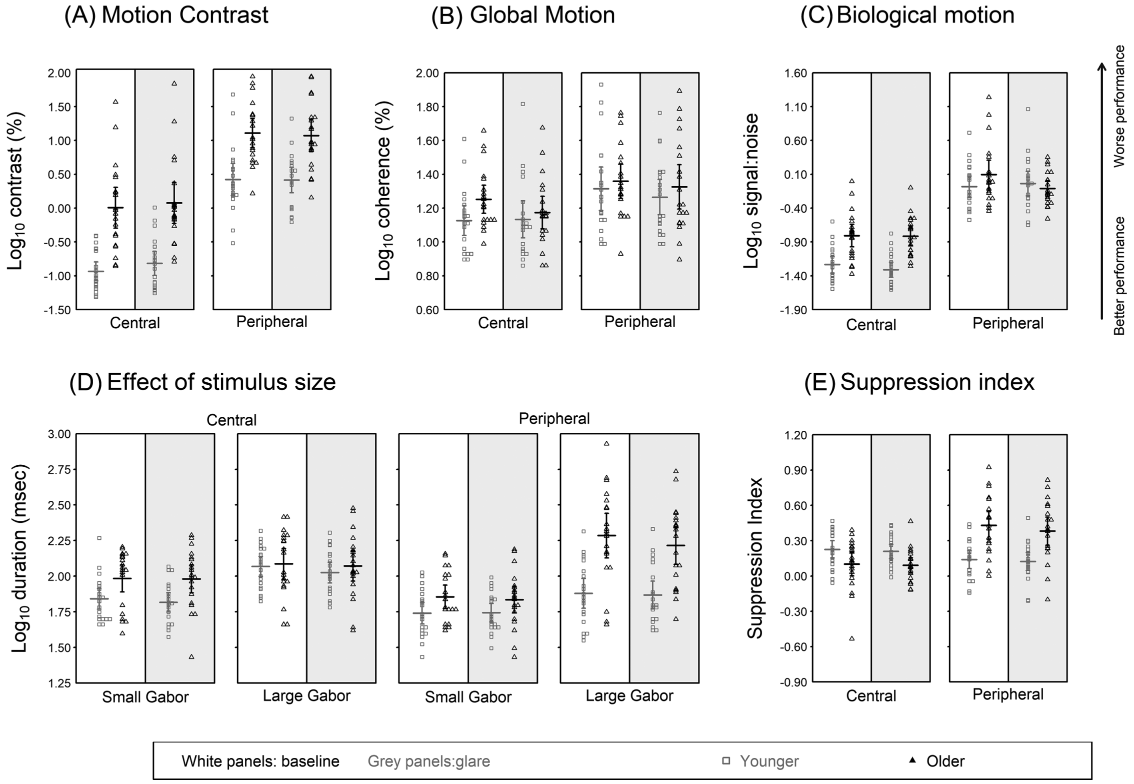

Figure 4. Results for the motion perception tasks without glare (*white panels*) and under glare conditions (*grey panels*). (**A**) Motion contrast. (**B**) Global motion coherence. (**C**) Biological motion. (**D**) Duration thresholds for the two Gabor sizes. (**E**) Suppression Index computed from the duration thresholds. *Grey squares* = younger adults, *black triangles* = older adults. For task A, B, and C, lower values represent better performances. For panel **D**, higher values represent longer stimulus duration, whereas for the suppression index (panel **E**) higher values represent more suppression.

and eccentricity for motion contrast: $F(1,76) = 1.35$, $P = 0.25$; translational global motion: $F(1,76) = 0.02$, $P = 0.90$; biological motion: $F(1,76) = 0.20$, $P = 0.66$, and the SI: $F(1,76) = 0.17$, $P = 0.68$).

We also explored whether our measured straylight values in both groups correlated with motion perception thresholds in central vision for the glare condition. Figure 5 and Table 2 present the results of this analysis, showing that the 2 motion tasks whose thresholds were significantly correlated with the straylight estimate (after correcting for multiple comparisons, resulting in a P value of 0.01 as statistically significant) were motion contrast ($r = 0.47$, $P = 0.005$, 95% confidence intervals = 0.26 to 0.66), and biological motion ($r = 0.55$, $P < 0.001$, 95% confidence intervals = 0.27 to 0.75).

