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ORIGINAL ARTICLE

A Delphi study to develop practical diagnostic guidelines for visual stress (pattern-related visual stress)

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KEYWORDS
Delphi study;
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Abstract
Purpose: Visual stress (VS) is characterised by symptoms of visual perceptual distortions and eyestrain when viewing text, symptoms that are alleviated by individually prescribed coloured filters. A recent review supports the existence of VS and its treatment, but noted that controversy remains, in part due to inconsistencies in the diagnosis of the condition. The present paper reviews the diagnostic criteria for VS in the literature and reports a Delphi analysis of the criteria currently used in clinical practice.
Methods: Twenty-six eyecare practitioners were invited to participate in a Delphi study. They were selected because they were frequent prescribers of precision tinted lenses. In the first round they were sent a list of the indicators for which there is literature to suggest a relevance in the diagnosis of VS. The practitioners were invited to rank the indicators and add any additional criteria they use in diagnosis. In the second round a revised list was circulated, including items added from the responses in the first round.
Results: The respondents included optometrists, orthoptists and opticians. In the first round the response rate was 85%. Ninety-one percent of those who participated in the first round also responded in the second round. Strong indicators in the second round included the symptom of words moving when reading, voluntary use of an overlay for a prolonged period, improved performance of $\geq$15% with an overlay on the Wilkins Rate of Reading test, and an abnormally high score on the Pattern Glare Test.

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Conclusions: The strongest diagnostic criteria are combined in a diagnostic tool. This is proposed as a guide for clinical practice and further research.

PALABRAS CLAVE
Estudio Delphi;
Estrés visual;
Estrés visual relacionado con patrones;
Lectura

Estudio Delphi para el desarrollo de pautas diagnósticas para el estrés visual (estrés visual relacionado con patrones)

Resumen
Objetivo: El estrés visual (EV) se caracteriza por síntomas de distorsión perceptual visual y astenopía, que pueden aliviarse mediante filtros coloreados de prescripción individual. Una revisión reciente respalda la existencia de EV y su tratamiento, aunque hay que resaltar que persiste la controversia, debido en parte a las inconsistencias en cuanto a diagnóstico. El presente documento revisa los criterios diagnósticos del EV en la literatura, y reporta un análisis Delphi sobre los criterios utilizados en la actualidad en la práctica clínica.
Métodos: Se invitó a participar en un estudio Delphi a veintiséis facultativos. Éstos fueron seleccionados debido a su elevada prescripción de lentes tintadas de precisión. En la primera ronda, se les envió un listado de los indicadores a los que la literatura aporta relevancia para el diagnóstico del EV. Se solicitó a los facultativos que clasificaran los indicadores, y que añadieran cualquier criterio adicional que ellos utilizaran en su diagnóstico. En la segunda ronda, se hizo circular un listado revisado, incluyendo los ítems añadidos a partir de las respuestas de la primera ronda.
Resultados: Entre los facultativos participantes se hallaban optometristas, ortoptistas y ópticos. En la primera ronda el índice de respuesta fue del 85%. El 91% de los participantes en la primera ronda aportaron también sus respuestas en la segunda. Los indicadores sólidos en la segunda ronda incluyeron: síntoma de movimiento de las palabras al leer, uso voluntario de filtros durante un periodo prolongado, mejora del desempeño de $\geq$15% en el índice de la prueba de lectura de Wilkins con el uso de filtros, y puntuación anormalmente elevada en la prueba PatternGlare.
Conclusiones: Se combinan los criterios diagnósticos más sólidos en una herramienta diagnóstica. Ello se propone como pauta en la práctica clínica y la investigación futura.

