Gaze Behaviour and Accuracy among Novice and Glaucoma Specialist Orthoptists During Optic Disc Examination: A Cross Sectional Study

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ABSTRACT

Aim: To examine the extent to which level of clinical experience of orthoptists influences eye movements, gaze behaviour and diagnostic accuracy when examining optic disc images for glaucoma.

Methods: Eye movements and gaze behaviour of participating orthoptists were recorded whilst examining 20 optic disc images for signs of glaucoma. A maximum of 90 seconds was given per image to perform the examination. At the conclusion of each examination, participants were asked to determine whether it was unlikely, possible, probable or certain that the optic disc image had glaucoma. The main outcome measures were examination time, number of fixations, time spent on areas of interest, gaze behaviour and glaucoma likelihood agreement between orthoptist groups.

Results: A total of 41 orthoptists (36 novices and 5 glaucoma specialist orthoptists) agreed to participate. Using multivariable linear regression, there was no difference in optic disc examination times between orthoptist groups or for the total number of fixations made. Those with more experience made significantly more fixations when assessing images with possible signs of glaucoma ($p = 0.024$). Glaucoma specialist orthoptists methodically examined the optics disc, visualising areas most likely to display glaucomatous damage. Novice orthoptists displayed random gaze behaviours and spent more time looking at areas less likely to display change. Glaucoma likelihood agreement was higher for glaucoma specialist orthoptists ($\kappa = 0.51$) compared to novices ($\kappa = 0.31$).

Conclusion: Glaucoma specialist orthoptists adopt a systematic gaze behaviour when examining the optic disc for glaucoma and achieved higher agreement when determining glaucoma likelihood.

Keywords: eye tracking, gaze, orthoptists, glaucoma

INTRODUCTION

Glaucoma is currently the most common cause of irreversible blindness in the world.[1,2] The prevalence of glaucoma is predicted to increase in line with population growth[1] and by 2020 it is expected that almost 80 million people will be diagnosed with the disease worldwide.[1] The proportion of undiagnosed glaucoma reported in population-based surveys is high in both developed and developing nations[3-8] and is estimated at around 50% in Australia and Europe.[4,8,9] In lower income areas of Asia and Africa, the percentage is much higher, reaching up to 90%.[3,5,7]

Whilst glaucoma can remain asymptomatic, even in the presence of severe damage it is possible to detect changes at the optic nerve head before functional loss occurs.[10-12] This means that the accurate assessment of the optic nerve head is crucial for detecting early glaucoma and implementing appropriate treatment to manage the disease. Despite advances in quantitative technologies, the current standard practice in many other parts of the world is to clinically examine and subjectively record the appearance of the optic nerve head.[13-15] Most orthoptists have little experience in the screening and monitoring of patients suspected of or diagnosed with glaucoma, however, more recently orthoptists have extended their scope of practice and become involved in comprehensive glaucoma care.[16] Despite the growing role of orthoptists

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in the screening and monitoring of glaucoma patients in Australia and the United Kingdom, their ability to provide valid and efficient glaucoma care has not been investigated.[16,17]

Optic disc examination, the central skill in glaucoma diagnosis, has been shown to improve with clinical experience.[18-20] Research suggests that more experienced clinicians are able to accurately assess key morphological features of glaucoma and are more systematic and logical in their approach to scanning the optic disc for pathology.[15,19] However, there is currently a lack of peer reviewed literature exploring orthoptists' accuracy in detecting glaucomatous pathology despite their extended scope of practice in this clinical area. The use of eye tracking technology provides one way to examine the visual search strategy of clinicians, as related to optic disc examination, alongside investigating their diagnostic accuracy. It also provides an opportunity to detect discrepancies between clinicians of various levels of experience and the way in which they examine the optic nerve head. Therefore, the aim of this study was to examine the extent to which level of clinical experience of orthoptists influences eye movements, gaze behaviour and diagnostic accuracy when examining optic disc images for glaucoma.

MATERIALS AND METHODS

Participants

Clinical orthoptists in the state of Victoria, Australia, were contacted via email and invited to participate. A list of orthoptists was compiled using publicly accessible resources such as hospital registries, registration and professional bodies including the Australian Orthoptic Board and Orthoptics Australia.

