

Research paper

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2 Prospective pilot study looking at the size and variation of the blind spot
3 scotoma in adults measured on the Octopus 900 field analyser.

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31 **Abstract**

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33 Purpose: Literature regarding the size of the blind spot is old and recorded on
34 instruments no longer in production. This pilot study looks to provide
35 normative data for the size of the visual blind spot scotoma in adults
36 measured by the Octopus 900 kinetic perimeter.

37

38 Methods: A prospective repeated measures study involved nineteen
39 participants, the blind spot scotoma area was measured in degrees² using
40 three kinetic targets. Two trials were conducted to assess variability across
41 the targets.

42

43 Results: The mean blind spot scotoma area decreased as target luminosity
44 increased. The mean blind spot scotoma area was; 197.6±152.8 deg² with the
45 I1e, 63.6±21.7 deg² with the I2e and 33.9±6.8 deg² with the I4e.

46

47 Agreement between the first trial and second trial for the three different forms
48 of target luminance was examined using Bland-Altman analysis. The target
49 I4e has the closest mean difference to zero and the I4e also has the highest
50 precision as shown by the SD; I1e bias -1.764±3.852SD, I2e bias -
51 0.368±0.938SD and I4e bias -0.151±0.477SD.

52

53 Conclusion: This study found the mean size of the blind spot scotoma to be
54 influenced by the luminosity of the target stimulus, with mean area (deg²)
55 decreasing as target luminosity increases. This can be attributed to the blind

spot's amblyopic zone or light 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.

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61 Keywords:

62 Kinetic Perimetry, Blind Spot

63 Visual Fields, Octopus

64 Word Count: 2791

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68 **1.0 Background**

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

75

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

80

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

84

85 i. Normative data of the blind spot scotoma size for adults.

86

87 ii. Variation of the size of the blind spot scotoma on repeat testing using
88 three targets of increasing luminosity 11e, 12e and 14e.

89

90 iii Normative data of the peripheral field using the targets 14e and 12e.

91

92

93 **2.0 Methods**

94

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

99

100 Volunteers were eligible to participate if they had a corrected visual acuity of
101 0.200 Log units (6/9.5 Snellen equivalent) or greater and had no previous
102 diagnosis of IHH, stroke, glaucoma or any known field defect.

103

104 This project was registered at Sheffield University and approved by the
105 Research Ethics Committee of the School of Health and Related Research

106 (SchARR). A sample size to determine statistical power was calculated using
 107 the statistical calculator G*power 3.1¹, for an ANOVA (repeated measures,
 108 between factors) measuring an effect size of 0.25 with 0.95 power and alpha
 109 being set to 0.05, the number of participants required for statistical power was
 110 a minimum of 14.

111

112 The outer visual field was measured in both the right and left eye in degrees²
 113 using the 14e and 12e targets moving at the speed of 5°/s.

114

115 The blind spot scotoma was similarly measured in degrees² for the right and
 116 left eye but using three target stimuli; I1e, I2e and I4e moving at the slower
 117 speed of 2°/s. Two trials were conducted to assess variability across the
 118 targets. Reaction times were corrected and appropriate refractive correction
 119 was calculated in accordance with the Octopus 900 user manual².

120

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

127

128 The average size of the outer (I4e) and the central (I2e) visual field shall be
 129 given in degrees². Again repeated measures ANOVA shall be conducted this
 130 time the factors considered shall be; eye and target stimulus.

131

132 Bland-Altman tests shall also be utilised to visually compare the bias
133 associated with plotting the blind spot with a I1e, I2e and 14e target showing
134 which gives more accurate and repeatable results and that most appropriate
135 for clinical use³.

136

137 The area of the visual field is known to be non-normally distributed, this is
138 because the area is related to the radius squared, if two people differ by a set
139 amount along this radius, the amount of radius increase has a non-
140 linear (squared) effect on the area, a small difference will become amplified.
141 Therefore by taking the square root of the area, this problem is eliminated
142 making the data normally distributed. All statistical analysis shall be conducted
143 on the square root of the area of the blind spot scotoma⁴.