Introduction

Visual stress (VS) is used in this manuscript to describe a syndrome characterised by symptoms of asthenopia and visual perceptual distortions that occur principally when reading and that are alleviated by individually selected coloured filters. VS is controversial.[1–3] The latest estimates are that VS is present in about 20% of people with dyslexia, although visual stress and dyslexia are different conditions.[4]

A neurological theory for VS was originally proposed in 1984 on the basis that the visual stimuli that evoke discomfort are generally those that also induce seizures in patients with photosensitive epilepsy.[5,6] A neural mechanism for VS has found support in studies showing that the visual stimuli that induce discomfort also induce a large haemodynamic response, both in absolute terms, and relative to the response to comfortable stimuli.[7] Individuals who are particularly susceptible to discomfort exhibit an abnormally large haemodynamic response.[8,9] The large haemodynamic response is consistent with neural models that show a larger neural response to these stimuli, one in which the sparseness of firing within the network is reduced, suggesting an inefficient cortical processing of uncomfortable stimuli.[10] This interpretation is in turn consistent with evidence that the mathematical properties of uncomfortable stimuli differ from those of natural scenes.[11–14] Natural scenes are those that the visual system presumably evolved to process efficiently.

Text provides a visual stimulus that is un-natural on account both of the spatial periodicity of the lines of text[15] and of the vertical strokes of the letters, which compromise vergence.[16] Reducing the spatial periodicity of the lines using a typoscope increases comfort.[6] Reducing the periodicity of the vertical strokes improves reading speed.[17] It is therefore to be expected that some individuals will find reading visually stressful.

In the literature, there are several behaviours or signs that have been used as indicators of VS. These are listed in Table 1.

Anecdotally, the indicators in Table 1 are all positively associated one with another, although sometimes weakly. Few of the many pairwise associations have been

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Table 1 Symptoms and signs that have been used as indicators of visual stress.

	Symptom or sign
1	Perceptual distortion, particularly letters appearing to move
2	Headaches, discomfort or pain, particularly when reading
3	Perceptual distortion and/or discomfort when observing gratings (Pattern Glare test)
4	Reduction in distortions or symptoms of discomfort or pain when using coloured filters
5	Long-term voluntary use of coloured filters (without prompting)
6	Increase with coloured filters in the speed of reading randomly ordered common words
7	Improved visual search performance with coloured filters
8	Improved reading of conventional prose with coloured filters

studied formally. In one study, the various illusions of shape, motion and colour seen in striped patterns were shown to resemble those seen in text.[15] They were usually associated with discomfort, and sometimes with pain.[5] In another study, the individual susceptibility to distortions reported in a grating predicted the improvement in rate of reading with a coloured filter.[18] The increase in reading speed with coloured filters has been shown to predict later long-term usage of overlays.[19] Coloured overlays have been shown to improve the reading of conventional prose, although this is measurable only after 10 min reading.[20] In a small sample of 8–16 year old children with reading difficulties there was a positive correlation of 0.55 between the increase in the speed of reading randomly ordered common words and the increase when reading prose.[21]

The reports of illusions in grating patterns has been formalised in the Pattern Glare Test (PGT),[22] and the rate of reading randomly ordered common words has been formalised in the Wilkins Rate of Reading Test (WRRT).[19] The Pattern Glare Test involves the presentation of 3 gratings, with spatial frequencies of 0.3, 2.3 and 9.4 cycles per degree when viewed at 0.4 m. The patient reports any perceptual distortion or discomfort using a check list. The WRRT comprises four paragraphs of text in which each line consists of the same 15 randomly ordered common words. The patient is required to read the paragraph aloud for one minute as rapidly and accurately as possible. Both tests are available to optometrists, as is a test of digit reading that has also shown positive effects of coloured filters in VS.[23] Effects of colour on visual search have also been demonstrated but the tests are not widely used in optometry.[24–27]

Many of the behaviours listed above have been used both in practice and in research to detect VS, but there have been few attempts to standardise the diagnostic process. Certainly, some of these items in isolation would not be suitable for diagnosis. For example, in Table 1 items 1 and 2 could have many optometric causes[28] which would have to be excluded before coloured lenses were considered. Reports of an immediate improvement in symptoms (Item 4 in Table 1), occurs with high frequency[29–31] and should not be used as a sole criterion for VS.

