CLINICAL AND EXPERIMENTAL OPTOMETRY
in partnership with Optometry Australia

The effect of viewing distance on responses to the Pattern Glare Test

Journal:	*Clinical and Experimental Optometry*
Manuscript ID:	CEOptom-14-285-OP.R2
Manuscript Type:	Original Research Paper
Date Submitted by the Author:	n/a
Complete List of Authors:	Monger, Laura; Anglia Ruskin University, Department of Vision and Hearing Sciences Shah, Dhruvi; Anglia Ruskin University, Department of Vision and Hearing Sciences Wilkins, Arnold; University of Essex, Department of Psychology Allen, Peter; Anglia Ruskin University, Department of Vision and Hearing Sciences and Vision and Eye Research Unit
Keywords:	pattern glare, accommodation, vergence, spatial frequency

Title: The effect of viewing distance on responses to the Pattern Glare Test

Running title: Test distance and pattern glare

Authors: Laura J Monger B Optom MCOptom*, Dhruvi Shah B Optom*, Arnold J Wilkins BSc DPhil FCOptom†, Peter M Allen BSc PhD FCOptom*

* Department of Vision and Hearing Sciences and Vision and Eye Research Unit, Anglia Ruskin University, East Road, Cambridge, CB1 1PT, UK

† Department of Psychology, University of Essex, Wivenhoe Park, Colchester, CO4 3SQ, UK

Email address of corresponding author: peter.allen@anglia.ac.uk

Background: We investigated whether symptoms of pattern glare were affected by viewing distance, as distinct from spatial frequency, because of an association between symptoms and anomalies of accommodation and vergence.

Methods: One hundred young adults viewed gratings with spatial frequencies of 0.3, 2.3 and 9.4 cycles per degree (cpd) at four test distances (0.4, 0.8, 1.6 and 3.2m). Participants were asked to grade the presence of 15 symptoms of visual perceptual distortions and discomfort, on a scale from 0 (no symptoms) to 10 (maximum perceptual and somatic symptoms).

Results: The viewing distance did not affect the nature and strength of symptoms when viewing gratings with similar spatial frequency. The symptoms increased with spatial frequency ($p<0.008$ for all comparisons).

Conclusion: The symptoms from the Pattern Glare Test do not appear to be modulated by the changes in accommodation and vergence associated with viewing distance, at least in an unselected sample of students. The highest spatial frequency of the current Pattern Glare Test was 9.4cpd at 0.4m, and this is insufficiently high to measure the reduction in symptoms at high spatial frequencies. If assessing relative aversion to gratings of different spatial frequencies, it may be useful to increase the testing distance to 0.6m so as to increase the spatial frequency of the third grating to 14.2cpd.

Key words: Pattern glare, accommodation, vergence, spatial frequency, viewing distance

Regular stationary patterns of lines can cause perceptual distortions and discomfort, sometimes referred to as pattern glare. The distortions are more commonly reported by individuals who suffer frequent severe headaches and migraine.[1,2] The distortions increase in the 24 hours before a headache, and predominate interictally in the visual field affected by aura. [3]

Susceptibility to pattern glare is assessed in optometric practice by using the Pattern Glare Test (i.O.O. Sales Ltd, London, UK, 2001).[4,5] The Pattern Glare Test consists of three, high-contrast, square wave gratings with a duty cycle of 50%, which are viewed binocularly. The gratings have spatial frequencies of 0.4, 4.4 and 13.3 cycles/cm. When held at 0.4m (the recommended viewing distance[4,5]) the patterns therefore have spatial frequencies of 0.3 cycles per degree (cpd), 2.3cpd and 9.4cpd.[5] The original test instructions quoted approximate spatial frequencies for each grating (0.5cpd, 3cpd and 12cpd), which are closer to the frequencies obtained at a viewing distance of 0.5m.[6] These estimations led to some inaccuracies in the values cited in the literature. The exact spatial frequencies for different viewing distances were provided in the second edition of the test instructions.[5]

To date, the Pattern Glare Test has been used clinically to assess the greater susceptibility to visual stress (perceptual distortions and associated discomfort) in symptomatic individuals, particularly those with migraine. The test has also been used

to identify those individuals whose reading speed or symptoms are likely to benefit from coloured filters. [1,7-11]