144

145 **3.0 Results**

146

147 Of a group of approximately 100 staff, a total of 19 participants (13 females, 6
148 males) mean age 35.3 ± 12.3 years (range 21 – 60 years) took part. The mean
149 visual acuity was -0.06 ± 0.1 logMAR in the right eye and -0.08 ± 0.1 logMAR in
150 the left eye. Ten participants were emmetropic, 6 were myopic (range -3.75DS
151 – -0.75DS) and 3 were hypermetropic (range +3.00DS – +0.75DS). Fourteen
152 participants were right eye dominant and five were left eye dominant.

153

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

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167 Table 1.

168 Summary of participant data

169

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
<i>Mean with</i>		35.3		-0.06	-0.08	1.68	70.79	24.99
<i>SD</i>		±12.3		±0.1	±0.1	±0.09	±17.9	±5.5

170

171 3.1 Blind Spot Scotomas

172

173 The mean blind spot scotoma area using the faintest target I1e was recorded
 174 for the right eye (RE) and left eye (LE) on two separate occasions. Eight
 175 (42.1%) out of 19 participants failed to respond to the I1e target stimulus with
 176 the RE and 3 (15.8%) out of the 19 with the LE. The I2e had a much better
 177 detection rate with only one participant (5.3%) failing to respond to the target
 178 stimulus with the RE using the I2e target and every participant seeing the I2e
 179 target with the LE. The I4e had a better detection rate again with 100% of
 180 participants identifying the I4e with either eye. A summary of the blind spot
 181 scotoma areas for each target size can be found in Table 2.

182

183 Table 2.

184 Summary of mean blind spot scotoma area in degrees².

Target size	1 st Trial		2 nd Trial	
	<i>Right</i>	<i>Left</i>	<i>Right</i>	<i>Left</i>
I1e	197.6 ±152.8	127.0 ±73.3	144.3 ±86.6	113.3 ±41.9
I2e	63.6 ±21.7	54.7 ±16.6	57.9 ±17.5	56.0 ±17.5
I4e	33.9 ±6.8	33.1 ±7.7	32.1 ±6.6	33.3 ±8.9

185

186

187 A four factor repeated measures ANOVA was conducted on area
 188 measurements whereby factors were; eye (right or left); dominant eye (right or
 189 left); target luminosity (I1e, I2e or I4e) and trial (1st trial or 2nd trial). The effect
 190 of eye was not significant $f(1,9) = 2.042$, $P = 0.187$, the dominant eye was
 191 also not significant $f(1,9) = 0.254$, $P = 0.626$. Target luminosity was
 192 statistically significant $f(2,18) = 35.828$, $P = <0.0001$. Trial however was not
 193 statistically significant $f(1,9) = 1.090$, $P = 0.324$. No other interactions were
 194 significant.

195

196 Given the lack of effect of the factor of eye and the possibility of
 197 overestimating statistical power if both eyes were pooled, a two factor
 198 repeated measures ANOVA was conducted just using the data from the RE.
 199 The two factors analysed were; target luminosity (I1e, I2e or I4e) and trial (1st
 200 or 2nd trial). The effect of target luminosity was significant $f(2,96) = 77.64$, $P =$
 201 < 0.0001 . No significant difference was found when looking at the trial as the
 202 source of variation $P = 0.0800$, this is however close to being significant and
 203 future study might look at a larger group of participants to test this.

204

205 No significant differences were found on post-hoc t-tests corrected by Bonferroni

206 adjustment between the first and second trial for the I1e, I2e and I4e ($P > 0.05$).

207

208 Figure 1 shows the 1st trial and second trial for the 3 types of target luminance,

209 against the mean square root blind spot scotoma area.

