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Title: Effect of Cognitive Demand on Functional Visual Field Performance in Senior Drivers with Glaucoma

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Abstract

Purpose: To investigate the effect of cognitive demand on functional visual field performance in drivers with glaucoma. **Method:** This study included 20 drivers with open-angle glaucoma and 13 age- and sex-matched controls. Visual field performance was evaluated under different degrees of cognitive demand: a static visual field condition (C1), dynamic visual field condition (C2), and dynamic visual field condition with active driving (C3) using an interactive, desktop driving simulator. The number of correct responses (accuracy) and response times on the visual field task were compared between groups and between conditions using Kruskal-Wallis tests. General linear models were employed to compare cognitive workload, recorded in real-time through pupillometry, between groups and conditions. **Results:** Adding cognitive demand (C2 and C3) to the static visual field test (C1) adversely affected accuracy and response times, in both groups ($p < 0.05$). However, drivers with glaucoma performed worse than did control drivers when the static condition changed to a dynamic condition (C2 vs C1 accuracy; glaucoma: median difference (Q1-Q3) 3 (2-6.50) vs controls: 2 (0.50-2.50); $p = 0.05$) and to a dynamic condition with active driving (C3 vs C1 accuracy; glaucoma: 2 (2-6) vs controls: 1 (0.50-2); $p = 0.02$). Overall, drivers with glaucoma exhibited greater cognitive workload than controls ($p = 0.02$). **Conclusions:** Cognitive demand disproportionately affects functional visual field performance in drivers with glaucoma. Our results may inform the development of a performance-based visual field test for drivers with glaucoma.

26 **1. Introduction**

27 Glaucoma is a progressive optic neuropathy characterized by slow degeneration of retinal ganglion cells and their axons resulting in
28 irreversible loss of peripheral field of vision.(1, 2) More than 70 million people worldwide are estimated to be affected by glaucoma
29 with approximately 10% being bilaterally blind.(3) The usual process of the disease diagnosis includes assessment of damage to the
30 optic disc and retinal nerve fiber layer, and clinical evaluation of the physiological visual field.(1, 4, 5)

31 The Humphrey visual field analyzer (HVF) is the most common used method of detecting physiological visual field in
32 individuals with glaucoma.(6-10) The physiological visual field assessed using the HVF comprises the detection of static stimuli
33 presented one at a time in the periphery. However, there is increasing evidence that physiological visual field defects do not reflect
34 performance in daily-life activities such as driving.(11-14) Driving requires an individual to respond appropriately to many static and
35 dynamic visual stimuli in cluttered environments. Outcomes on the HFV test are only moderately predictive on driving safety
36 outcomes in glaucoma (15, 16) which may be attributed to the fact that safe diving not only requires intact physiological visual field,
37 but also depends on the attentional capacity of the driver and the cognitive demand of the task.(17-19) These three factors define the
38 individual's functional visual field.

39 Since the HVF test lacks the face validity to determine functional visual field performance while driving, the Useful Field of
40 View (UFOV®) test was developed to evaluate the impact of cognitive demand on functional visual field performance.(20) The size
41 of the functional visual field is narrowed when a subject attempts to accurately detect a centrally presented stimulus while paying
42 attention to another stimulus that is simultaneously presented in the periphery without (divided attention) and with (selective attention)
43 additional distracters.(21, 22) The functional field of view of the UFOV® test is determined by the performance in speed of
44 processing, divided attention, and selective attention. The UFOV® test shows to be more sensitive in predicting the motor vehicle
45 crashes of older drivers and also of drivers with glaucoma compared with the HFV test.(15, 16) Yet, the UFOV® test only evaluates
46 30 degrees of horizontal field of view and does not account for the visual flow and the psychomotor activity of steering and pedal
47 operation that is typical of driving.

