Prospective Pilot Study Looking at the Size and Variation of the Blind Spot Scotoma in Adults Measured on the Octopus 900 Field Analyser

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Author's contribution

This work was carried out by the author MJR. Author MJR read and approved the final manuscript.

ABSTRACT

Aims: Literature regarding the size of the blind spot is old and recorded on instruments no longer in production. This pilot study looks to provide normative data for the size of the visual blind spot scotoma in adults measured by the Octopus 900 kinetic perimeter.
Study Design: A prospective repeated measures study involving nineteen participants.
Place and Duration of Study: Ophthalmology department, Royal Hallamshire Hospital, Sheffield, between April 2012 and July 2012.
Methodology: The blind spot scotoma area was measured in degrees^2 using three kinetic targets. Two trials were conducted to assess variability across the targets.
Results: The mean blind spot scotoma area decreased as target luminosity increased. The mean blind spot scotoma area was; 197.6±152.8 deg^2 with the I1e, 63.6±21.7 deg^2 with the I2e and 33.9±6.8 deg^2 with the I4e.
Agreement between the first trial and second trial for the three different forms of target luminance was examined using Bland-Altman analysis. The target I4e has the closest mean difference to zero and the I4e also has the highest precision as shown by the SD; I1e bias -1.764±3.852SD, I2e bias -0.368±0.938SD and I4e bias -0.151±0.477SD.
Conclusion: This study found the mean size of the blind spot scotoma to be influenced by the luminosity of the target stimulus, with mean area (deg^2) decreasing as target luminosity increases. This can be attributed to the blind spot's amblyopic zone or light

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scattering across the refractive media of the eye. The target I4e shows the least variation between subsequent measures and would be the most reliable of the targets used for monitoring change in blind spot scotoma area over time.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

Idiopathic Intracranial Hypertension (IIH): Also known as Benign Intracranial Hypertension or Psedotumor Cerebri, IIH is a neurological condition defined as an increase in the intracranial pressure (ICP) around the brain, without the presence of a tumour or disease. Its cause is unknown.

Perimetry: The process of using an instrument to map the extent of a persons visual field.

Scotoma: A small area of abnormally less sensitive or absent vision in the visual field, surrounded by normal sight.

1. INTRODUCTION

A literature review was conducted asking the question "What is the normative size of the blind spot scotoma in adults and how much do these measurements vary?" A lack of data appropriate for clinical use was identified, no standard way of recording the blind spot scotoma was found and measurements were recorded using equipment that is no longer in production.

Advancements in technology have provided new equipment offering greater precision in measuring the size of the blind spot scotoma. Benefits such as correcting for reaction times are now incorporated in the most recent field analysers, one of which is the Octopus 900.

The Octopus 900 is the official successor to the Goldmann perimeter and is commonly used in clinical practice to conduct perimetry in patients with neurological visual field deficit. The target can be presented in a range of sizes ranging from $1/16mm^2$ to $64mm^2$ these are represented by a roman numeral, '0' being the smallest 'V' being the largest. The luminance intensity of the targets can also be changed and these are represented numerically, '1' being the faintest and '4' being the brightest. These numbers are further split into five levels of luminosity represented by alphabetic letters; 'a' being the faintest and 'e' the brightest.

The Octopus 900's advantages over the Goldmann are that of reaction time compensation and the ability to standardise the speed in which the targets are moved, leading to greater reliability in testing.

This project aims to provide normative data on the size and repeatability of the blind spot scotoma as measured by the Octopus 900. The main objectives of this research project are to provide:

i. Normative data of the blind spot scotoma size for adults.
ii. Variation of the size of the blind spot scotoma on repeat testing using three targets of increasing luminosity I1e, I2e and I4e.

iii   Normative data of the peripheral field using the targets I4e and I2e.

2. METHODOLOGY

A prospective repeated measures study involved nineteen participants all were employed in the Ophthalmology department at the Royal Hallamshire Hospital, Sheffield. All employment roles and ethnic backgrounds were given the opportunity to participate.