Orthoptists who worked in a clinical setting were eligible for participation. These included orthoptists working in either ocular motility or general ophthalmology settings. Clinicians who had more than 12 months clinical experience working in a specialist glaucoma clinic and were involved in screening and monitoring glaucoma, were considered glaucoma specialist orthoptists for the purpose of this study.

At the time of recruitment there were approximately eight glaucoma specialist orthoptists practising in Victoria. The clinicians who did not meet the criteria for glaucoma specialist orthoptist were classified as novice orthoptists. Ethics approval was sought and granted from the La Trobe University Faculty of Health Sciences Human Ethics Committee (FHEC14/235). Written informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

Optic disc images

The optic disc images included for eye tracking assessment were selected from a set of 2,500 high-resolution images of normal subjects and patients with glaucoma previously utilised in the Glaucomatous Optic Neuropathy Evaluation (GONE) project.[19] Twenty optic disc images which illustrated a range of optic disc appearances and varying levels of glaucomatous damage were carefully selected and validated by two experienced glaucoma specialist ophthalmologists. The characteristics of optic disc images selected, and their glaucoma likelihood rating, can be found in Table 1.

The selected optic disc images were stored as high-quality JPEG images and were standardised in size and magnification to fit to the Tobii T120 eye tracker screen resolution. Participants assessed each optic disc image and when finished were asked to classify the image using a four-point ordinal scale (unlikely, possible, probable or certain) for glaucoma likelihood.

Table 1. Optic disc characteristics and glaucoma likelihood of eye tracking images as assessed by glaucoma specialist ophthalmologists

Disc characteristics	Scale	Number of discs
Disc size	Hypoplastic Small Medium Large Macro	0 2 16 2 0
Disc shape	Regular Ovoid	9 11
Disc tilt	No tilt Tilt	17 3
Vertical CDR	<0.5 0.5 0.6 0.7 0.8 0.9 >0.9	2 4 3 4 3 4 0
Cup shape	Normal Concentric rim loss Superior rim loss Inferior rim loss Superior & inferior rim loss	10 1 0 7 2
Cup depth	Shallow Moderate Deep Undermined	7 9 4 0
Haemorrhage	Absent Present	18 2
Peri-papillary atrophy	Mild or None Moderate Extensive	11 7 2
Retinal nerve fibre layer loss	No loss Focal loss superiorly Focal loss inferiorly General loss	13 0 3 4
Glaucoma likelihood	Unlikely Possible Probable Certain	8 3 4 5

Eye tracking

The Tobii T120 eye tracker (Tobii Technology, Stockholm, Sweden) was used to record the eye movements and gaze behaviour. The eye tracker consists of a 17-inch, thin film transfer (TFT) monitor with a screen resolution of 1280 x 1024 pixels and has a data rate of 120Hz. The Tobii T120 is able to tolerate moderate head movements at 50 to 80cm in front of the screen without compromising data collection accuracy. This enables clinicians to be able to make slight adjustments to get a better view of the image, which mimics a normal clinical environment.

Before the commencement of data collection, participants were given verbal instructions about the procedure and how to conduct the experiment. Participants were seated 60 cm ± 10cm in front of the screen, as per the protocol described by Tobii Technology. A standard 5-point calibration was performed for each participant. A sample optic disc image was displayed before the commencement of the 20 test images to allow for participants to become familiar with the procedure. After the sample image, images were shown consecutively and in the same order for all participants. A maximum of 90 seconds was given to examine each image. Once satisfied with their examination, participants were instructed to click the attached mouse when they had completed their examination. Answers were verbally delivered to the researcher who entered them onto a paper proforma. Participants were given no further information about the patients' medical history, ophthalmic tests and were not given an image of the opposite eye for comparison. Eye movements were tracked from when the first fixation was made until the mouse was clicked.