48 The shrinkage of the functional visual field is postulated to result from an increase in cognitive demand of the task. This
49 increased cognitive demand imposes a greater strain on the available cognitive resources, resulting in a greater cognitive workload
50 exhibited by the subject to continue performing the task.(23). Psychophysiological studies have identified several neurophysiological
51 measures that can accurately assess the amount of cognitive workload needed to execute a task in real-time.(24) Task-evoked pupillary
52 response (TEPR) accurately reflects cognitive workload through inhibition of the parasympathetic nucleus of Edinger Westphal,
53 resulting in pupil dilation.(25, 26)

54 Recently, studies have investigated the use of TEPR as a measure of cognitive status in individuals at risk of cognitive
55 impairment. (27, 28) Ranchet et al demonstrated that cognitive workload extracted from TEPR was greater in individuals with

56 Parkinson's disease at risk for cognitive impairment when compared to age-matched control participants in a simple speed of
57 processing task.(29) The loss of peripheral field of view in glaucoma may impose a greater cognitive workload, especially under
58 heavy cognitive demand. This increased cognitive workload may reflect a compensatory mechanism for the loss of peripheral visual
59 field. Although the link between glaucoma and cognitive impairment remains elusive, some studies have shown a significant
60 association between scores on a general screen of cognitive functions and visual field loss in glaucoma.(30-33) In addition,
61 neurodegenerative lesions have been detected in the intracranial optic nerve, lateral geniculate nucleus, and visual cortex, suggesting
62 that glaucoma could be grouped with Alzheimer's and Parkinson's diseases as a neurodegenerative condition.(34, 35) In support of
63 this hypothesis, individuals with glaucoma are expected to exhibit greater cognitive workload compared to controls, especially under
64 strenuous cognitive demand.

65 Therefore, the aim of this study was to investigate the effect of an increase in cognitive demand on the functional visual field
66 of individuals with glaucoma while driving in a dynamic and cluttered environment. We hypothesized that 1) an increase in cognitive
67 demand while driving in a dynamic and cluttered environment significantly alters the functional visual field of individuals with
68 glaucoma and healthy controls, 2) functional visual field is affected more in individuals with glaucoma than in healthy controls and 3)
69 cognitive demand disproportionately worsens the functional visual field in individuals with glaucoma than in healthy controls.

70 **2. Materials and methods**

71 **2.1 Participants and recruitment.** Twenty participants with open-angle glaucoma were recruited from the Department of
72 Ophthalmology at Augusta University, Augusta, GA. Eligibility criteria included: (1) diagnosis of open-angle glaucoma exemplified
73 by optic nerve damage and visual field loss; (2) a valid driver's license; (3) drove at least 500 miles one year prior to testing; and (4)
74 devoid of other visual, neurological, internal or psychiatric conditions that might interfere with driving. Thirteen age- and sex-
75 matched controls who met the same criteria but without glaucoma were recruited through word-of-mouth and flyers.

76 **2.2 Protocol.** Participants were consented and evaluated on the same day. This protocol was approved by Augusta University
77 Institution's Review Board. All subjects gave written informed consent in accordance with the Declaration of Helsinki. Demographic
78 and driving data such as age, education, driving experience, and annual mileage were collected. The Trail Making Test A and B (TMT
79 A & B) (36-39) and Montreal Cognitive Assessment (MOCA) (40) were administered. TMT A is a paper-and-pencil test of
80 information processing and visuomotor tracking in which participants were required to connect 25 circles in an increasing order (1, 2,
81 3, 4 etc.). TMT B, which additionally tested shifting of attention, required participants to connect 25 circles containing either numbers
82 of letters in alternating order (1, A, 2, B etc.). (36-39) The time to complete each test and the number of errors was recorded. MOCA
83 is a comprehensive assessment of cognitive functions that was scored on an ordinal scale ranging from 0 to 30.(40)

84 **2.3 Vision tests.** The vision screening apparatus from Keystone view (Visionary Software version 2.0.14) was used as a general
85 screen for binocular visual acuity (on /20) and horizontal field of view (in degrees). The Humphrey Visual Field Analyzer (Humphrey

86 Instrument, Dublin, USA) SITA Fast 24-2 was used for monocular visual field testing and had been established previously with
87 standardized protocols and test-retest reliability.(41) Mean deviation (MD) corrected absolute values and pattern standard deviation
88 (PSD) were used as outcome measures.