A recent systematic review criticised the strength of evidence for VS and in particular noted the wide variety of diagnostic criteria that has been used in different studies.[4]

The aim of the study was to establish contemporary clinical practice in the diagnosis of VS using the Delphi method.[32] This method relies on a panel of experts who give their opinions in two or more rounds. In each round, the opinions are summarised and fed back to respondents in subsequent round(s) in order to reduce disparity and achieve an expert consensus. The technique has been used to standardise and improve diagnosis and has been used in optometry to develop competency frameworks.[33,34]

Round 1: Methods

We selected a panel of clinicians who were identified by the manufacturer of MRC precision tinted lenses as the most frequent prescribers of precision tinted lenses in the UK. The authors of the present paper were excluded. Altogether, 26 practitioners were contacted, comprising 17 optometrists, 5 orthoptists, and 4 opticians. Although three of the optometrists worked in the same optometric clinic and three of the orthoptist respondents worked in the same hospital clinic, these clinicians did not collude.

The potential participants were contacted by BJWE and asked to complete a questionnaire (Appendix 1) rating the importance they attached to the items listed below in the diagnosis of VS:

a family history of migraine
a family history of epilepsy
a personal history of dyslexia
a personal history of migraine
symptoms of words blurring when reading
symptoms of words moving when reading
a worsening of symptoms with small text when age-appropriate
sustained voluntary use of an overlay
an improvement with an overlay in reading speed on the WRRT
the results of the PGT
inconsistent errors on the Ishihara test

Respondents were asked to place an asterisk next to any items that they thought were essential in the diagnosis of VS and to add any items that they thought were important and were not in the list. Respondents were asked to assume that the person under investigation had received a detailed eye examination to rule out other causes of their symptoms.

Round 1: Results

Of the 26 potential participants who received an invitation and a reminder, 22 participated in the first round. Respondents' post codes were widely distributed throughout the UK.

In Round 1 there were 12 items that respondents rated from 0 to 10, with 10 being most useful. Respondents were

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Table 2 Mean and standard deviation (SD) of the ratings of each item in Round 1, together with the proportion of the respondents who thought that this item was essential in the diagnosis of VS.

Item	Mean	SD	Proportion of respondents who considered item essential
Symptom of words moving when reading	9.1	1.0	21%
Sustained voluntary use of overlay	8.9	1.2	26%
Overlay improves WRRT	8.8	1.1	26%
Words blurring when reading	8.0	1.2	5%
PGT result	7.6	2.6	21%
Symptoms of headaches when reading	7.5	1.9	5%
Symptoms worsen with small text	7.0	2.5	5%
Personal history of dyslexia	6.6	1.5	0
Personal history of migraine	6.5	1.4	0
FH migraine	4.0	2.0	0
FH epilepsy	2.4	1.6	0
Inconsistent errors on Ishihara test	1.5	1.9	0

asked to place an asterisk next to any items they considered essential.

Table 2 shows that just over a quarter thought that an increase in performance with the WRRT was essential and a similar proportion thought that sustained use of overlay was essential. These were often the same respondents, so they were evidently using both criteria together. The mean rating for each item is shown in Table 2, which also includes the standard deviation of the rating (SD), which is a measure of agreement.

Respondents expressed somewhat different opinions as to how best to summarise their PGT findings although this might be related to the open nature of this question. The average length of time prescribers used as a criterion for sustained voluntary use of an overlay was 10 weeks (range 4 weeks to 12 months, with some respondents regarding this as age dependent).

Participants were asked to add any other items that they thought should be used. Those who gave additional items unsurprisingly tended to rate these highly. This revealed several new items, and those that were not synonymous with an item in the Round 1 were added in Round 2.

The top seven items in Table 2 can all be characterised as either symptoms (e.g., words moving) or signs (e.g., sustained use of overlay) of VS (see ''Discussion'' section). One question that arises is whether some practitioners favoured signs over symptoms (or vice versa) and, if practitioners tended to look for both signs and symptoms, whether this was a consistent feature. The latter seems to be the case because for every respondent their top three rated criteria included at least one sign and one symptom.