Volunteers were eligible to participate if they had a corrected visual acuity of 0.200 Log units (6/9.5 Snellen equivalent) or greater and had no previous diagnosis of Idiopathic Intracranial Hypertension (IIH), stroke, glaucoma or any known field defect. No participants had lid abnormalities that could interfere with perimetry. If any Ocular anomalies were detected during screening these were to be investigated further by the on-call Ophthalmologist.

This project was registered at Sheffield University and approved by the Research Ethics Committee of the School of Health and Related Research (ScHARR). A sample size to determine statistical power was calculated using the statistical calculator G*power 3.1 [1] for an ANOVA (repeated measures, between factors) measuring an effect size of 0.25 with 0.95 power and alpha being set to 0.05, the number of participants required for statistical power was a minimum of 14.

The peripheral visual field was measured in both the right and left eye in degrees^2 firstly using the I4e and secondly the I2e moving at the speed of 5º/s, these targets were chosen as they follow protocol commonly used in the United Kingdom.

The blind spot scotoma was similarly measured in degrees^2 for the right and left eye but using three target stimuli; I1e, I2e and I4e moving at the slower speed of 2º/s. Two trials were conducted on the same day to assess variability across the targets, a minimum of five minutes rest period was given between trials. Reaction times were corrected and appropriate refractive correction was calculated in accordance with the Octopus 900 user manual [2], this is important as under or over corrected prescriptions can unjustly influence the size of the blind spot scotoma [3].

The size of the blind spot using each of the three different targets stimuli (I1e, I2e and I4e) will be shown. Repeated measures ANOVA shall be conducted on area measurements the factors that shall be analysed will be; eye, dominant eye, target luminosity and trial. It may be that the second recordings of the blind spot scotoma are of a smaller area due to a learning experience and familiarity with the field analyser.

The average size of the peripheral field using the I4e and I2e shall be given in degrees^2. Again repeated measures ANOVA shall be conducted this time the factors considered shall be; eye and target stimulus.

Bland-Altman tests shall also be utilised to visually compare the bias associated with plotting the blind spot with a I1e, I2e and I4e target showing which gives more accurate and repeatable results and that most appropriate for clinical use [4].

The area of the visual field is known to be non-normally distributed, this is because the area is related to the radius squared, if two people differ by a set amount along this radius, the amount of radius increase has a non-linear (squared) effect on the area, a small difference will become amplified. Therefore by taking the square root of the area, this problem is

eliminated making the data normally distributed. All statistical analysis shall be conducted on the square root of the area of the blind spot scotoma [5].

3. RESULTS AND DISCUSSION

3.1 Results

Of a group of approximately 100 staff, a total of 19 participants (13 females, 6 males) mean age 35.3±12.3 years (range 21 – 60 years) took part. The mean visual acuity was -0.06±0.1 logMAR in the right eye and -0.08±0.1 logMAR in the left eye. Ten participants were emmetropic, 6 were myopic (range -3.75DS – -0.75DS) and 3 were hypermetropic (range +3.00DS – +0.75DS). Fourteen participants were right eye dominant and five were left eye dominant. Only one volunteer was excluded, this was due to a very high myopic prescription and previous retinal detachment surgery.

A summary of the participant data can be found in Table 1.