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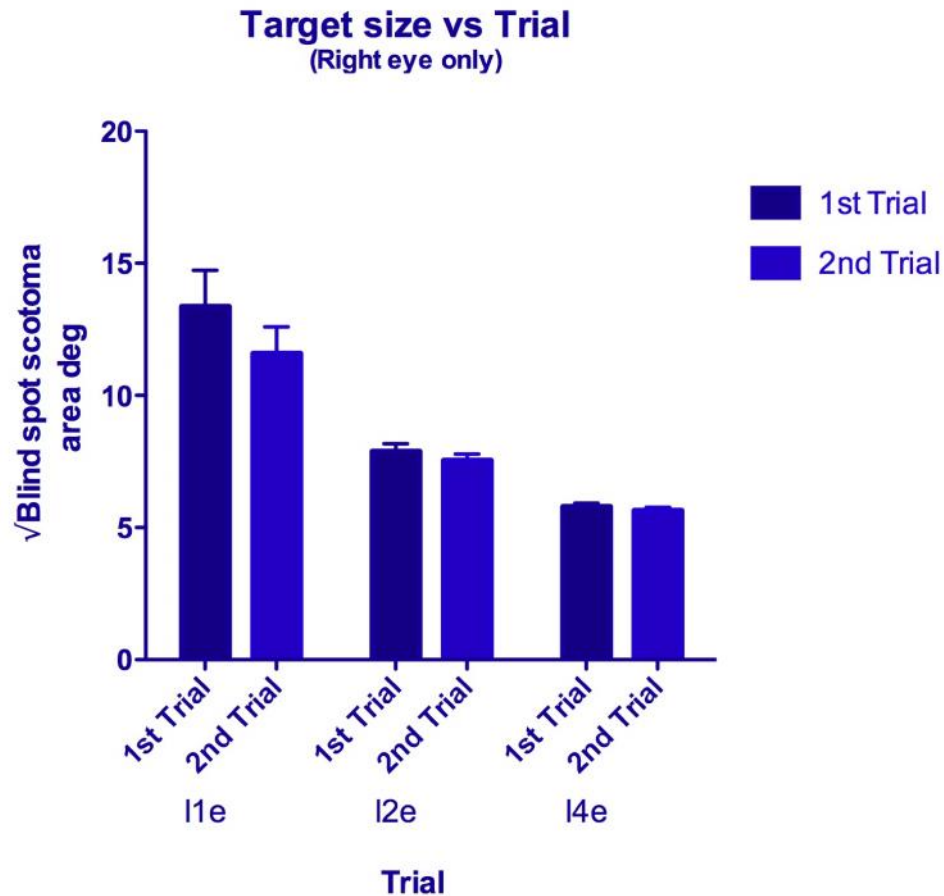
216

217 Figure 1 showing 1st trial (dark blue) and second trial (light blue) for the 3 types of

218 target luminance on the x axis, against the mean square root blind spot scotoma

219 area on the y axis

220



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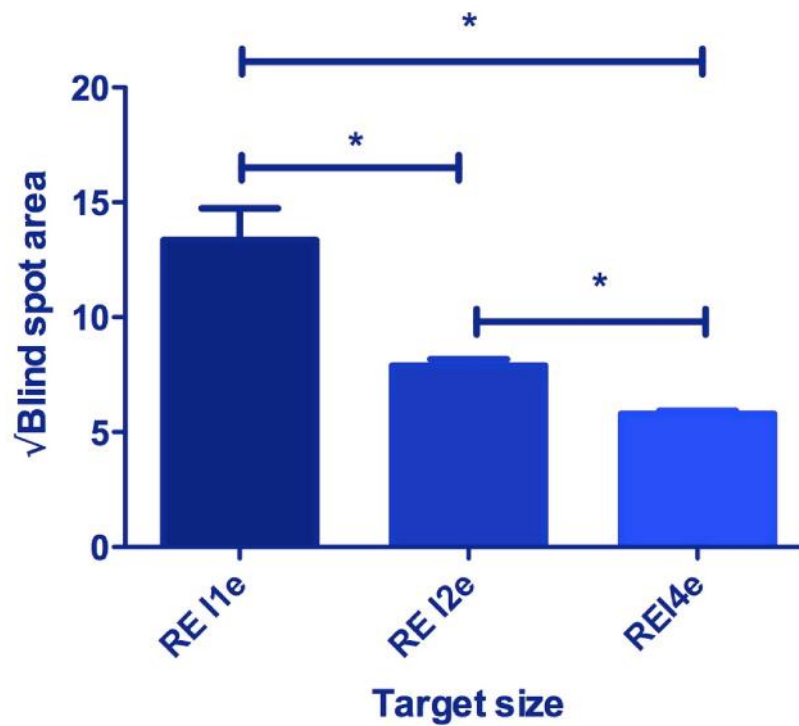
223 Further post-hoc analyses were conducted to explore where significant
 224 differences occurred between target luminosities. Again these were corrected
 225 using Bonferroni adjustment for type I error. Figure 2 shows the square root of
 226 the blind spot scotoma in degrees for the RE, significant differences occurred
 227 between all target luminosities and are illustrated with an asterisk (* =
 228 Statistically significant).