Neurological mechanisms for the distortions have been proposed. Wilkins et al.[12] drew attention to the similarities between the patterns that induce discomfort and distortion and those that evoke seizures in patients with photosensitive epilepsy. Subsequently it has been shown, that in individuals with migraine, the visual cortex is hyperexcitable,[3,13,14,] and it is possible that the distortions and discomfort reflect this hyperexcitability.[15,16,]

On the other hand, it is also possible that the distortions arise from peripheral factors. Campbell, Robson and Westheimer[17] argued that perceptual instability may arise from accommodative fluctuations. Accommodative fluctuations have been reported to be greater in individuals who experience visual distortions and benefit from coloured filters.[18] The accommodative lag is greater in individuals who report visual discomfort[19,20,] and pattern glare,[21] although these differences may take time to appear and be more apparent at close viewing distances.[20]

Close viewing distances affect not only accommodation but also vergence. Convergence insufficiency is known to be associated with symptoms of discomfort and distortions.[22,23,] Viewing distance might therefore be expected to affect the distortions and discomfort reported in the Pattern Glare Test because of changes in accommodation and/or vergence.

The aim of this study was to investigate the effect of viewing distance on the symptoms of pattern glare. It was hypothesised that there would be more symptoms of pattern glare in response to the nearer targets, which required greater accommodation and convergence. The symptom list used in this study included somatic symptoms because these are often reported in addition to perceptual distortions.

Methods

Participants

One hundred young adults (37 male and 63 female), aged between 17 and 31 years (mean= 21.4, SD= 2.3) participated in the study. The participants were an opportunistic sample of young adult undergraduates reading Optometry and Ophthalmic Dispensing at Anglia Ruskin University, Cambridge. Two participants had a diagnosis of dyslexia, one of whom currently used coloured filters, as did one participant without dyslexia. Eight participants had a clinical diagnosis of migraine. One individual with a personal history of unexplained seizures was excluded. All participants gave informed consent after a written and verbal explanation of the research study. All procedures conformed to the tenets of the Declaration of Helsinki and were approved by the Anglia Ruskin University Ethics Committee.

Procedure

Each of the three gratings in the Pattern Glare Test[5] were laser printed on matt card from the original electronic files actual size and at twice, four times and eight times that

size, so as to create targets for use at a viewing distance of 0.8m, 1.6m and 3.2m, in addition to 0.4m. The spatial frequencies of the gratings were 0.3cpd, 2.3cpd and 9.4cpd at a viewing distance of 0.4m, equivalent to the gratings in the second edition of the Pattern Glare Test.

The test battery was administered by two examiners without awareness of the test results obtained by the other examiner.

Examiner 1: All of the participants were refracted and wore their optimal distance vision refractive correction throughout the entire procedure. The Intuitive Overlays pack (i.O.O. Sales Ltd, London, UK) was used to identify participants' preferences for coloured overlays, in accordance with the instructions.

Examiner 2: The three spatial frequencies were presented in random order, once at each viewing distance, and the viewing distances were also presented in a random order. The participants were asked to look at the fixation spot in the centre of each grating. After 5 seconds, participants were read a list of 15 symptoms (shown in Table 1). The list of symptoms was that used by Allen et al.[21] with the addition of 'fading'. Participants were asked to grade each symptom in order, on a scale from 0 to 10, where 0 meant they experienced no discomfort (no experience of the symptom) and 10 meant that the symptom was very uncomfortable.

Insert Table 1 here

Results

The number of perceptual distortions reported (red, green, blue, yellow, bending, blurring, shimmering, flickering, fading, and shadowy shapes) were summed to give a perceptual score (maximum of 10) for each participant. The number of somatic symptoms reported (pain, discomfort, nausea, dizziness, and unease) were summed to give a somatic score (maximum of 5) for each participant. The data were not normally distributed, so non-parametric tests were used.

The average number of perceptual and somatic symptoms for each of the three spatial frequencies and four viewing distances are shown in Tables 2 and 3 respectively.

Insert Tables 2 and 3 about here

Figure 1 shows how many participants reported each symptom in response to the 0.3cpd, 2.3cpd and 9.4cpd gratings presented at 0.4m. 43/100 participants reported at least one symptom of pain, discomfort, nausea, dizziness or unease when viewing the targets at 0.4m.