Table 1. Summary of participant data

Participant	Gender ♂=male ♀=female	Age (Years)	Dominant Eye R = right L = left	Right Visual Acuity LogMAR	Left Visual Acuity LogMAR	Height (M)	Weight (KG)	BMI
1	♀	21	L	0.0	-0.3	1.68	56	19.927
2	♂	22	R	-0.1	-0.1	1.86	70.85	20.528
3	♀	26	L	-0.32	-0.3	1.75	68.03	22.148
4	♀	31	R	-0.2	-0.2	1.72	72.6	24.540
5	♀	37	R	0.0	0.0	1.63	51	19.195
6	♂	29	R	0.02	0.02	1.70	109.76	37.899
7	♀	25	R	-0.1	-0.1	1.63	51.71	19.568
8	♀	60	R	0.22	0.02	1.55	62.59	26.072
9	♂	31	R	-0.1	-0.1	1.70	80.8	27.899
10	♀	30	R	-0.1	-0.1	1.63	60.8	22.772
11	♀	48	R	-0.1	-0.1	1.57	52.16	21.032
12	♀	37	L	0.0	0.0	1.55	54.43	22.673
13	♂	25	R	-0.1	-0.12	1.78	74	23.408
14	♀	28	R	0.0	0.0	1.70	70.76	24.433
15	♀	31	L	0.0	0.0	1.80	100.9	31.025
16	♀	29	R	-0.1	-0.1	1.60	95	37.100
17	♂	57	L	-0.06	-0.02	1.68	73.93	26.307
18	♂	50	R	0.0	0.0	1.78	90.71	28.694
19	♀	54	R	-0.1	0.0	1.57	48.98	19.750
Mean with		*35.3*		*-0.06*	*-0.08*	*1.68*	*70.79*	*24.99*
SD		*±12.3*		*±0.1*	*±0.1*	*±0.09*	*±17.9*	*±5.5*

3.1.1 Blind spot scotomas

The mean blind spot scotoma area using the faintest target I1e was recorded for the right eye (RE) and left eye (LE) on two separate occasions. Eight (42.1%) out of 19 participants failed to respond to the I1e target stimulus with the RE and 3 (15.8%) out of the 19 with the LE. The I2e had a much better detection rate with only one participant (5.3%) failing to respond to the target stimulus with the RE using the I2e target and every participant seeing the I2e target with the LE. The I4e had a better detection rate again with 100% of

participants identifying the l4e with either eye. A summary of the blind spot scotoma areas for each target size can be found in Table 2.

Table 2. Summary of mean blind spot scotoma area in degrees

Target size	1st Trial		2nd Trial	
	Right	*Left*	*Right*	*Left*
l1e	197.6±152.8	127.0±73.3	144.3±86.6	113.3±41.9
l2e	63.6±21.7	54.7±16.6	57.9±17.5	56.0±17.5
l4e	33.9±6.8	33.1±7.7	32.1±6.6	33.3±8.9

A four factor repeated measures ANOVA was conducted on area measurements whereby factors were; eye (right or left); dominant eye (right or left); target luminosity (l1e, l2e or l4e) and trial (1st trial or 2nd trial). The effect of eye was not significant f(1,9)=2.042, *P*=0.187, the dominant eye was also not significant f(1,9)=0.254, *P*=0.626. Target luminosity was statistically significant f(2,18)=35.828, *P*=<0.0001. Trial however was not statistically significant f(1,9)=1.090, *P*=0.324. No other interactions were significant.

Given the lack of effect of the factor of eye and the possibility of overestimating statistical power if both eyes were pooled, a two factor repeated measures ANOVA was conducted just using the data from the RE. The two factors analysed were; target luminosity (l1e, l2e or l4e) and trial (1st or 2nd trial). The effect of target luminosity was significant f(2,96)=77.64, *P*=<0.0001. No significant difference was found when looking at the trial as the source of variation *P*=0.0800, this is however close to being significant and future study might look at a larger group of participants to test this.

No significant differences were found on post-hoc t-tests corrected by Bonferroni adjustment between the first and second trial for the l1e, l2e and l4e (*P* >0.05).

Fig. 1 shows the 1st trial and second trial for the 3 types of target luminance, against the mean square root blind spot scotoma area.