Round 2: Methods

A new questionnaire was used for Round 2 that included items suggested by respondents in Round 1. In Round 2 the items were categorised as symptoms from text, other symptoms, signs when reading, history, and investigations. The Round 2 questionnaire is in Appendix 2 and this was sent to all of the Round 1 respondents.

Round 2: Results

Of the 22 potential participants who received an invitation and two reminders, 20 participated in the second round. These included three optometrists from one clinic and two orthoptists from a different clinic (who, as in round 1, did not collude). All other respondents were sole representatives of a clinic and respondents' post codes were again widely distributed throughout the UK.

The mean ratings for each item are shown in Table 3, together with the standard deviation of the rating (SD). Items have been categorised as in the questionnaire. The overall degree of agreement was high. One measure of the agreement was the correlation between each individual rating and the mean rating for the group. With the exception of two respondents, this correlation was acceptable and greater than 0.53 (a moderate positive correlation).

The items with a high rating and a low standard deviation are those that all respondents regarded as important.

Table 3 reveals that respondents understandably attach most significance to those aspects that help differentiate VS from other conditions. ''Words moving'' is taken as more significant than ''words blurring'', possibly because the former is not easily attributable to refractive error. Non-specific symptoms such as eye pain or headache were regarded as less important.

Understandably, respondents regarded an increase of 10% or 15% in reading speed as more indicative of VS than 5%, but a 5% increase (which previously has been mooted as an acceptable criterion; see ''Discussion'' section) was given a low rating.

The PGT was not used by three of the practitioners. Further questioning revealed that two of these three did not own a copy of the PGT.

The top 18 items in Table 3 can all be characterised as either symptoms or signs of VS (see ''Discussion'' section). Note that for 19 out of 20 respondents the top three rated criteria included at least one sign and one symptom.

Discussion

The Delphi Round 1 identified a list of symptoms and signs of VS (Table 2). This list was refined and prioritised in Round 2 (Table 3).

A recent review discusses the reasons why children may, on testing with coloured overlays, express an immediate subjective preference for an overlay and these are illustrated in Fig. 1.[4] Many reasons (e.g. refractive error, binocular vision anomalies, accommodative anomalies) will

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Table 3 Mean and standard deviation of ratings of each item in Round 2, together with the category of the item.

Item	Mean	SD	Category
Words moving when reading	8.9	1.3	Symptom from text
Voluntary use of overlay for >4 months	8.8	1.4	Investigation
Avoiding reading unless with an overlay	8.7	1.5	Sign when reading
Overlay improves WRRT by ≥15%	8.6	2.4	Investigation
Preference to use colour	8.3	1.5	Signs when reading
Words merge together	8.3	1.6	Symptom from text
Patterns or shadows in the text (e.g., rivers)	8.1	1.9	Symptom from text
Voluntary use of overlay for 3 months	8.1	1.4	Investigation
Strong aversion to striped patterns	8.0	1.5	Other symptom
Words or letters seem to stand out in 3-D above the page	7.7	1.8	Symptom from text
Words or letters fade & darken	7.6	2.0	Symptom from text
Discomfort with certain artificial lights & flicker	7.6	1.4	Other symptom
Symptoms originating spontaneously from student	7.5	1.8	Other symptom
Dislikes light/dark stripes	7.5	1.6	Other symptom
Overlay improves WRRT by ≥10%	7.5	2.2	Investigation
Symptoms variable depending on font/spacing of text	7.4	2.5	Symptom from text
Pattern glare pattern 2 >3	7.4	2.4	Investigation
Reduced reading ability after a short period	7.3	1.6	Symptom from text
FH visual stress	7.2	1.3	History
PH migraine	7.2	1.3	History
Pattern glare score >1 on pattern 2–3 difference	7.1	2.4	Investigation
Repeating words and/or lines	7.0	1.8	Symptom from text
Words blurring when reading	7.0	1.7	Symptom from text
PH of dyslexia	6.9	1.6	History
Using a ruler/finger to trace text	6.8	1.9	Sign when reading
FH of dyslexia	6.5	1.7	History
Headaches when reading	6.5	1.8	Symptom from text
FH of migraine	6.2	1.5	History
Photophobia	6.1	1.7	Other symptom
Voluntary use of overlay for 3 weeks	5.5	2.1	Investigation
Overlay improves WRRT by 5%	5.4	1.9	Investigation
Eye pain when reading	5.3	2.3	Symptom from text
FH of epilepsy	4.9	1.7	History
Inconsistent errors on Ishihara test	3.4	2.4	Investigation