89 **2.4 Driving simulator and conditions.** A low fidelity (desktop model) driving simulator with images generated using the STISIM
90 Drive software (STI Inc., Hawthorne, CA) and displayed on three 22-inch DELL® computer screens was used to measure binocular
91 functional visual field (Figure 1). The three screens provided a horizontal field of view of 100° and a vertical field of view of 20°.
92 Participants drove through all simulated scenarios using a Logitech® steering wheel and pedals that were connected to the simulator
93 system. Each condition followed the same protocol. After standardized auditory and written instructions, participants completed a
94 practice trial of 45 seconds, followed by the actual evaluation of 13 minutes. The ambient luminance in the darkened room was on
95 average 0.40 cd/m². The display luminance of condition 1 was on average 21.64 cd/m², and 24.56 cd/m² for conditions 2 and 3.

96 *Simulator Test Condition 1 (figure 2A)* involved static visual field testing on a black background. Participants were to focus on a
97 central fixation point (White Square, RGB 255/255/255) at eye height in the middle of a black screen (RGB 0/0/0). Participants were
98 instructed to press a button on the steering wheel with their right thumb as soon as they localized a red square (RGB 255/0/0) that
99 appeared in the periphery of the black screen. The size and dimensions of the squares (2.0 cm x 2.0 cm) were carefully determined
100 after review of the literature.(42) The red square appeared at different degrees of eccentricity (5°-100° of horizontal angle and 5°-20°
101 of vertical angle, each in 5° increments) on 8 line coordinates at various degrees of radial angles (0°-337.5° in 22.5° increments).
102 Horizontal and vertical angles were defined as the angle between the line perpendicular to the screen through the origin of gaze and
103 the line through the center of the symbol and the origin of gaze. Overall, 114 symbols were presented at random time intervals
104 (between 0.5 seconds and 2 seconds) and at an unpredictable amplitude (Figure 3).

105 *Simulator Test Condition 2 (figure 2B)* involved a dynamic visual field task with no active driving to evaluate the effect of optic flow
106 on functional visual field. Like condition 1, participants were requested to press the thumb button as soon as they localized the
107 peripheral target. However, the background was changed to a dynamic driving scene with an automatic pilot of 45mph. A white lead
108 vehicle with the same dimensions as the central white square in condition 1 was used as fixation point.

109 *Simulator Test Condition 3 (figure 2C)* involved the same dynamic visual field task but with the participant actively driving to
110 evaluate the additional impact of psychomotor activity on functional visual field. In this condition, the participant was requested to
111 drive the car on a straight road at a constant speed of 45 mph. The participant focused on a lead car and there were auditory speed
112 warnings if the driver drove at 5mph above or below the stipulated speed. In addition to focusing on the lead car, the participant
113 pressed the thumb button whenever a red square appeared on the screen.

114 Computer-generated measures of number of correct responses (accuracy) and the response time to the peripheral target in all three
115 conditions were the primary outcome measures. Automatically generated driving data from condition 3 such as time spent and

116 distance driven over the speed limit, time spent and distance driven over the center lane, mean lateral position and speed, and standard
117 deviation of lateral position and velocity were used as secondary outcome measures at 60 Hz.

118 **2.5 Useful field of view test (UFOV®).** The UFOV® is a binocular functional visual field test involving three subtests that increased
119 in cognitive demand with each subsequent subtest. In the speed of processing subtest, the participant had to identify a target presented
120 in the central vision. In the divided attention subtest, the participant had to identify the target presented in the central vision along with
121 a concurrent peripheral target localization task. In the selective attention subtest, the participant performed similar tasks as in divided
122 attention subtest. However, the target displayed in the periphery was embedded in distracters. All subtests were measured in
123 milliseconds. More detailed description of the UFOV® test has been reported elsewhere.(15, 16)