Further post-hoc analyses were conducted to explore where significant differences occurred between target luminosities. Again these were corrected using Bonferroni adjustment for type I error. Fig. 2 shows the square root of the blind spot scotoma in degrees for the RE, significant differences occurred between all target luminosities and are illustrated with an asterisk (* = Statistically significant).
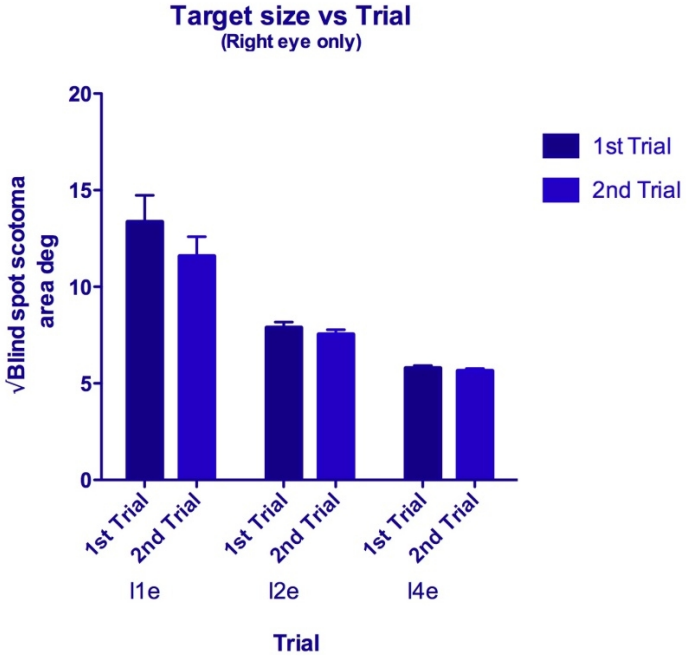
Fig. 1. showing 1st trial (dark blue) and second trial (light blue) for the 3 types of target luminance on the x axis, against the mean square root blind spot scotoma area on the y axis
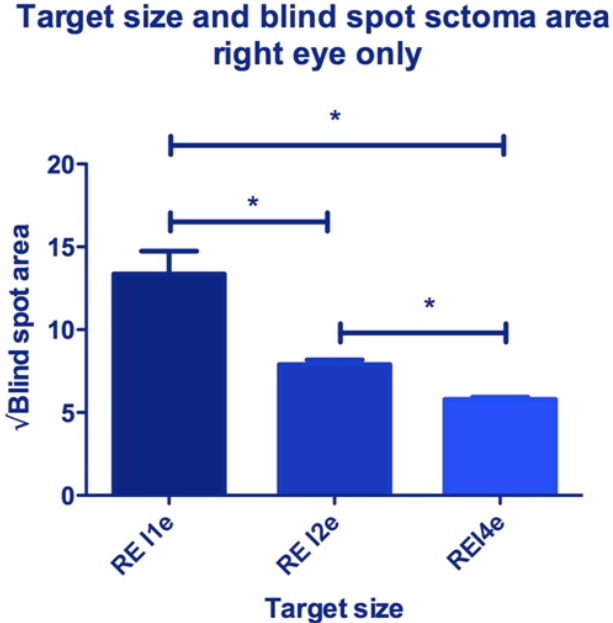

Fig. 2. Target size and square rooted blind spot scotoma area in deg for the RE
* = Statistically significant.

3.1.2 Peripheral field

The mean RE area for the peripheral visual field using the target stimulus I4e was 10446.6± 1058.2 deg^2, mean LE area was 10466.2±1120.7 deg^2. The mean peripheral area using the target stimulus I2e was 2920.6±755.6 deg^2 with the RE and 3013.7±824.3 deg^2 with the LE. No second trials were conducted on the peripheral field.

A two factor repeated measures ANOVA was conducted using the factors; eye (right or left) and target luminosity (I2e or I4e). The effect of eye was not significant f(1,70)=0.086, *P*=0.770. Target luminosity proved to provide as a statistically significant factor f(1,70)=948, *P*=< 0.0001. The interaction of eye and target were not significant f(1,70)=0.058, *P*=0.810.

