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Peripheral vision loss affects the processing of spatial frequencies in the central vision of people with glaucoma

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Introduction

Glaucoma is an ocular disease characterized by a progressive destruction of the optic nerve and retinal ganglion cells (Fechtner & Weinreb, 1994). This results in a progressive vision loss starting with a deficit in peripheral vision.

Retinal sensitivity loss impact more complex aspects of visual processing in patients with glaucoma, even early in the disease. Patients reported having difficulty performing a wide range of daily activities, such as walking, reading or driving. Behavioral experiments showed of visual deficits for global motion, global form, low-contrast object and scene perception with stimuli displayed in the central vision of patients (Mc Kendrick et al., 2005; Lenoble et al., 2016; Roux-Sibilon et al., 2018).

These findings suggest a dysfunction on tasks mediated by parasol retinal ganglion cells (RGC), also called M cells sensitive to low luminance contrast, movements and more sensitive to low than high spatial frequencies. Consistent with these findings, parasol RGC should be selectively damaged in early glaucoma (Quigley et al., 1988; see however Della Santina & Ou, 2017).

Aim: We assessed the spatial frequency processing in the central vision of glaucomatous patients during scene categorization, considering the progression of the disease.

Hypotheses: We expected a greater spatial frequency processing for LSF than for HSF at the early stage of the disease, and that advanced disease has a greater impact on HSF processing.



References

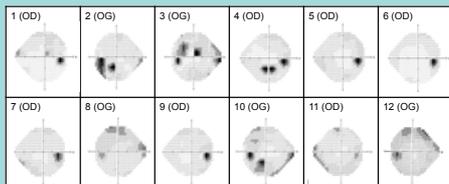
Dalla-Santina, L., & Ou, Y. (2017). Who's lost first? Susceptibility of retinal ganglion cell types in experimental glaucoma. *Exp Eye Res*, 158, 43-50.
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Method

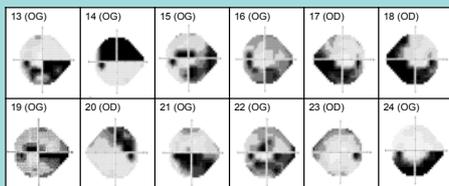
Participants

- 24 patients with Primary Open Angle Glaucoma (POAG)
 - 22 age-matched control participants (67 years ± 5)
 Patients were divided into two groups, based on the severity of the visual field (Humphreys Visual Field analyzer, 24-2 SITA-Standard)

> 12 patients with early glaucoma: Mean Deviation > -6 dB (68 years ± 9)

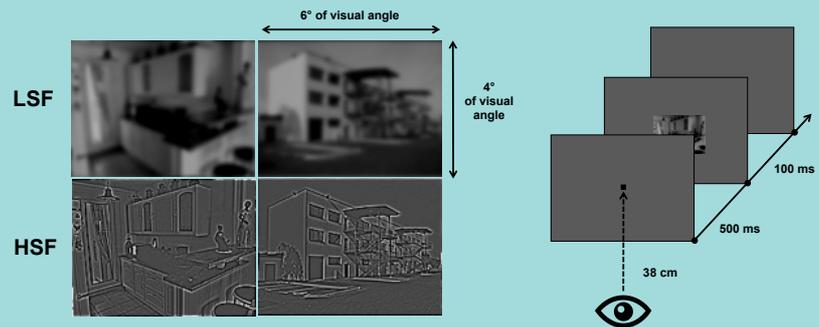


> 12 patients with non early glaucoma: Mean Deviation < -6 dB (70 years ± 10)



Stimuli

Indoor and outdoor scenes (6°x4° of visual angle) selected from ReCor Database. <http://doi.org/10.17605/OSF.IO/XJDQ4> filtered in
 - Low spatial frequencies (LSF; < 2 cpd or 12 cpi),
 - High spatial frequencies (HSF; > 6 cpd or 36 cpi).
 Luminance and contrast luminance contrast were normalized between LSF and HSF
 Luminance: 72 on a 256 grey level scale (0.28 for luminance value between 0 and 1)
 RMS contrast: 33 on a 256 grey level scale (0.13 for luminance value between 0 and 1) → Contrast of 46%