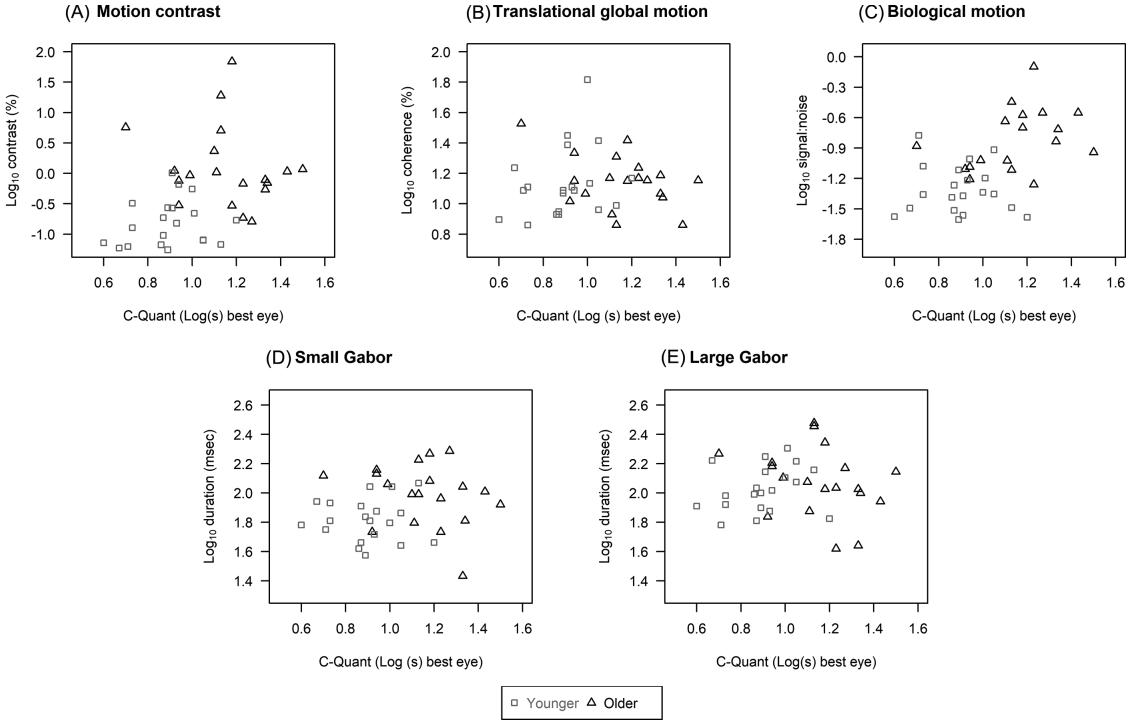

Figure 5. Scatterplots of the relationship between C-Quant values and motion perception tasks under glare in central vision. Statistically significant Pearson's correlation coefficients after correcting for five comparisons (adjusted $P < 0.01$) are highlighted in the plot (*bold* value).

Table 2. Pearson Correlations Between C-Quant Values (Best Eye) and Motion Perception Thresholds Under Glare

	r	*P* Value	Bootstrapped 95% CI
Motion contrast	**0.47**	**0.005**[*]	0.26, 0.66
Translational	0.05	0.79	−0.22, 0.35
Biomotion	**0.55**	**<0.001**[*]	0.27, 0.75
Small Gabor	0.18	0.30	−0.13, 0.49
Large Gabor	0.004	0.98	−0.31, 0.34

[*] Significant correlation after correcting for five comparisons (adjusted $P < 0.01$).

Discussion

In this study, we explored the effects of glare on motion perception of visually healthy older adults resulting from a light source designed to simulate car headlights located at 25 meters away from a driver. We also included the effects of eccentricity and different motion perception tasks (contrast levels to identify direction of motion of a Gabor, translational global motion coherence, identification of biological motion direction within noise dots, and spatial surround suppression of motion), in order to determine the types of motion stimulus that might be more impaired by this form of glare. In this experiment, we selected illuminance values for the glare source that exceeded the current standards for low beam headlights[38,39] by a factor of three, because these values may represent typical values found in poorly aligned headlights or when vehicles drive across uneven surfaces. In addition, we tested the presence of a continuous glare source to avoid sudden changes in retinal illuminance between the presence and absence of the light source. The results of our experiment demonstrated that the presence of a continuous off-axis light source exceeding the permitted values of illuminance for headlights did not significantly impact motion perception in central or peripheral vision of older adults. This suggests that the glare resulting from headlights that comply with current illuminance standards (and even exceed these by a factor of 3) should not impact on the perception of motion of either younger or older adults with visual acuity within current driving license standards (6/9.5 or better).