Statistical analysis

The agreement on glaucoma likelihood between specialist ophthalmologists and each orthoptic group was estimated using a weighted kappa. The students t-test was used to compare agreement between orthoptist groups. Multivariable linear regression was performed to compare log-transformed values of total time taken (for each image), number of fixations and proportion of time spent fixating on areas of interest (AOI) between participant groups (glaucoma specialist orthoptists vs novice orthoptists) adjusting for likelihood of glaucoma. AOIs on optic disc images were defined by two glaucoma specialist ophthalmologists as areas of focal pathology and were inserted using the Tobii pro software. Gaze data were qualitatively analysed for each participant, taking note of gaze behaviour and patterns of fixations. Statistical significance was set at <0.05. Data were analysed using Stata/IC 13.1 (College Station, Texas).

RESULTS

Participant characteristics

Forty-one orthoptists agreed to participate in this study and undertook testing. The sample included five glaucoma specialist orthoptists and 36 novice orthoptists. Of the study population 42.9% had less than 5 years of experience as an orthoptist, 8.6% had 5-10 years, 25.7% had 11-20 years, 17.1% had 21-30 years and 5.7% had 30 or more years of experience. Over a third (37.1%) worked only in public ophthalmology clinics, 40% worked exclusively in private ophthalmology clinics, and 22.9% worked in both sectors. Four novice orthoptists were excluded from all analyses except for those relating to total time taken and glaucoma likelihood assessment. This was due to a high percentage of missing or unreliable eye tracking data for those four clinicians.

Optic disc assessment time

There was insufficient evidence for a difference in optic disc examination time between orthoptist groups. The total time for all included optic disc images was calculated to be 9.97 seconds (14%) greater for the expert orthoptist group than for the novice orthoptist group (95%CI -21% to +65%, p = 0.48). Similarly, no statistically significant relationship was evident between orthoptist groups, when images were grouped by glaucoma likelihood status. Figure 1 shows the median image assessment time for both expert and novice orthoptists for unlikely, possible, probable and certain glaucoma likelihood. Glaucoma specialist orthoptists spent 10.88 seconds (33%) (95%CI -3% to +82%), 8.08 seconds (25%) (95%CI -15% to +84%) and 9.75 seconds (12%) (95%CI -31% to +83%) longer to assess possible, probable and unlikely images respectively, and 1.03 seconds (1%) (95%CI -31% to +42%) less on certain images but this was not significant.

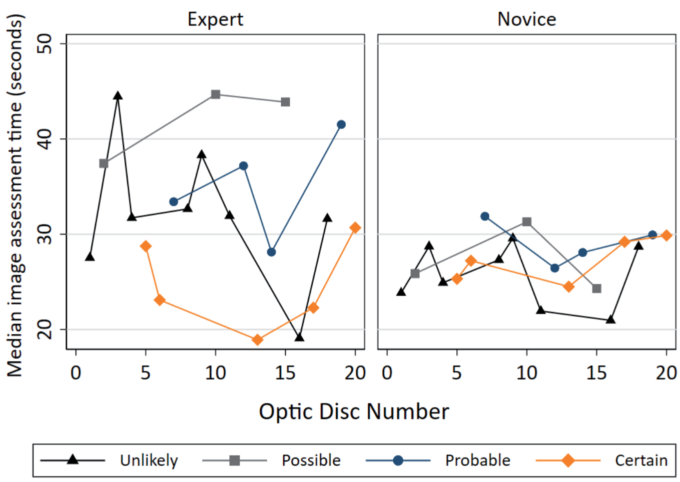

Figure 1. Median image assessment time (seconds) for novice and glaucoma specialist orthoptists for optic disc images.

Number of fixations

No significant relationship was found between orthoptist groups and the total number of fixations for all images. Glaucoma specialist orthoptists had a median of 5.4 (19%) more fixations across all images, (95%CI -15% to +67%, p = 0.30). The greatest difference in fixation count between orthoptist groups was for images with a glaucoma likelihood of 'possible'. Glaucoma specialist orthoptists had 29.16 (38%) more fixations when assessing possible images and this difference was statistically significant (95%CI +5% to +82%, p = 0.02). Figure 2 shows the median fixation count across all images for both orthoptist groups.