Procedure

- Scenes were presented in the central visual field for 100 ms.
 - Participants performed a categorization task (go/no-go response): they were instructed to press the keyboard spacebar whenever the scene appearing on the screen belonged to a target category (indoor or outdoor category; target category is counterbalanced across participants of each group).
 - Each participant was tested monocularly (Near visual acuity: Parinaud < 2; Far visual acuity: > 7/10^e).

Results

Errors (%)

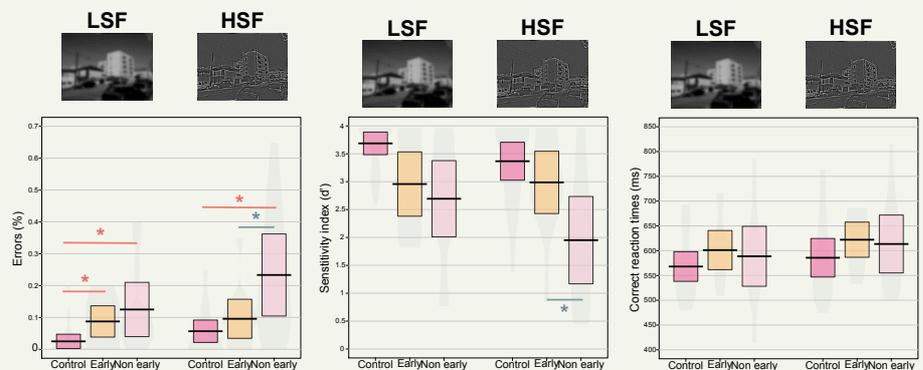
- group effect: Controls > Patients $F(2,43) = 8.08, p < .001$
 - SF effect: LSF < HSF $F(1,43) = 10.49, p < .001$
 - group*SF: $F(2,43) = 3.43, p < .05$
 • Control < Early on LSF $F(1,43) = 4.11, p < .05$,
 • No difference between Control and Early on HSF $F(1,43) < 1$
 • Control < Non early on LSF $F(1,43) = 10.53, p < .01$,
 • Control < Non early on HSF $F(1,43) = 15.17, p < .001$
 - severity*SF: $F(1,43) = 5.14, p < .05$
 • no severity effect on LSF $F(1,43) = 1.14, p = .29$
 • severity effect on HSF: Early > Non early $F(1,43) = 7.11, p < .01$

Index of sensitivity (d')

- group effect: Controls > Patients $F(2,43) = 10.04, p < .001$
 - SF effect: LSF > HSF $F(1,43) = 7.22, p < .01$
 - no group*SF: $F(2,43) = 2.58, p = .08$
 - severity*SF: $F(1,43) = 6.06, p < .05$
 • no severity effect on LSF $F(1,43) < 1$
 • severity effect on HSF: Early > Non early $F(1,43) = 7.36, p < .01$

Correct reaction times (ms)

- no group effect $F(2,43) < 1$
 - SF effect: LSF < HSF $F(1,43) = 6.65, p < .01$
 - no group*SF effect $F(2,43) < 1$



Conclusion

The global deficit for HSF processing could be linked to the functional decline of the parvocellular pathway in normal aging (Elliott & Werner, 2010). Patients classified as having early visual field defect had a selective deficit for low-pass filtered scenes, in comparison to controls, while patients with a more severe glaucoma were impaired in all spatial frequencies. A deficit for spatial frequency processing should appear sequentially as a function of the disease progression. The simple loss of peripheral vision could be detrimental to scene recognition in the relatively preserved central vision of patients. The deficits observed in central vision can be thought as a result of a trans-synaptic degeneration in glaucoma following the optic nerve damage and resulting in a disorganization of high-level visual cortical regions (e.g., Scene-selective parahippocampal place area, Epstein & Kanwisher, 1998).