Insert Figure 1 here

The perceptual score was compared for each spatial frequency across the four viewing distances. There was no significant effect of test distance on the perceptual illusions for the 0.3cpd targets ($\chi^2(9)=2.17$, p=0.99), 2.3cpd targets ($\chi^2(15)=7.97$, p=0.93) or 9.4cpd targets ($\chi^2(21)=13.9$, p=0.88). There was similarly no effect of test distance on the somatic scores for the 0.3cpd targets ($\chi^2(3)=0.82$, p=0.84), 2.3cpd targets ($\chi^2(6)=3.54$, p=0.74) or 9.4 targets ($\chi^2(9)=6.31$, p=0.71).

There was an effect of spatial frequency on the perceptual score for targets viewed at 0.4m ($\chi^2(6)=104.1$, p<0.0001). Fisher Exact Probability Test was used to compare the presence/absence of distortions for each pair of targets. The number of perceptual distortions increased with spatial frequency (0.3cpd; mean=0.5, SD=0.96, 2.3cpd; mean=2.6, SD=2.63, 9.4cpd; mean=3.7, SD=2.45, p<0.002 for all comparisons, less than the Bonferroni adjusted p-value of 0.017. The increase in average number of symptoms with spatial frequency was also found to targets at 0.8m, 1.6m and 3.2m, p<0.005).

There was also an effect of spatial frequency on the somatic score for targets viewed at 0.4m ($\chi^2(2)=26.2$, p<0.0001). Post-hoc tests identified a significant difference between the 0.3cpd (mean=0.15, SD=0.59) and 2.3cpd targets (mean=0.63, SD=1.18) (Fisher's Exact, p<0.0001) and between the 0.3cpd and 9.4cpd targets (mean=0.81, SD=1.26) (Fisher's Exact, p<0.0001). There was no significant difference between the number of somatic symptoms reported to the 2.3cpd and 9.4cpd targets (Fisher's Exact, p=0.29). The same significant relationships were found for the targets at 0.8m ($\chi^2(2)=33.8$,

p<0.0001), 1.6m ($\chi^2(2)=34.1$, p<0.0001) and 3.2m ($\chi^2(2)=37.6$, p<0.0001), including the non-significant difference between the 2.3cpd and 9.4cpd targets using Fisher's exact tests.

The above analyses were repeated based on the grades of each symptom, and gave similar findings.

Using the original Pattern Glare Test list of symptoms

To allow the present work to be compared with the norms in the literature[6], and to improve the relevance for practitioners who use the test in the way recommended in the instructions, the symptoms were scored as indicated in the Pattern Glare Test instruction manuals.[4,5] The list of symptoms in the Pattern Glare Test manuals[4,5] (and used by Evans and Stevenson[6]) were: colours, bending of lines, blurring of lines, shimmering/flickering, fading, shadowy shapes, others (summed to give a maximum pattern glare score of 7 for each pattern). Reports of shimmering and flickering in this study were combined as in the original list, and only counted as present once. The presence of any colour in this study was counted only once in the "colour" symptom. When the symptoms were considered as in the original list, there was a statistically significant difference in the average number of symptoms reported in response to the 0.3cpd (mean=0.53, SD=0.99), 2.3cpd (mean=2.2, SD=2.04) and 9.4cpd (mean=3.37, SD=2.00) targets, when presented at 0.4m ($\chi^2(6)=111.8$, p<0.0001). Post hoc analysis showed that there was an increase in the average number of symptoms with increasing target spatial frequency (Fisher's Exact, p<0.002 for all comparisons). The 95th

percentiles for the three gratings were 3, 6 and 7 respectively. The mean 2.3-9.4cpd difference (equivalent to the "3-12 difference" discussed by Evans and Stevenson[6]) was -1.17 (SD=1.52). The increase in number of symptoms with increasing spatial frequency was also present at 0.8m, 1.6m and 3.2m (Fisher's Exact, $p<0.008$ for all comparisons).

The score, considered as in the original Pattern Glare Test list (maximum of 7 symptoms), was compared for each spatial frequency across the four viewing distances. There was no significant effect of test distance on the score for the 0.3cpd targets ($\chi^2(9)=4.05$, $p=0.91$), 2.3cpd targets ($\chi^2(18)=14.0$, $p=0.73$) or 9.4cpd targets ($\chi^2(18)=25.9$, $p=0.10$).

When the symptoms were considered as in the original Pattern Glare Test list, excluding the symptoms in the "other" category, there remained a statistically significant difference in the average number of symptoms reported to the 0.3cpd (mean=0.46, SD=0.90), 2.3cpd (mean=1.9, SD=1.79) and 9.4cpd (mean=3.0, SD=1.79) targets, when presented at 0.4m ($\chi^2(4)=101.1$, $p<0.0001$). Post hoc analysis showed that there also remained an increase in the average number of symptoms with the increase in target spatial frequency (Fisher Exact, $p<0.002$ for all comparisons).