124 **2.6 Fixation stability and cognitive workload.** The FOVIO eye tracker (Seeing Machines Inc., Canberra, Australia) was used to
125 confirm fixation of the central point when peripheral targets were presented to ensure reliability of visual field testing. The percentage
126 gaze time on the central fixation target across three conditions was used as an outcome variable. The cognitive workload, i.e., the
127 amount of mental effort indexed through TEPR, was also recorded at 60 Hz by analyzing the changes in raw pupil size of the left eye,
128 while adjusting for individual differences in pupil size, lighting and accommodation.(43) Although TEPR is sensitive to cognitive
129 workload and task difficulty in working memory, it is not accurate to detect complexity of sentences in older adults.(44) Calibration of
130 pupils takes about two minutes. TEPR has been found to correlate well with other indices of neural activity, such as electro-
131 encephalogram and functional magnetic resonance imaging. (29) The TEPR scores were transformed into a continuous scale of
132 cognitive workload. This Index of Cognitive Activity (ICA) ranges from 0 to 1, with greater values indicating more cognitive
133 workload. The resulting ICA scores are thought not to be subject to practice effects, education, race, and sex.(45)

134 **2.7 Data analysis.** Data were checked for normal distribution using the Kolmogorov-Smirnov statistic. Results from the normality
135 testing enabled us to use non-parametric analyses for all hypotheses. Friedman analysis and post-hoc pairwise comparisons using the
136 Wilcoxon Signed Rank Test were conducted for hypothesis 1. The Wilcoxon Rank Sum test was conducted for hypothesis 2 and 3 and
137 to examine between group differences in demographics, UFOV metrics and driving simulator measures. Since the ICA data was
138 normally distributed, general linear models were used to verify the main effects of group (glaucoma vs healthy controls) and condition
139 (1, 2, and 3), and the interaction effect of group by condition, on cognitive workload. Post-hoc pairwise comparison was employed to
140 investigate differences in main and interaction effects. Chi-square analysis was performed to determine the effect of cognitive demand
141 on the eccentricity of missed responses across the three conditions for both groups. All analyses were conducted with SPSS version
142 23. P values of less than 0.05 were considered significant.

143 **3. Results**

144 **3.1 Comparison of demographic, clinical, and visual characteristics.** Sixteen participants had bilateral open-angle glaucoma and
145 four had unilateral open-angle glaucoma. The differences between the glaucoma and healthy control groups in demographics, clinical

146 and visual field measures are presented in Table 1. Both groups differed significantly in TMT B, mean deviation and pattern standard
147 deviation of left eye and mean deviation of right eye derived from HVF.

148 **3.2 Effect of cognitive demand on functional visual field.** Within group comparisons showed a significant effect of cognitive
149 demand on functional visual field performance in both groups (Table 2). Post-hoc comparisons showed that both groups responded
150 less accurately and slower in conditions 2 and 3 compared to condition 1 ($p < 0.05$). Between groups comparisons did not reveal
151 significant differences in the performance on the static visual task (condition 1, Table 2, Supplementary Figures 1A and 1B).
152 However, the glaucoma group responded less accurately and slower in the dynamic visual field task without active driving (condition
153 2) and with active driving (condition 3) compared with healthy controls ($p < 0.05$) (Table 2, Supplementary Figures 1A and 1B).
154 Pairwise comparisons showed that adding visual flow to the visual field test without (C2 – C1) or with active driving (C3 – C1)
155 affected accuracy on the functional visual field worse in the glaucoma group than in healthy controls (Table 2). No such effects were
156 observed on response time.

157 No differences in percentage gaze time on the central fixation were found between both groups, indicating that both groups
158 spent an equal amount of time looking at the central target ($p > 0.05$, data not shown). Finally, with increased cognitive demand,
159 drivers with glaucoma missed more responses at greater angles of eccentricity ($\chi^2 = 32.11$, $p < 0.05$, Supplementary Table 1). No such
160 effect was seen in healthy controls.

161 **3.3 Cognitive workload.** General linear models further revealed a significant effect of glaucoma ($F = 5.45$; $p = 0.02$) on the cognitive
162 workload, as indexed by increased ICA (Figure 4). Overall, individuals with glaucoma exhibited greater cognitive workload across all
163 3 conditions compared to controls (condition 1: ICA glaucoma mean (SD), 0.37 (0.13); controls, 0.35 (0.19); condition 2: ICA
164 glaucoma, 0.36 (0.11); ICA controls, 0.29 (0.17); condition 3: ICA glaucoma, 0.41 (0.11); ICA controls 0.28 (0.16) Within group
165 analyses revealed no significant differences in the cognitive workload ($F = 0.38$; $p = 0.68$). Likewise, the interaction effect of group by
166 condition was not significant ($F = 1.03$; $p = 0.36$).