229

230 Figure 2. Target size and square rooted blind spot scotoma area in deg for the
 231 RE.

232

Target size and blind spot scotoma area right eye only



233

234 * = Statistically significant

235

236 3.2 Peripheral field

237

238 The mean RE area for the peripheral visual field using the target stimulus I4e
 239 was $10446.6 \pm 1058.2 \text{ deg}^2$, mean LE area was $10466.2 \pm 1120.7 \text{ deg}^2$. The
 240 mean peripheral area using the target stimulus I2e was $2920.6 \pm 755.6 \text{ deg}^2$
 241 with the RE and $3013.7 \pm 824.3 \text{ deg}^2$ with the LE. No second trials were
 242 conducted on the peripheral field.

243

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

249

250 There were no significant differences between the RE and LE, therefore post-
 251 hoc paired t-test analyses were conducted between the target stimulus of the
 252 RE only. These were corrected using Bonferroni adjustment for type I error.
 253 Significant differences occurred between the two target stimuli ($P = < 0.0001$,
 254 Two-tailed, $t=31.3$ $df=17$) indicated by the asterisk on the graph seen in Figure
 255 3.

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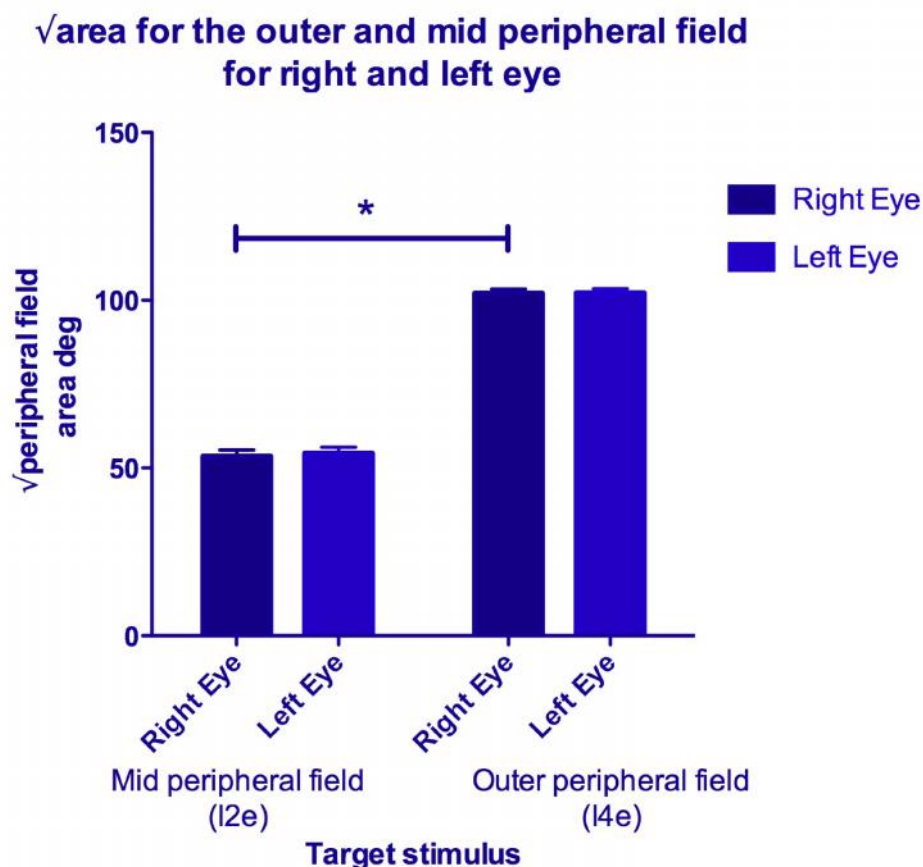
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265 Figure 3. Visual field area for the I2e and I4e targets, right (dark blue) and left
 266 eye (light blue).