Effect of the order of testing

To investigate the order of testing, the results of participants who viewed the 0.4m targets in order of increasing spatial frequency (the original order, according to the Pattern Glare Test instructions)[4,5] were compared to those who viewed the targets in the reverse order. The original Pattern Glare Test list of symptoms was used, as described above. The number of symptoms was not affected by the order of target presentation ($p=0.85$, Fisher's Exact test).

Discussion

Neither the average number of perceptual symptoms nor the average number of somatic symptoms was affected by viewing distance (0.4m, 0.8m, 1.6m and 3.2m). There was nevertheless a large effect of spatial frequency (0.3cpd, 2.3cpd or 9.4cpd), which was similar for both categories of symptoms and all four viewing distances. This suggests that symptoms of pattern glare are not influenced by greater demands on accommodation or vergence at close viewing distances, and is consistent with a predominantly neurological basis for the effects, as previously proposed.[12]

It should be noted that the prevalence of binocular vision anomalies and accommodative dysfunction in this study was unknown. There is a lack of epidemiological studies concerning the prevalence of these conditions[24], but 5% has been estimated.[25] In a sample of symptomatic patients, the prevalence was larger (22%).[26] Since the present population was not selected as being symptomatic in everyday life, the presence of these abnormalities was likely to be small. A sample of symptomatic patients, likely to have a

greater prevalence of binocular vision and accommodative anomalies, may have yielded different results.

The current study consistently demonstrates that participants scored higher (had more symptoms) on the highest spatial frequency target at all viewing distances. This was also reported by Evans and Stevenson for normal participants.[6] Conlon et al.[27] reported that participants with low and moderate levels of visual discomfort found gratings with 8cpd and 12cpd more unpleasant to observe than those with a spatial frequency of 4cpd. On the other hand, individuals with high levels of visual discomfort found 4cpd gratings more aversive than those with higher spatial frequency.[12,27] The most aversive spatial frequencies therefore appear to depend on the overall level of visual discomfort that the participant experiences. Although it remains possible that individuals with low levels of visual discomfort are more affected by illusions attributable to mechanisms that involve accommodation/vergence and less by neurological mechanisms, there was nothing to suggest that the nature of the symptoms reported varied with viewing distance.

Although there was no effect of viewing distance in this study, which controlled for spatial frequency, varying the distance at which the Pattern Glare Test is held has a large effect on the spatial frequency of the gratings and will influence the reports of symptoms for this reason. Evans and Stevenson[6] suggest an alternative method of scoring the Pattern Glare Test where the score for the highest spatial frequency target is subtracted from the score for the mid-spatial frequency target (the "3-12 difference") The normal value for the difference (mean = -1.17, SD=1.52, 95th Percentile=+1) and

the absence of test order effect on the difference were the same as found by Evans and Stevenson.[6]

Gratings with higher spatial frequency can be obtained by increasing the viewing distance, and this may provide a preferable method of assessing the relative aversion to gratings with low- mid- and high spatial frequencies, as suggested by the work of Conlon. At a viewing distance of 0.6m the spatial frequencies of the current test are 0.4, 3.4 and 14.2cpd, and suitable for exploration of the effects of gratings with spatial frequencies that are *both* below (0.4cpd), *and* above (14.2cpd) those at which illusions and discomfort are maximally likely (3-4cpd). The smaller field size at this viewing distance will reduce the symptoms overall. The test norms will need adjustment for this viewing distance.

The symptoms list in the Pattern Glare Test normally consists of a maximum of seven items (colours, bending of lines, blurring of lines, shimmering/flickering, fading, shadowy shapes, others). In the present study, symptoms of pain, discomfort, nausea, dizziness and unease were included, increasing the potential sensitivity of the test. Discomfort and unease were commonly reported, and these are of obvious importance when the test is used in clinical practice. However, the number of these somatic symptoms reported did not differ significantly for the 2.3cpd and 9.4cpd targets, whereas the number of perceptual illusions increased. Whilst the additional questions concerning somatic symptoms used in this study might potentially have improved the sensitivity of the test, there was little in the data to suggest that this was in fact the case.