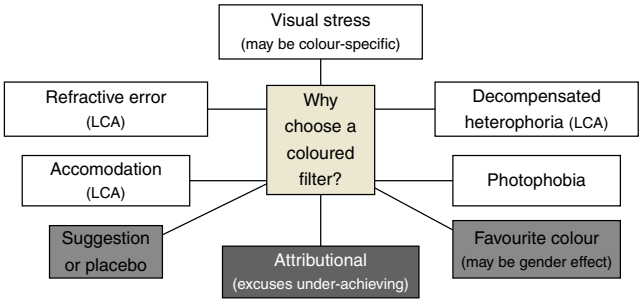

Figure 1 Possible reasons why children might choose a coloured overlay on first testing. LCA, longitudinal chromatic aberration.

be excluded by an eye examination and the UK College of Optometrists guidelines recommend that coloured lenses are not prescribed until such factors have been excluded.[4] The goal of the diagnostic process is to rule out, as far as possible, the other non-specific reasons for a child choosing an overlay (the grey boxes in Fig. 1).

The highest rated item in both Delphi rounds is the symptom of ''words moving when reading''. This is not a common symptom in routine eye examinations[35] and this is therefore a strong candidate indicator of VS (see ''Limitations'' section).

The second highest rated item in both rounds is ''sustained voluntary use of an overlay''. The use of Intuitive Overlays in diagnosing VS has been criticised, because of the use of ''the intervention under evaluation to screen and enrol subjects''.[3] The use of a treatment for diagnosis also occurs for other conditions[36–38] and indeed some conditions are diagnosed purely on the presence of symptoms and exclusion of other causes.[39] One concern is that a child who experiences reading difficulties may report symptoms when viewing text as a result of suggestion or acquiescence. The advantage of a sustained use criterion is that it seems unlikely that many children continue with coloured overlays for several months when there is no benefit.

There is evidence, of borderline statistical significance, that dyslexic children are more likely to have VS than good readers[25,40] and that VS may be more problematic when it co-occurs with dyslexia.[25]

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The time interval used as a criterion for sustained voluntary use of an overlay is difficult to specify as it may vary with the child's age and with the strength of response. Wilkins recommended six weeks if the benefit was obvious, and a school term or longer for less convincing cases.[41] Not surprisingly, in Table 3 longer periods were considered more compelling with >4 months having a very high mean rating (8.8) and 3 months a rating of 8.1. Three weeks is certainly not considered by most practitioners to be long enough, as this only received a rating of 5.5. It would seem that 3 months is the minimum period that most practitioners find to be convincing.

Concerning the WRRT, historically a criterion of >5% improvement has often been recommended.[30,31,42–44] One paper suggested that a >10% criterion might be more appropriate.[40] A recent analysis indicates that an increase of 15% is unlikely to be due to chance.[45] A contemporary review notes that the severity of VS is likely to lie on a continuum and the spectrum of the severity of VS can be characterised as the percentage improvement in WRRT with overlays.[4] It is interesting that the present Delphi study, which was carried out before the new >15% criterion had been recommended or publicised, reveals that the most experienced clinicians have independently adopted a >15% criterion.