267

268

269 3.3 Blind spot Scotoma Repeatability

270

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

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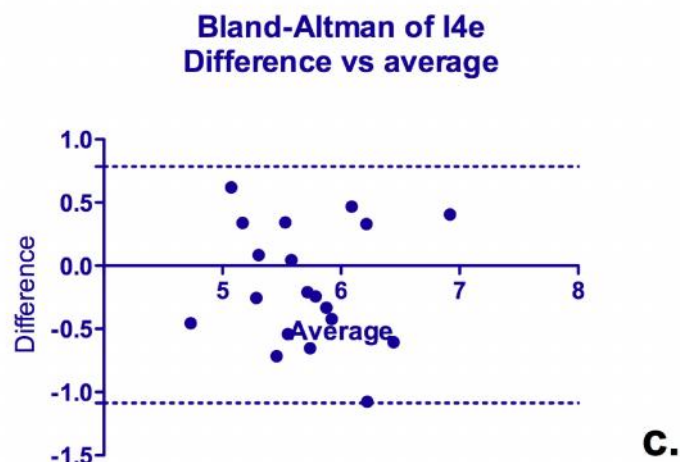
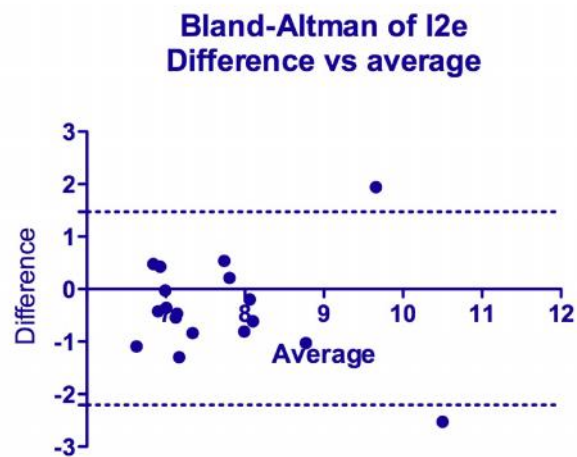
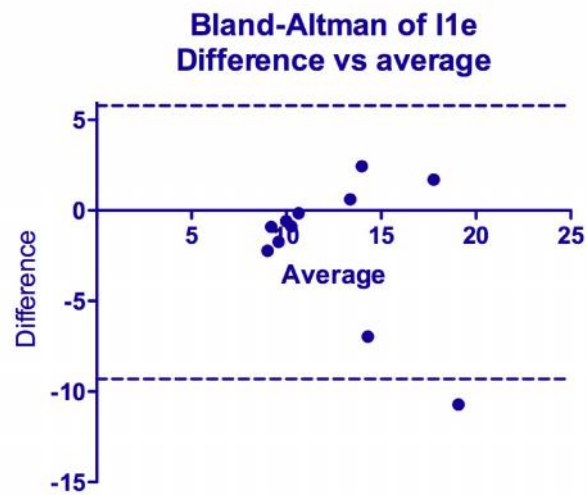
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301 Figure 4. Bland-Altman plots for each of the different target stimulus also
302 demonstrating the 95% Limits of Agreement.



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304

305 The I1e target shows the largest amount of bias (-1.764), this reduces with the

306 I2e (-0.368) and reduces still further with the I4e (-0.151). The SD of the bias

307 follows this same pattern, the I1e has a very large SD of the bias (3.852), this
 308 reduces dramatically with the I2e (0.938) and then again with the I4e (0.477).
 309 Out of all the targets the I4e has the closest mean difference to zero the I4e
 310 also has the highest precision as shown by the SD.