Conflicts of interest

Arnold Wilkins and Bruce Evans developed the Pattern Glare Test, which is published by i.O.O. Sales. They receives royalties on sales.

Funding sources

This research was undertaken as part of a PhD scholarship from The College of Optometrists.

References

1. Harle DE, Shepherd AJ, Evans BJW. Visual stimuli are common triggers of migraine and are associated with pattern glare. *Headache* 2006; 46:1431-1440.

2. Marcus DA, Soso MJ. Migraine and stripe-induced visual discomfort. *Arch Neurol* 1989; 46:1129-1132.

3. Wilkins AJ. Visual stress. Oxford: Oxford University Press, 1995.

4. Wilkins AJ, Evans BJW. Pattern glare test instructions. London: IOO Sales Ltd, 2003.

5. Wilkins AJ, Evans BJW. Pattern glare test instructions. London: IOO Sales Ltd, 2012.

6. Evans BJW, Stevenson SJ. The Pattern Glare Test: a review and determination of normative values. *Ophthalmic Physiol Opt* 2008; 28:295-309.

7. Evans BJW, Cook A, Richards IL, Drasdo N. Effect of pattern glare and colored overlays on a stimulated-reading task in dyslexics and normal readers. *Optom Vis Sci* 1994; 71:619-628.

8. Evans BJW, Busby A, Jeanes R, Wilkins AJ. Optometric correlates of Meares-Irlen Syndrome: a matched group study. *Ophthalmic Physiol Opt* 1995; 15:481-487.

9. Evans BJW, Wilkins AJ, Brown J, Busby A, Wingfield A, Jeanes R, Bald J. A preliminary investigation into the aetiology of Meares-Irlen Syndrome. *Ophthalmic Physiol Opt* 1996; 16:286-296.

10. Evans BJW, Patel R, Wilkins AJ. Optometric function in visually sensitive migraine before and after treatment with tinted spectacles. *Ophthalmic Physiol Opt* 2002; 22:130-142.

11. Hollis J, Allen PM. Screening for Meares-Irlen sensitivity in adults: can assessment methods predict changes in reading speed? *Ophthalmic Physiol Opt* 2006; 26:566-571

12. Wilkins AJ, Nimmo-Smith I, Tait A, McManus C, Della Sala S, Tilley A, Arnold K, Barrie M, Scott S. A neurological basis for visual discomfort. *Brain* 1984; 107:989-1017.

13. Welch KM. Brain hyperexcitability: the basis for antiepileptic drugs in migraine prevention. *Headache* 2005; 45:S25-S32.

14. Aurora SK, Wilkinson F. The brain is hyperexcitable in migraine. *Cephalalgia* 2007; 27:1442-1453.

15. Huang J, Zong X, Wilkins AJ, Jenkins B, Bozoki A, Cao Y. fMRI evidence that precision ophthalmic tints reduce cortical hyperactivation in migraine. *Cephalalgia* 2011; 31: 925-36.

16. Haigh SM, Barningham L, Berntsen M, Coutts LV, Hobbs EST, Irabor J, Lever EM, Tang P, Wilkins AJ. Discomfort and the cortical haemodynamic response to coloured gratings. *Vision Res* 2013; 89:47-53

17. Campbell FW, Robson JG, Westheimer G. Fluctuations of accommodation under steady viewing conditions. *J Physiol* 1959; 145:579-594.

18. Simmers AJ, Gray LS, Wilkins AJ. The influence of tinted lenses upon ocular accommodation. *Vision Res* 2001; 41:1229-1238.

19. Chase C, Tosha C, Borsting E, Ridder III W. Visual discomfort and objective measures of static accommodation. *Optom Vis Sci* 2009; 86:883-889.

20. Tosha C, Borsting E, Ridder III W, Chase C. Accommodation response and visual discomfort. *Ophthalmic Physiol Opt* 2009; 29:625-633.

21. Allen PM, Hussain A, Usherwood C, Wilkins AJ. Pattern-related visual stress, chromaticity, and accommodation. *Invest Ophthalmol Vis Sci* 2010; 51:6843-6849.