167 **3.4 UFOV tasks.** A similar pattern of effect of cognitive demand was observed for the UFOV. Within group analyses revealed that
168 both groups showed slower speed of processing as the tasks became more difficult ($p < 0.05$, Supplementary Table 2). Between group
169 differences in UFOV metrics demonstrated that the glaucoma group was significantly slower while performing the divided and
170 selective attention tasks than the healthy controls ($p < 0.05$, Supplementary Table 2). The addition of a car symbol in a non-cluttered
171 (divided attention) and cluttered (selective attention) periphery disproportionately worsened speed of processing in the glaucoma group
172 compared to the control group (pairwise comparisons ($p < 0.05$, Supplementary Table 2).

173 **3.5 Comparison of driving simulator characteristics.** Analyzing the driving simulator performance (condition 3) of both groups
174 revealed that the glaucoma group was significantly different from the control group in time spent ($p = 0.05$) and distance ($p < 0.05$)

175 driven over the lane (Table 3). However, no significant differences were observed between these groups in other driving simulator
176 measures.

177 **4. Discussion**

178 This study is one of the very few studies to investigate the effects of cognitive demand on the functional visual field of drivers
179 with glaucoma in comparison to healthy controls. Our findings support our hypotheses that an increase in cognitive demand reduced
180 the functional visual field performance both in drivers with glaucoma as well as healthy controls. However, drivers with glaucoma
181 performed worse on the visual field task, especially when dynamic visual flow was added. Furthermore, the study findings
182 demonstrated that an increase in cognitive demand disproportionately worsened the functional visual field performance of drivers with
183 glaucoma compared with healthy controls. Our results therefore suggest that visual field testing for activities that require timely
184 detection of stimuli in a highly dynamic and rapidly changing environment such as driving should consider the participants'
185 physiological visual field, their cognitive capacity, and the cognitive demand of the task to fully appreciate the impact of any visual
186 field loss performance.

187 Drivers with glaucoma differed significantly from healthy controls in the functional visual field while reacting to an increase in
188 cognitive demand in a driving simulator. Although the addition of visual flow affected the functional field of view similarly in both
189 groups, participants with glaucoma performed disproportionately worse when the psychomotor component of operating the steering
190 wheels and pedals was added. The allocation of cognitive resources to focusing on the central target, concentrating on identifying the
191 peripheral target in a cluttered environment, while maintaining control over the vehicle, resulted in disproportionately greater
192 cognitive workload in drivers with glaucoma. As a result, drivers with glaucoma identified fewer symbols than controls in the
193 functional visual field tests compared to their baseline performance on the static visual field test. In particular, the symbols in the
194 periphery became more difficult to detect with increased cognitive demand. Our findings support the results of Prado Vega et al that
195 also showed drivers with glaucoma to detect fewer peripheral stimuli.(46)

196 The relationship between increased cognitive demand of the task and reduction in functional visual field has been studied
197 previously using the UFOV® test.(16, 47, 48) In those studies, the divided attention subtest of the UFOV® showed to correlate best
198 with motor vehicle crashes in drivers with glaucoma.(16, 47, 48) Tatham et al observed that individuals with glaucoma who had a
199 history of motor vehicle collisions (MVC) reported reduced divided attention metrics of the UFOV® test than those drivers with no
200 MVC history, suggesting that increased cognitive demand shrunk the functional visual field, and in turn, impacted driving safety.(16)
201 Our study confirms that drivers with glaucoma perform worse on the UFOV®, but only in the dual task conditions of divided attention
202 and selective attention.