There were no significant differences between the RE and LE using the I4e and I2e (*P*=0.160 and *P*=0.827 respectively), therefore post-hoc paired t-test analyses were conducted between the target stimulus of the RE only. These were corrected using Bonferroni adjustment for type I error. Significant differences occurred between the two target stimuli (*P*=< 0.0001, Two-tailed, t=31.3 df=17) indicated by the asterisk on the graph seen in Fig. 3.
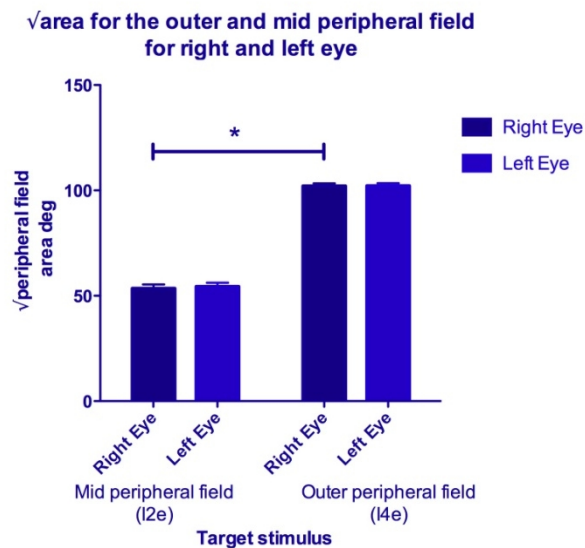

Fig. 3. Visual field area for the I2e and I4e targets, right (dark blue) and left eye (light blue)

3.1.3 Blind spot Scotoma Repeatability

Agreement between the 1st trial and 2nd trial for the three different forms of target luminance was examined using Bland-Altman analysis. Bland-Altman plots graphically representing the differences between the 1st and 2nd trial for each of the target stimuli, can be seen in Fig. 4 where the difference between trials is shown on the y axis and the average of the two trials is shown on the x axis for the I1e (a), I2e (b) and I4e (c). Each dot represents an individual participant. Note the different scale of axis for the ordinates to give the best graphical illustration of spread of variance.
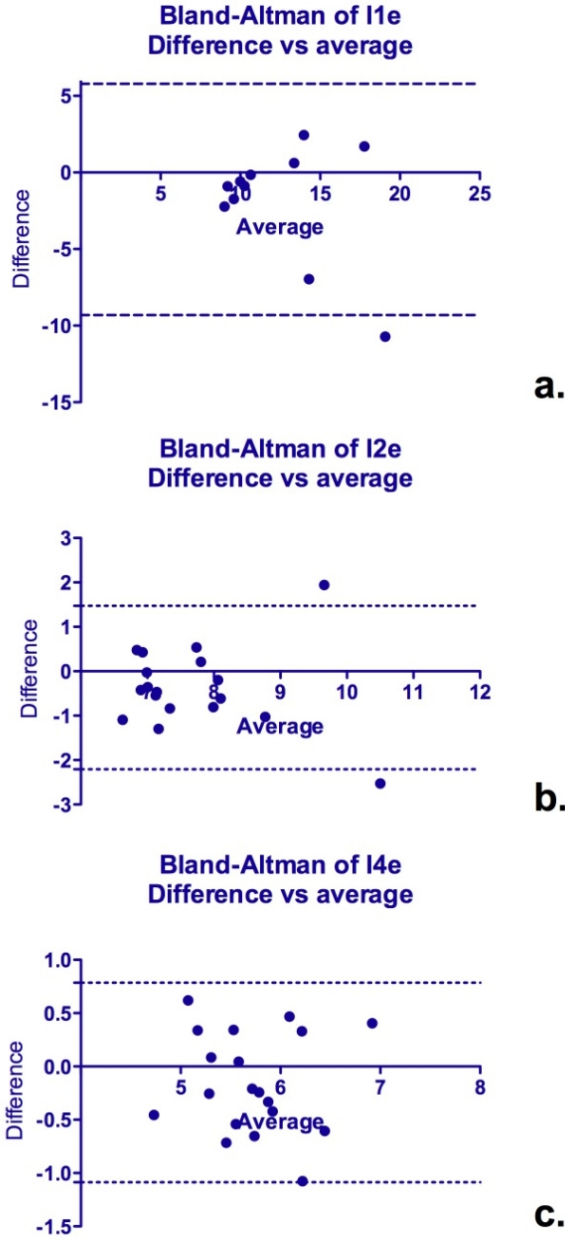
Fig. 4. Bland-Altman plots for each of the different target stimulus also demonstrating the 95% limits of agreement

The I1e target shows the largest amount of bias (-1.764), this reduces with the I2e (-0.368) and reduces still further with the I4e (-0.151). The SD of the bias follows this same pattern, the I1e has a very large SD of the bias (3.852), this reduces dramatically with the I2e (0.938) and then again with the I4e (0.477). Out of all the targets the I4e has the closest mean difference to zero the I4e also has the highest precision as shown by the SD.

