A validated web-application (GFDC) for automatic classification of glaucomatous visual field defects using Hodapp-Parrish-Anderson criteria

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Background

- Glaucoma is the most frequent cause of irreversible blindness worldwide, and perimetry (visual field) analysis is essential for diagnosis, prognostication, and management decisions.
- Subjectivity and ambiguity of visual field classification limits accuracy and reliability.
- Patients often receive substandard care as a consequence of missed defects on perimetry.
- Standardised rules for classifying glaucomatous visual field defects exist, but these are labour-intensive and therefore impractical for day-to-day clinical work.
- Artificial intelligence is often suggested as a means of automating healthcare work, but is complicated by issues concerning accuracy, interpretability, and safety.

Methods

- We developed a web-application: Glaucoma Field Defect Classifier (GFDC) to automatically apply Hodapp-Parrish-Anderson (HPA) criteria.
- We validated GFDC in a single-centre cross-sectional study of 89 consecutive glaucoma patients attending outpatient clinic.
- 168 visual fields were obtained and classified by GFDC, as well as two blinded researchers applying HPA criteria manually; with a third researcher resolving any disagreement.
- Accuracy was gauged by comparing GFDC outputs to gold-standard human appraisal.
- For 20 evaluations, the GFDC operator or researcher were timed to compare the practicality of each method of appraisal.

Development

- The HPA criteria were adapted to provide a simplified algorithm (Table 1) for transposition into Python code, and for human researchers to apply in validation trials.

Variable	General rule
Mean deviation	≥-1 dB: no defect <-1 dB & ≥-6 dB: mild defect < -6 dB & ≥-12 dB: moderate defect > 12 dB: severe defect
Central 5º points on global plot	All >15 dB: no defect Any points (not in both hemifields) <15 dB: moderate defect Points in both hemifields <15 dB: severe defect Any points =0 dB: severe defect
Pattern deviation plot (proportion of points depressed below P < 5%)	0%: no defect >0% & ≤25%: mild defect >25% & ≤50%: moderate defect >50%: severe defect
Pattern deviation plot (proportion of points depressed below P < 1%)	0: no defect >0 & <10/76: mild defect ≤10/76 & <20/76: moderate defect ≤20/76: severe defect

Table 1 | *HPA criteria distilled into a concise algorithm. Where criteria output different results, the most severe result is taken as the overall grading.*

- OpenCV, a Python programming package, was used to convert pattern deviation plots into matrices with identifies corresponding to levels of pattern deviation.
- The HPA algorithm was implemented in Python with data from the perimetry results, including pattern deviation, taken as inputs.
- The algorithm was deployed on a web-application, with a graphical-user interface developed in CSS, JavaScript and HTML.
- The web-application is hosted online, freely available for clinicians and researchers to use (https://gfdc.app; or via the QR code).

GFDC

Validation

- Across 168 perimetry results, GFDC reached the same conclusion as human experts applying HPA criteria (Figure 1).
- The performance of GFDC was perfect across mild, moderate, and severe glaucomatous field defects.
- Overall accuracy and F1 score were therefore 100%, and the κ-score quantifying agreement between human graders and GFDC was 1.00.
- Comprehensive interpretability analysis confirmed that GFDC correctly identified perimetry plot boundaries, interpreted plot data, and applied the HPA criteria faithfully.
- Errors were only returned where there were problems with data entry (by the user), such as if perimetry plots were cropped.

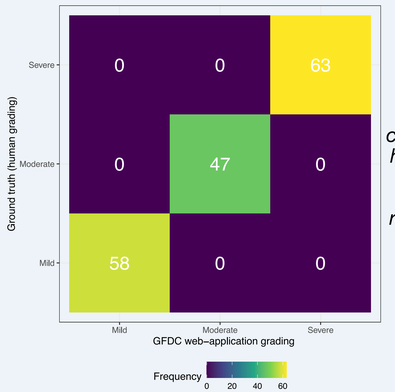


Figure 1 | *Comparative classification results from GFDC and human researchers (gold-standard). In every case, GFDC reached the same conclusion as human researchers, across mild, moderate, and severe glaucomatous field defects.*

- Using GFDC was significantly faster than human-dependent appraisal (Table 2; t-test, p = 0.003)), but a subset of human appraisals were faster, as 'obvious' classifications could be concluded without running through the whole algorithm.

Schema	Average duration ± standard deviation (s)	t statistic	p value
GFDC	26.5 ± 3.3	-3.46	0.003
Manual	48.6 ± 28.4		

Table 2 | *Duration of evaluations with GFDC and by human researchers.*

Conclusions

- GFDC provides accurate and reliable classification of glaucomatous visual field defects, making identical decisions to human experts applying HPA criteria.
- No failure cases of GFDC have been identified, although fields must be inputted carefully to the web-app to obtain a result.
- The computer vision algorithm is more interpretable and therefore trustworthy than a machine learning model.
- Subsequent work is underway applying GFDC in larger cohorts; the app is well-suited to large-scale research studies requiring classification of perimetry results.
- GFDC may also be used to diagnose and triage glaucoma patients in settings where access to specialists is limited, such as in lower income countries.
- The web-application is free to use online and its code has been published on GitHub for researchers to appraise and modify.

Peer-Reviewed Report

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