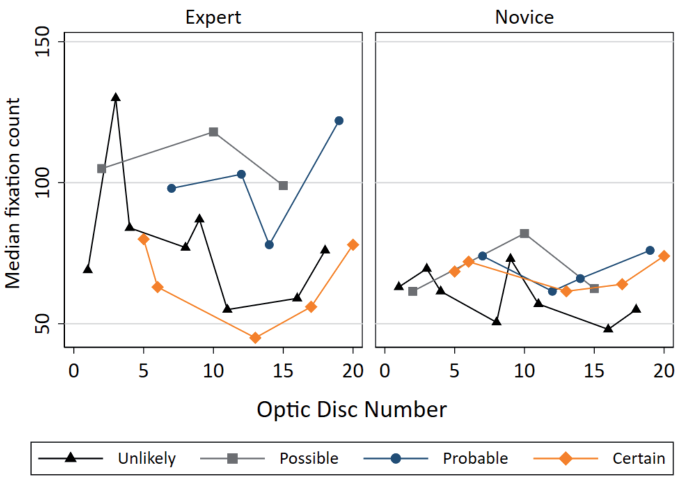

Figure 2. Median fixation count of expert and novice orthoptists for all optic disc images.

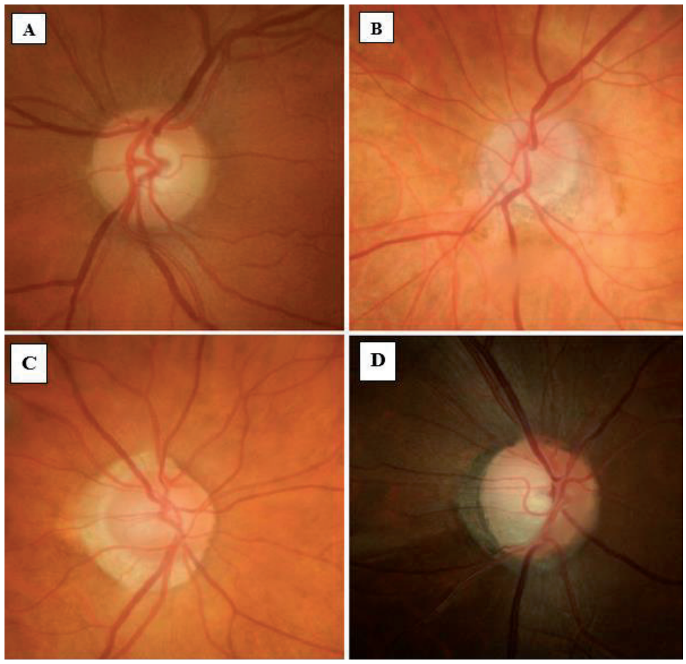

Figure 3. Sample images examined by orthoptists during eye tracking. Image A = unlikely to be glaucomatous; Image B = possible glaucoma; Image C = probable glaucoma; and Image D = certain glaucoma.

Fixation patterns

Three broad trends emerged from the qualitative assessment of the fixation patterns and gaze behaviour of orthoptists. One image from each disease status was randomly selected from the dataset to display the scan paths of orthoptists. Figure 3 displays the images without superimposed scan paths. Generally, the glaucoma specialist orthoptist group exhibited a methodical viewing pattern when assessing each optic disc. The experts examined the image by looking at regions more likely to show signs of glaucomatous damage such as the superior temporal and inferior temporal neuro-retinal rims and the retinal nerve fibre layer. The fixation pattern and gaze behaviour of expert orthoptists did not vary substantially by glaucoma likelihood status. The same methodical patterns were shown across all images. Figure 4 displays an example of the gaze behaviour and fixation pattern of two expert orthoptists whilst examining: unlikely, possible, probable and certain glaucomatous optic disc images.