311

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

316

317 **4.0 Discussion**

318

319 **4.1 Blind spot scotoma size and target luminosity.**

320

321 In this study the size of the blind spot scotoma changed depending on the
 322 luminosity of the stimulus target used, this could be for a number of reasons.
 323 One explanation could be related to the blind spots amblyopic zone. The blind
 324 spot has an area of absolute blindness, and around this area is an amblyopic
 325 zone that is seen to increase when plotted with smaller targets⁵. In this study
 326 the target size was small and remained constant, luminosity was the factor
 327 that varied. This study shows the amblyopic zone may also be extended when
 328 using fainter targets.

329

330 Bek⁶ found a link between the stimulation target size and blind spot scotoma
 331 size using static perimetry and interpreted this finding to be a result of “light

332 scattering in the refractive media of the eye.” Bek found that if a large target
333 was projected within the optic nerve head (an area that the target should not
334 be seen), the target could actually be sensed by the surrounding retina due to
335 this light scattering. It could also be that target luminosity may also be linked
336 to this phenomenon, the brighter the stimulus, the more likely this scattered
337 light is to be picked up by the surrounding retina.

338

339 In summary if the target size increases (with constant luminance), or the
340 luminosity increases (with constant target size), the measurement of the
341 scotoma reduces. This may be due to light scattering around the optic nerve
342 heads amblyopic zone with larger or brighter lights being picked up by the
343 surrounding retina. From a clinical perspective when monitoring the progress
344 of a disease through repeated measures of the blind spot scotoma it is
345 essential that the target size and luminosity remain constant or results cannot
346 be compared.

347

348 The ability to correct the visual field for the participants reaction time (RT) is a
349 new concept in mainstream perimetry, allowing greater accuracy when
350 assessing a participants blind spot scotoma. When an RT is accounted for the
351 size of the blind spot scotoma is reduced by an amount proportional to that of
352 the reaction time. If a participants reaction time is particularly slow the blind
353 spot is no longer exaggerated as a result of the reaction time when this
354 correction is applied.

355

Dolderer⁷ 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.

367

368 **4.2 Peripheral Field**

369

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 Goldmann⁸. The main purpose of recording this is to establish a mean outer peripheral field for both targets I2e and I4e that can be used as reference.

378

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

381 allowing for a larger sample size and a more in depth analysis to be
 382 undertaken. The analysis of blind spot scotomas may be further augmented
 383 through application of mixed methods research, bringing together quantitative
 384 and qualitative elements. In particular qualitative research may aid in
 385 developing effective protocol with regards to patient preference and feedback.

386

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

393

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

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403 **5.0 Conclusion**

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

412

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

415

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

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428 Table 3. Table showing normative data for differing target luminosities of the
429 blind spot scotoma area and the mean peripheral field area in degrees² as
430 measured on the Octopus 900 (RE only).

Blind Spot Target Stimulus	Area in deg ²
I1e	197.6±152.8
I2e	63.6±21.7
I4e	33.9±6.8
Peripheral Field	
I2e	2920.6±755.6
I4e	10446.6± 1058.2

431
432 In conclusion when monitoring the progress of a disease through repeated
433 measures of the blind spot scotoma it is essential that the target size and
434 luminosity remain constant. The results of this study show that from the
435 targets examined, the I4e is the most appropriate target to use when
436 monitoring the size of the blind spot, it was the only target that could be seen
437 by all participants and it displayed the least bias on repeated measures and a
438 refraction of those undertaking kinetic visual perimetry is recommended to
439 ensure that under or over corrected prescriptions do not unjustly influence the
440 size of the blind spot scotoma⁹.

441
442 This study provides normative data of the size of the blind spot scotoma on
443 the Octopus 900 and provides pilot data allowing clinicians to evaluate their
444 current practice, adjusting protocol in order to better monitor the size of the

445 blind spot scotoma; this in turn benefits both patients and clinicians in the
446 monitoring of the blind spot.

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