Recent research adds convincing weight to the usefulness of using a PGT.[46] The independence of this test from the process of choosing colour makes a PGT a compelling candidate for inclusion in the diagnosis of VS. Another advantage of this test is that it asks children about their immediate symptoms when they view patterns, compared with their memory of symptoms that have occurred during everyday reading. Two normative criteria have been suggested for the PGT, and of these the criterion that the Delphi process rated highest is that the score with the mid-spatial frequency pattern should be >3.[22] The viewing distance is very critical with the high spatial frequency pattern and its use is not recommended.[47]

In the first scientific description of VS, by the neurologist MacDonald Critchley in 1964,[48] it is clear that VS was considered to be an exceptional finding and not a commonplace feature of dyslexia. Twenty years later, Irlen claimed that VS occurs as a ''layer'' in 46% of people with dyslexia.[49] More recently Wilkins et al. argue for dissociating dyslexia from VS because the two are not strongly associated.[45] A recent review,[4] applying the new >15% WRRT to earlier data,[40] indicates that VS occurs in approximately 20% of people with dyslexia. Indeed, in studies that have assessed the link between VS and dyslexia we have found that VS is not present in most people with dyslexia.[40,50] Other authors take a less conservative approach. For example, one proponent argues that there is a condition called ''visual dyslexia'' which affects 10% of all children[51] and another claims that optometrists ''have the means to cure dyslexia''.[52] It is worth noting that in both Delphi rounds the respondents placed a personal history of dyslexia low down their list, 8th in the first Round and 24th in the second Round. It is clear from Tables 2 and 3 that practitioners attach much greater significance to the individual signs and symptoms of each case than to their status as dyslexic. The key features emerging from the results of this Delphi study are used in the ''Recommendations'' section.

Table 4 Table of putative diagnostic indicators for VS.

At least three of the following six typical symptoms:

1. Words move
2. Words merge
3. Patterns or shadows in text (e.g., ''rivers'')
4. Text seems to stand out in 3-D above the page
5. Words or letters fade or darken
6. Discomfort with certain artificial lights and flicker

And

At least two of the following three signs from investigations:

1. Voluntary unprompted use of an overlay for 3 months or more
2. Overlay improves performance at the WRRT by ≥15%
3. PGT result >3 with mid-spatial frequency grating

Recommendations

Before considering a diagnosis of VS, eyecare practitioners need to satisfy themselves that none of the findings in Table 3 can be attributed to a conventional optometric anomaly (e.g., refractive error, binocular or accommodative anomaly). Six of the top 12 rated items in Table 3 are symptoms that, on the basis of this Delphi study, are commonly used by experienced clinicians in the diagnosis of VS. These six have been selected as the five symptoms with text that respondents report using most commonly, plus the most highly ranked ''other symptom'' that relates to conditions that are likely to be encountered very frequently (discomfort with certain artificial lights and flicker). These six symptoms are reproduced in Table 4 and it is suggested that the presence of one or more of these symptoms is suggestive of VS.

Also in the top 12 items of Table 3 are all three clinical signs (investigation results) that are commonly used in the diagnosis of VS. These are specified in Table 4.

It should be stressed that the diagnostic tool in Table 4 is preliminary and it is recommended that experienced clinicians interpret this flexibly. Our Delphi respondents indicated that the severity of symptoms and the age of the patient may in some cases override the recommendations in Table 4. Additionally, some children may not report symptoms to which they are habituated, until symptoms remit with an overlay. Clinicians who are experienced at dealing with patients will be skilled at judging the veracity of symptoms and patient reports.

Table 4 is a starting point for future research to test this, and other variations, using retrospective and prospective clinical data. Such research could determine which of the symptoms and signs listed in Table 4 best predict those patients who will go on to use precision tinted lenses for a given period.

It is perhaps surprising that a personal history of migraine and reports of headaches when reading both have low ratings, see Table 3. For this reason, these items have not been included in Table 4. Nevertheless there is research suggesting that visual stimuli can be common triggers for migraine[53]

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and that precision tinted lenses can be helpful for some patients with migraine.[54–56]

Strengths and limitations

Strengths of the present work are that a cohort of the most frequent prescribers of precision tinted lenses in the UK was identified and a high response rate was obtained (85% in Round 1 and 91% in Round 2, which is 78% of the full sample). Amongst them, the respondents had up to 20 years of experience of prescribing precision tinted lenses and represented a varied population, both geographically and in professional background. The only eyecare profession that was not represented is ophthalmology. Nearly all ophthalmologists in the UK are involved in the diagnosis and management of ocular pathology and very few work in primary care where patients with VS are most likely to be encountered.