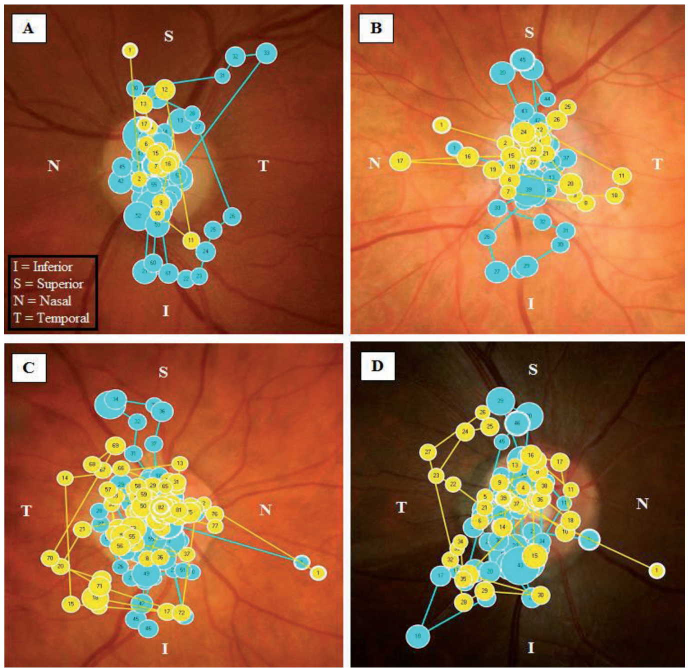

Figure 4. Tobii eye tracker scan paths of gaze behaviour and fixation patterns displayed by two expert orthoptists. Each colour represents a different orthoptist and numbers indicate the order of fixations. Participants were asked to assess optic disc images for signs of glaucoma, the images were given a glaucoma likelihood status of either unlikely (A), possible (B), probable (C) and certain (D) glaucomatous optic disc images.

Novice orthoptists did not exhibit the same methodical viewing pattern as glaucoma specialist orthoptists. Their gaze behaviour and fixation pattern were focused on the optic disc or displayed in a random pattern. For the group of orthoptists who focused on the optic disc, the fixations were predominantly located centrally on the optic disc. There were very few fixations made out into the superior and inferior retinal nerve fibre layer. Figure 5 displays an example of the gaze behaviour and fixation pattern of novice orthoptists who displayed the viewing pattern which focused primarily on the optic disc. For the orthoptists who displayed a random pattern, the fixations were mostly located centrally on the optic disc with large directional changes seen into areas of the retinal nerve fibre layer, which appeared to be random and spiral shaped. Figure 6 shows an example of the random gaze behaviour and fixation pattern displayed by novice orthoptists.

Time spent on areas of severe focal pathology

Of the included optic disc images, there were 11 AOIs across six images that displayed severe focal pathology. This included severe superior and inferior neuro-retinal rim thinning, notching, optic disc haemorrhages and retinal nerve fibre layer defects. Only one AOI exhibited a statistically significant difference between orthoptist groups. Specifically, novices spent significantly longer fixating on an area of inferior neuro-retinal rim thinning on Image 13 (p = 0.03) (Figure 7).

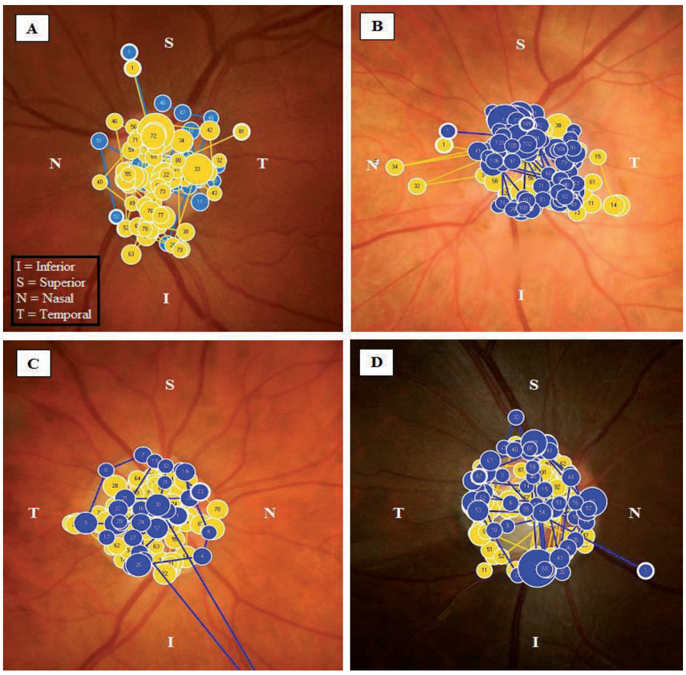

Figure 5. Tobii eye tracker scan paths of gaze behaviour and fixation patterns displayed by two novice orthoptists who displayed the viewing pattern which focused primarily on the optic disc. The images display the scan paths of unlikely (A), possible (B), probable (C) and certain (D) glaucomatous optic disc images.