In summary the I4e target had the best detection rate followed by the I2e, then the I1e. As the target luminosity increased the blind spot scotoma area decreased in size. The precision of the measurements improved as the luminosity of the target increased.

An explanation for the variation found between the first and second trials especially using the faintest target (I1e) can be described as multi-factoral. Primarily it has to be stated that all subjective measurements are reliant on the subject's response which may be affected by the participant's attentiveness, their prone to fatigue, and learning. It could be argued that learning had an effect in reducing the blind spot scotoma area between the two trials, a trend can be seen showing the second trial results measuring as slightly smaller than the previous trial, however this was not calculated as being statistically significant (P = 0.0800).

The blind spot scotoma measured with the I1e showed the most variability. All tests were conducted in the same order in keeping with hospital protocol. The order was; I2e, I1e and then I4e, with the RE preceding the LE. To counter any fatigue or learning effects in subsequent study the order in which the targets were presented to the patient should be randomised.

3.2 Discussion

3.2.1 Blind spot scotoma size and target luminosity.

In this study the size of the blind spot scotoma changed depending on the luminosity of the stimulus target used, this could be for a number of reasons. One explanation could be related to the blind spots amblyopic zone. Traquair [6] described this blind spot amblyopic zone as…

> *"The area of absolute blindness corresponds not to the head of the nerve (optic), but to the area in which no retinal receptive elements are present, an area usually slightly larger than the nerve itself. The presence of the amblyopic zone is at least partly anatomically explained by the gradual rather than abrupt termination of the retinal outer layers towards the nerve. At the upper and lower ends of the blind spot, narrow curve prolongations of the amblyopic zone are found which represent the projections of the large retinal vessels near the optic disc, and which with care may be traced some little way over the field even as far as 30°…"*

The blind spot has an area of absolute blindness, and around this area is an amblyopic zone that is seen to increase when plotted with smaller targets [6]. In this study the target size was small and remained constant, luminosity was the factor that varied. This study shows the amblyopic zone may also be extended when using fainter targets.

Bek [7] found a link between the stimulation target size and blind spot scotoma size using static perimetry and interpreted this finding to be a result of "light scattering in the refractive media of the eye." Bek found that if a large target was projected within the optic nerve head (an area that the target should not be seen), the target could actually be sensed by the surrounding retina due to this light scattering. It could also be that target luminosity may also be linked to this phenomenon, the brighter the stimulus, the more likely this scattered light is to be picked up by the surrounding retina.

In summary if the target size increases (with constant luminance), or the luminosity increases (with constant target size), the measurement of the scotoma reduces. This may be

due to light scattering around the optic nerve heads amblyopic zone with larger or brighter lights being picked up by the surrounding retina. From a clinical perspective when monitoring the progress of a disease through repeated measures of the blind spot scotoma it is essential that the target size and luminosity remain constant or results cannot be compared. The ability to correct the visual field for the participants reaction time (RT) is a new concept in mainstream perimetry, allowing greater accuracy when assessing a participants blind spot scotoma. When an RT is accounted for the size of the blind spot scotoma is reduced by an amount proportional to that of the reaction time. If a participants reaction time is particularly slow the blind spot is no longer exaggerated as a result of the reaction time when this correction is applied.

Dolderer [8] found that correction for the subject's RT almost halved the level of random variance to allow greater repeatability of testing. Dolderer also reported high variability in inter-individual response times with smaller target stimuli resulting in significantly longer RTs. Each participant in this study had their RT corrected with the I2e target, the Octopus 900 field analyser corrects each target with one reaction time target that can be chosen by the clinician. It is not possible to correct each recorded target area with its appropriate target stimulus RT. For the purposes of practical application, when measuring the blind spot with a single target stimulus it would be most appropriate to test the patients RTs with the target corresponding to the target used to plot the blind spot scotoma.