22. Evans BJW. Pickwell's Binocular Vision Anomalies, 5th ed. Oxford: Butterworth Heinemann Elsevier, 2007.

23. Allen PM, Evans BJW, Wilkins AJ. Vision and Reading Difficulties. London: Ten Alps Creative, 2010.

24. Cacho-Martinez P, Garcia-Munoz A, Ruiz-Cantero MT. Do we really know the prevalence of accommodative and nonstrabismic binocular dysfunctions? *J Optom* 2010; 3:185-197

25. Stidwill D. Clinical survey: epidemiology of strabismus. *Ophthalmic Physiol Opt* 1997; 17:536-539.

26. Lara F, Cacho P, Garcia A, Megias R. General binocular disorders: prevalence in a clinic population. *Ophthalmic Physiol Opt* 2001; 21:70-74

27. Conlon E, Lovegrove W, Barker S, Chekaluk E. Visual discomfort: the influence of spatial frequency. *Perception* 2001; 30:571-582.

Figure 1. Number of participants who reported each symptom to the 0.3cpd, 2.3cpd and 9.4cpd targets presented at 0.4m.

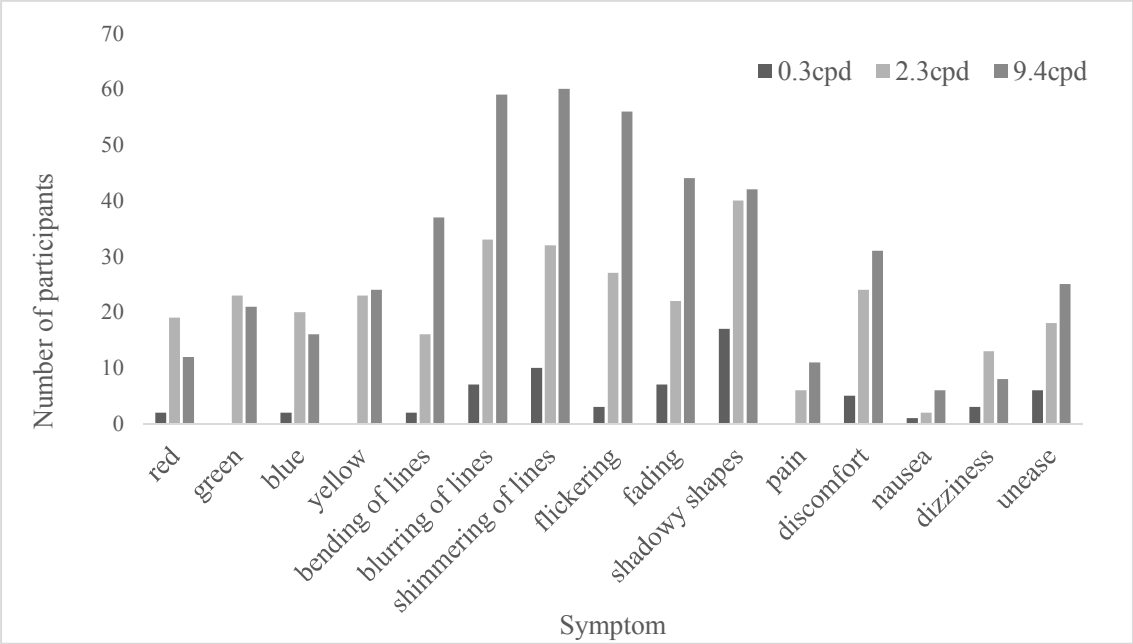

Table 1. List of symptoms used in the test procedure

Symptoms
Red
Green
Blue
Yellow
Bending of lines
Blurring of lines
Shimmering of lines
Flickering
Fading
Shadowy shapes among the lines
Pain
Discomfort
Nausea
Dizziness
Unease

Table 2. Average number of perceptual symptoms (SD) reported for each target at the four test distances.

Distance (m)	0.3cpd	2.3cpd	9.4cpd
0.4	0.50 (0.96)	2.55 (2.63)	3.71 (2.45)
0.8	0.59 (1.14)	2.49 (2.61)	3.55 (2.59)
1.6	0.57 (1.32)	2.50 (2.68)	3.49 (2.38)
3.2	0.52 (0.97)	2.34 (2.78)	3.31 (2.71)

Table 3. Average number of somatic symptoms (SD) reported for each target at the four test distances.

Distance (m)	0.3cpd	2.3cpd	9.4cpd
0.4	0.15 (0.59)	0.63 (1.18)	0.81 (1.26)
0.8	0.10 (0.44)	0.55 (0.91)	0.81 (1.23)
1.6	0.14 (0.57)	0.61 (0.99)	0.86 (1.21)
3.2	0.11 (0.51)	0.46 (0.95)	0.84 (1.23)