Similar to previous reports,[25,26,28,29,51,52] our study demonstrated that the level of deterioration of motion perception in older adults depends upon the specific nature of the motion stimulus, in both the absence and presence of glare. For instance, some tasks, such as the contrast required to identify the direction of motion of Gabors, and the ability to identify the direction of motion of a point light walker embedded in noise, were impaired in older adults. On the other hand, the coherence threshold to identify translational global motion from noise was unimpaired in older adults. Interestingly, for the surround suppression tasks, we were able to replicate our previous findings of eccentricity-related effects in a separate group of participants.[28] Specifically, older adults exhibited lower suppression indices in central vision, but higher in peripheral vision, compared with younger adults. Differences in surround suppression of motion with age have been studied in detail, with the mechanisms being the subject of some debate,[25,27,53,54] but the finding of elevated suppression in the periphery is a relatively new observation.[28,55,56] Surround suppression of motion has been shown to be relevant for object segmentation from its background,[53] and so it may be that our current findings are relevant to the many driving tasks that require discrimination of moving objects from their surroundings.

Although our findings demonstrated that the presence of a continuous glare source did not further impact the deficits exhibited by older adults in some motion tasks, it is important to highlight that these findings may be specific to the particular visual and ocular health characteristics of the participants that we included. Current standards for driving in many legislations, including Australia,[57] require binocular visual acuity values of 6/12 or better. The rationale behind the strict exclusion criteria set in our study was because we wanted to explore disability glare on motion perception of visually healthy individuals, as most drivers meet visual standards, and older adults with cataracts tend to self-restrict their driving.[58] It is known that older adults report difficulties with driving in the presence of glare,[1] often modifying their driving behavior to avoid these situations.[59,60] Therefore, the potential deficits in motion perception in the presence of glare experienced by healthy individuals would be expected to be exacerbated in cases of media opacities, such as cataracts. As shown in Table 1, our older adults had visual acuity and straylight levels that were significantly worse than the younger group, but these values were within normal limits for age.[4,5,61] These differences between groups are supported by the large effect sizes reported in Table 1. Therefore, we can assume that our older sample is representative of a visually healthy aged population.

Although we did not find an interaction between age and glare condition for any of our measures, our data do show that straylight measures were significantly correlated with poorer motion contrast and biological motion performance under glare conditions (see Table 2). Although the mechanisms underpinning these findings cannot be directly determined by our experiment, we hypothesize that, in the case of the motion contrast task, it relates to the reduction in sensitivity to contrast due to the presence of intraocular light scatter, a hypothesis that is supported by existing evidence.[3] In the case of the biological motion task, the potential mechanism is less clear, but may relate to the requirement to integrate both motion and form cues to disambiguate biological motion from noise in the presence of the glare source. It is possible that elevated straylight levels impair identification of the point light walker form rather than the identification of its motion cues, however, this needs to be explored in future studies.

In interpreting our findings, it is important to note that we assessed the effect of a continuous glare source rather than that of sudden onset of glare, that may be experienced when vehicle headlights appear suddenly (e.g. when an oncoming vehicle changes direction), which requires the driver to quickly adapt to changing light levels. In a recent paper from our group,[55] we found that motion contrast, translational global motion, and biological motion are elevated in mesopic viewing conditions. It is possible that the sudden onset of headlight glare may further impact on the perception of motion at mesopic levels, as there is evidence that older adults experience slower times for dark and light adaptation.[62,63] Additionally, in glare situations, drivers are able to avoid viewing the light source directly through moving their fixation,[64] a situation that was not explored in our current experiment. Indeed, in this study, the glare source was presented peripherally, rather than along the visual axis, as long as participants maintained appropriate fixation throughout the experiment, which was monitored by the experimenter. A study by Schmidt-Clausen and Bindel[65] demonstrated that when a glare source is presented more peripherally, it reduces the level of disability glare, and the subjective sensation of discomfort. A final note is that during real driving, drivers direct their gaze to different locations of the visual scene, as compared to our experimental design, where participants were required to directly fixate on the center of the stimulus or the fixation cross. The sudden presence of oncoming vehicle headlights may trigger the driver to direct their gaze toward the light, which may produce disability glare. This aspect of possible attentional capture by headlights is not represented in our experimental design.

In conclusion, our study showed that although visually healthy older adults had elevated levels of intraocular straylight, the presence of a continuous light source did not exacerbate the deficits in motion perception experienced by this age group in central and peripheral vision. As the illuminance of our glare source exceeded that permitted by current legislations, we can conclude that well aligned car headlights within the standards, which are not fixated directly by the driver, similarly do not significantly impact on the driving-relevant visual function of motion perception. However, further exploration of the effects of the sudden onset of a glare source and one that is presented centrally on the motion perception of adults both with and without media opacities is required to better understand these effects.

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