203 The increase in cognitive demand did not only affect their performance on the visual field test, drivers with glaucoma also
204 exhibited poorer performance in vehicle control. Participants with glaucoma drove closer to the center lane and crossed the center lane

205 for a longer distance than did controls. Previous studies showed that driving performance of participants with glaucoma was
206 significantly reduced with higher number of collisions than the age matched controls on a driving simulator.(49) This was in spite of
207 the fact that tasks used in one particular study were neither cognitively demanding nor did they evaluate visual field tasks in a
208 functional setting.(49) Participants in that study were asked to follow simple traffic signals or stop signs, obstacle avoidance in terms
209 of vehicles or children rushing out from the sides. By contrast, Prado Vega et al did not find significant differences between groups in
210 the performance of primary tasks such as lane keeping and obstacle avoidance.(46) Yet, drivers with glaucoma in their study exhibited
211 increased steering activity, suggesting more difficulty performing the driving task.(46)

212 In addition to decrements in performance on the visual field tasks and the driving tasks, participants with glaucoma also
213 showed increased cognitive workload across all three conditions. This finding suggests that drivers with glaucoma had to concentrate
214 harder to detect the visual field symbols in all three conditions. Our Index of Cognitive Activity was based on TEPR, a real-time
215 physiological measure of mental effort. To our knowledge, this is the first time that a neurophysiological measure of cognitive
216 workload was used to determine mental effort during functional visual field tasks in glaucoma. Prado-Vega et al. found no significant
217 differences in self-reported cognitive workload between drivers with glaucoma and controls in four simulator conditions.(46)
218 However, self-report ratings depend on the perception of the individuals, whereas the Index of Cognitive Activity is thought to be a
219 reliable, objective estimate of cognitive workload.(45) Whereas Prado-Vega et al. found a significant effect of cognitive demand on
220 subjective cognitive workload, our study did not show a linear relationship between cognitive demand and cognitive workload.
221 Psychophysiological studies have demonstrated that cognitive workload increases as a function of cognitive demand, until a tipping
222 point is reached where the task becomes too difficult to complete.(25) The decrements in accuracy and response time with increased
223 cognitive demand may have resulted in cognitive overload. As a result, no within group effects on cognitive workload were observed
224 in our study. Further research is warranted to confirm the usefulness of pupillometry as an objective, real-time measure of cognitive
225 workload in glaucoma.

226 The results of the study should be considered preliminary. We found that the functional visual field of the participant with
227 glaucoma with slight to moderate visual impairment was altered when driving in a highly-cluttered environment such as driving.
228 However, care should be taken when generalizing these findings to a larger patient population since our sample size was small. Future
229 studies should include a larger sample of drivers with glaucoma with various severity of visual impairment to confirm our findings.
230 Such studies should also aim at generalizing the driving simulator findings to real-life on-road driving ability because our dynamic
231 driving simulator task only included a car following task.

232 **5. Conclusions**

233 Cognitive demand, especially in a functional context such as driving, significantly reduced the functional field of view of individuals
234 with glaucoma. The disproportionate impact of cognitive demand on functional visual field in glaucoma was more evident when
235 cluttered visual flow was added than when a psychomotor activity was added to the visual field task. Our findings suggest that visual
236 field testing to determine eligibility for driving resumption in glaucoma need to be conducted in a cluttered, driving-related setting to

237 fully appreciate the cognitive demands of real-world driving.

238

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380 **Tables**

381 **Table 1. Demographics, clinical and visual measures between the Glaucoma (n = 20) and healthy control group (n = 13).**

Variable	Glaucoma		Controls		W value*	p value
	Median	Q1 - Q3	Median	Q1 - Q3		
Demographics						
Age (years)	62.50	59 - 71	57	53 - 70	178	0.11
Education (years)	13.50	12 - 16	12	12 - 14	197.50	0.39
Driving experience (years)	46.50	40.50 - 51.50	42	37 - 54	205.50	0.58
Annual mileage (miles/year)	12000	5500 - 15500	12500	8000 - 18200	232	0.70

Clinical measures

TMT A (seconds)	36	28.50 - 48.50	29.50	26.50 - 40.57	156.50	0.11
TMT B (seconds)	124.50	81.50 - 190.50	72	57.50 - 96.00	145.50	0.04**
MOCA (0 -30)	26.50	24.50 - 29.00	27.50	27.00 - 28.50	216.50	0.47