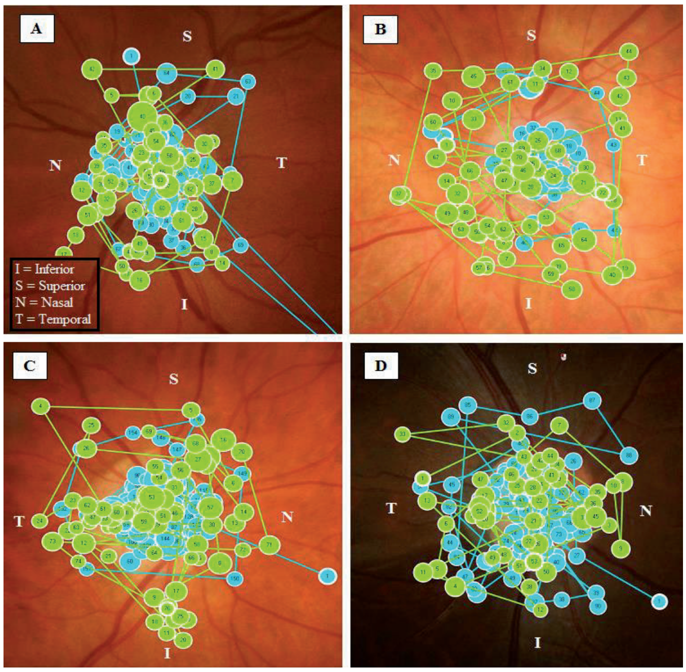

Figure 6. Tobii eye tracker scan paths of gaze behaviour and fixation patterns displayed by two novice orthoptists who displayed the random viewing pattern. The images display the scan paths of unlikely (A), possible (B), probable (C) and certain (D) glaucomatous optic disc images.

Figure 7. Image 13: Area of inferior neuro-retinal rim thinning shaded in purple.

Agreement on glaucoma likelihood

The agreement on glaucoma likelihood between glaucoma specialist orthoptists and the glaucoma specialist ophthalmologists was moderately strong ($\kappa = 0.51$) and fair for novices ($\kappa = 0.31$). Although agreement was higher among the glaucoma specialist orthoptists, the difference in kappa of 0.19 between groups was not statistically significant (95%CI -0.01, 0.39, $p = 0.07$). The variation in kappa scores between novices and glaucoma specialist orthoptists can be seen in Figure 8.

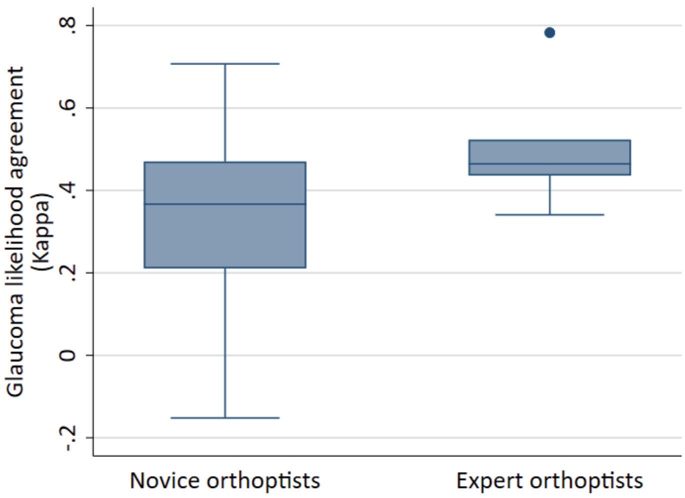

Figure 8. Box plot of the distribution of glaucoma likelihood agreement scores (kappa) for novice and glaucoma specialist orthoptists.