3.2.2 Peripheral field

There was no significant difference when comparing the right and the left eye with either the I2e or the I4e (P=0.160 and P=0.827 respectively). However the outer peripheral field measured significantly larger with the I4e than it does with the I2e (P=<0.0001). The study shows that the brighter the target luminosity the wider the peripheral field becomes, this is to be expected and has been found previously on the Goldmann [9]. The main purpose of recording this is to establish a mean peripheral field for both targets I2e and I4e that can be used as reference.

As is common to many, if not all research projects, further confidence in the outcomes of the study may be gained through greater allocation of resources allowing for a larger sample size and a more in depth analysis to be undertaken. The analysis of blind spot scotomas may be further augmented through application of mixed methods research, bringing together quantitative and qualitative elements. In particular qualitative research may aid in developing effective protocol with regards to patient preference and feedback.

The pilot study identifies areas in which further research would be beneficial to gain a fuller understanding of the variability in measurement of blind spot scotomas. Investigation to how these targets fair with patients with Optic nerve disease needs to be conducted, specifically looking for correlation between the size of the blind spot scotoma, the size of the optic nerve head, and grade of papilloedema.

Visual field tests do not as a matter of course accurately measure the size of the blind spot scotoma, could there be some merit in developing a programme to inform clinicians if the blind spot scotoma lies outside of the normal limit?

4. CONCLUSION

Literature concerning the size of the normal blind spot scotoma is old and outdated. Clinicians are forced to rely on information collected on instruments no longer in production and with no standard unit to measure the blind spot scotoma. Additionally clinicians need to have accurate information on the instruments they use to successfully monitor changes in the size of the blind spot scotoma and a standardised unit of measurement needs to be introduced.

The question that was asked by this study was "What is the normative size of the visual blind spot in adults and how much do these measurements vary?"

The normative data established from this pilot study for the blind spot scotoma size and the peripheral field for adults are summarised in Table 3.

Table 3. Table showing normative data for differing target luminosities of the blind spot scotoma area and the mean peripheral field area in degrees^2 as measured on the Octopus 900 (RE only)

Blind Spot Target Stimulus	Area in deg^2
l1e	197.6±152.8
l2e	63.6±21.7
l4e	33.9±6.8
Peripheral Field	
l2e	2920.6±755.6
l4e	10446.6± 1058.2

In conclusion when monitoring the progress of a disease through repeated measures of the blind spot scotoma it is essential that the target size and luminosity remain constant. The results of this study show that from the targets examined, the l4e is the most appropriate target to use when monitoring the size of the blind spot, it was the only target that could be seen by all participants and it displayed the least bias on repeated measures and a refraction of those undertaking kinetic visual perimetry is recommended to ensure that under or over corrected prescriptions do not unjustly influence the size of the blind spot scotoma.

This study provides normative data of the size of the blind spot scotoma on the Octopus 900 and provides pilot data allowing clinicians to evaluate their current practice, adjusting protocol in order to better monitor the size of the blind spot scotoma; this in turn benefits both patients and clinicians in the monitoring of the blind spot.

This study has opened the door to further research. Investigation needs to be conducted to look at how these targets fair with patients of varying optic disc size, specifically looking for correlation between the size of the blind spot scotoma, the size of the optic nerve head, and grade of papilloedema. The next step would be to connect this studies finding to modern imaging data from Optical Coherence Tomography (OCT) in order to explain the variation in blind spot size anatomically. It may be that a ratio of blind spot scotoma to anatomical size could identify disease much more effectively.

CONSENT

The author declares that written informed consent was obtained from each study participant.

ETHICAL APPROVAL

The author hereby declares that all experiments have been examined and approved by the Research Ethics Committee of SCHARR (URMS133654) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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COMPETING INTERESTS

The author declares that no competing interests exist.

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