Visual measures

Visual acuity (0/20 - 20/20)	30	20 - 40	25	20 -30	137	0.28
Total visual field (0°- 170°)	170	155 - 170	170	170 -170	183	0.19
Humphrey left MD	5.04	1.45 - 13.24	-0.90	0.53 - 2.17	252	0.006**
Humphrey left PSD	2.84	2.00 - 9.20	1.51	1.32 - 2.30	116	0.003**
Humphrey right MD	2.90	1.20-10.72	-0.61	0.08 - 2.51	258	0.02**
Humphrey right PSD	1.93	1.60 - 8.63	1.90	1.51 - 2.34	173.50	0.35

382 * indicate Wilcoxon Rank sum test; ** indicate p value < 0.05; MOCA, Montreal Cognitive Assessment; TMT A and TMT B, Trail making test A and B; MD,
 383 Mean Deviation; PSD, Pattern Standard Deviation.

384 **Table 2. Functional visual field performance of the Glaucoma (n = 20) and healthy control group (n = 13).**

	Condition 1 (C1)	Condition 2 (C2)	Condition 3 (C3)	Within group p-value ‡	Pairwise comparisons§		
Correct responses							
Glaucoma^	114 (113 - 114)	111 (106 - 112)	111.50 (104 - 112)	0.001*	C2 - C1*	C3 - C1*	C3 - C2
Controls^	114 (114 - 114)	112 (111 - 114)	113 (112 - 114)	0.02*	C2 - C1*	C3 - C1*	C3 - C2
Between group p-value §	0.20	0.01*	0.01*		0.05	0.02*	0.047*
Response time (s)							
Glaucoma^	0.52 (0.49 - 0.60)	0.63 (0.56 - 0.82)	0.76 (0.64 - 0.95)	0.001*	C2 - C1*	C3 - C1*	C3 - C2*

Controls [^]	0.47 (0.43 - 0.52)	0.58 (0.52 - 0.60)	0.64 (0.57 - 0.73)	0.001*	C2 - C1*	C3 - C1*	C3 - C2*
Between group p-value §	0.08	0.01*	0.04*		0.17	0.34	0.73

385 [^] indicate values in median (Q1 – Q3); *indicate p value < 0.05; Response time in seconds; § indicate p-value from Wilcoxon rank sum test; † indicate p-value
386 from Friedman Test; [§] Wilcoxon signed rank test

387 **Table 3. Driving simulator performance of the Glaucoma (n = 20) and healthy control group (n = 13) during condition 3.**

	Glaucoma		Controls		W value*	p value
	Median	Q1 - Q3	Median	Q1 - Q3		
Time spent over the speed limit (seconds)	48.4	31.0 - 59.4	52.5	35.3 - 61.0	285	0.68
Distance drove over the speed limit (feet)	51.3	61.0 - 33.7	54	36.9 - 62.6	287	0.75
Time spent over the center lane (seconds)	4.2	3.1 - 6.5	1.1	0.6 - 3.5	125	0.05**
Distance drove over the center lane (feet)	4.6	3.2 - 7.4	1.1	0.6 - 3.5	114	0.01**
Mean lateral position (feet)	5.3	4.6 - 5.8	5.9	5.0 - 6.2	266	0.22
Mean speed (miles/hour)	44.9	44.4 - 45.1	44.9	44.5 - 45.1	281	0.56
Standard deviation lateral position (feet)	1.2	0.8 - 1.3	0.9	0.8 - 1.4	163	0.75
Standard deviation velocity (miles/hour)	1.3	1.1 - 1.9	1.3	1.1 - 1.4	155	0.50

388 * indicate Wilcoxon Rank sum test; ** indicate p value ≤ 0.05

389 **Figure legends**

390 **Figure 1: Low-fidelity driving simulator (©STISIM drive)**

391 **Figure 2: Three different visual field conditions used in the study**

392 **Figure 3: Visual field targets expanding 100° of horizontal field of view and 20° of vertical field of view**

393 **Figure 4: Mean and standard deviations for cognitive workload between the Glaucoma (n = 20) and healthy control group (n = 13)**
394 **across three conditions; between group effect p = 0.02**