DISCUSSION

This investigation into the relationships between eye movements, gaze behaviour and accuracy in determining glaucoma likelihood by orthoptists with different levels of experience, revealed some novel findings. Orthoptists with greater experience in assessing patients for glaucoma demonstrated systematic eye movements and gaze behaviour across all levels of disease severity. The viewing patterns for experts were methodical, but they took longer to assess optic disc images and amassed a higher number of fixations. Novices displayed viewing patterns that were less predictable. At times they failed to scan within the retinal nerve fibre layer. A trend towards greater agreement was displayed by glaucoma specialist orthoptists when determining glaucoma likelihood and they were likely to be better equipped to confidently assess the optic disc for disease.

Current literature investigating eye tracking of clinicians with varying degrees of expertise when making a disease diagnosis primarily focuses on viewing radiological images. These studies have found that those with more experience make quicker assessments, fixate faster to a lesion site and make less fixations.[21-24] This is in contrast to the current study and may be explained by different level of experience of included clinicians and the type of tasks performed. For instance, Kok et al[22] compared disparate groups which included medical students and experienced radiologists. The clinicians in the current study are more closely comparable in regard to years of experience which may potentially explain the lack of statistically significant differences between the groups. In addition, clinicians in the current study were asked to make a diagnostic decision about glaucoma likelihood. This involved distinguishing between many potential ambiguous diagnostic features compared to identifying a single fracture which requires a less extensive visual search strategy.

Eye movements and gaze behaviour of ophthalmologists whilst examining the optic disc for glaucoma has been sparsely investigated. O'Neill et al[15] previously reported that glaucoma specialist ophthalmologists spend significantly less time examining optic disc images compared to trainee ophthalmologists. However, the eight images included for assessment all had diffuse or focal neuro-retinal rim loss which could potentially explain the disparate findings to the current study. The inclusion of optic disc images with severe forms of the disease could possibly inflate results, as advanced disease is easier to detect.[25] Glaucoma specialist ophthalmologists are highly experienced and are easily able to identify glaucomatous features, especially advanced pathology. This could help to explain the difference in examination times compared to trainee ophthalmologists.

Our finding that glaucoma specialist orthoptists displayed a methodical order of examination of the optic disc are in agreement with O'Neill et al.[15] Glaucoma specialist orthoptists showed comparable visual search strategies to ophthalmologists with sub-specialty training in glaucoma. They visualised common areas of pathology seen in glaucoma and did not spend time assessing areas unlikely to assist them with a diagnosis, such as the retinal periphery. This type of systematic search strategy has also been reported in the radiology literature and suggests a greater level of skill and knowledge.[23,24,26-28]

The search strategy displayed by some novice orthoptists has also been displayed by trainee ophthalmologists.[15] This gaze behaviour has been attributed to inexperience regarding the characteristic features of glaucomatous damage. In addition, studies which have investigated the detection and interpretation of chest lesions have found that clinicians with less experience exhibit a central search strategy and focus within one region repetitively.[29,30] The random pattern displayed by novices in our study has also been noted by novices when searching for chest or lung lesions in studies by Donovan and Litchfield[31] and Kok et al.[27] Both noted that novice clinicians tend to focus on areas of low probability for containing pathology. They also cover more areas of the image due to lack of experience in knowing where to look and what to look for. Greater visual search efficiency and less distribution of fixations displayed by experts in the current study was likely due to more comprehensive training and greater experience in assessing optic discs for glaucoma.

There are several limitations of the current study which warrant further consideration. Firstly, the small number of glaucoma specialist orthoptists likely resulted in a lack of statistical power to show differences between the groups. Furthermore, participants in the novice group were not categorised based on their years of clinical experience. It is possible that orthoptists who were trained before the introduction of general ophthalmology training in University courses could have used different methods of scanning and have less knowledge about glaucomatous disease processes than more recent graduates. Finally, monoscopic images were utilised which may have impacted orthoptists ability to perceive three dimensional structures such as the optic cup.

CONCLUSION

To conclude, this study is the first of its kind to investigate the eye movements, gaze behaviour and accuracy of orthoptists when performing optic disc examinations for glaucoma. Overall, glaucoma specialist orthoptists displayed more efficient eye movements and gaze behaviour. These findings provide some support for the use of experienced glaucoma specialist orthoptists in the assessment of the optic disc in glaucoma, however, future research which includes a greater number of glaucoma specialist orthoptists from outside of Victoria is required to further strengthen these findings.

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