We concentrated on the Intuitive Colorimeter system because this is fully described in the scientific literature,[57,58] systematically and efficiently samples colour space,[57] and has been shown to have the properties required for an appropriate method (overlays that are sufficiently large and overlays or lenses that have a sufficient number of colours that systematically sample colour space).[59–61] Furthermore, this system is used by eyecare professionals who, in accordance with professional guidelines, will exclude other optometric causes of symptoms before considering a diagnosis of VS.

Although, for simplicity, we did not ask about age differences it is likely that the overwhelming majority of patients seen by our respondents were children. Respondents were encouraged to add any relevant comments and few raised the issue of age (see ''Results'' section).

The Delphi process is useful to identify the symptoms and signs that practitioners use most often in the diagnosis of VS, but does not indicate the sensitivity or specificity of these indicators. The Delphi can be considered as the starting point in developing a diagnostic tool and further work will be required to refine the tool, as suggested above.

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None.

Contributors

All authors participated in conceptualising and designing the study, analysing the results, and preparing the manuscript.

Conflict of interest

BJWE and PMA have no financial involvement with manufacturers of coloured filter systems used to treat visual stress. AJW receives royalties for a pattern glare test that is sometimes used to test for visual stress. AJW invented the Intuitive Overlays, Intuitive Colorimeter, and Rate of Reading Test when he was employed by the Medical Research Council. Under their Awards to Inventors scheme he receives a proportion of royalties on sales of the Colorimeter and the Rate of Reading Test. No royalties are payable on overlays or lenses. All authors have received honoraria for lectures on this topic from the International Institute for Colorimetry and Cerium Visual Technologies. BJWE has acted (many years ago) as an expert witness on this topic and is Director of Research at the Institute of Optometry which is an independent charity that receives donations from i.O.O. Sales Ltd which sells, amongst other products, Intuitive Overlays, the Pattern Glare Test, and the Wilkins Rate of Reading Test. BJWE has an optometric practice in Essex in which he uses these items and the Intuitive Colorimeter and Precision Tinted lenses. The Institute of Optometry also uses these items in some of its clinics. BJWE and AJW are unpaid committee members of the not-for-profit Society for Coloured Lens Prescribers (www.s4clp.org).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.optom.2016.08.002.

References

1. Uccula A, Enna M, Mulatti C. Colors, colored overlays, and reading skills. *Front Psychol*. 2014;5.
2. Henderson LM, Taylor RH, Barrett B, et al. Editorials: treating reading difficulties with colour. *Br Med J*. 2014;349:g5160–g5260.
3. Albon E, Adi Y, Hyde C. *The effectiveness and cost-effectiveness of coloured filters for reading disability: a systematic review*; 2008.
4. Evans BJW, Allen PM. A systematic review of controlled trials on visual stress using Intuitive Overlays or the Intuitive Colorimeter. *J Optom*. 2016;9:205–218.
5. Wilkins A, Nimmo-Smith I, Tait A, et al. A neurological basis for visual discomfort. *Brain*. 1984;107:989–1017.
6. Griffiths PG, Taylor RH, Henderson LM, Barrett BT. The effect of coloured overlays and lenses on reading: a systematic review of the literature. *Ophthal Physl Opt*. 2016;36:519–544.
7. Wilkins A. A physiological basis for visual discomfort: application in lighting design. *Lighting Res Technol*. 2016;48:44–54.
8. Haigh SM, Barningham L, Berntsen M, et al. Discomfort and the cortical haemodynamic response to coloured gratings. *Vis Res*. 2013;89:47–53.
9. Mechanisms whereby precision spectral filters reduce visual stress: an fMRI study.Huang J, Wilkins AJ, Cao Y, eds. *Tenth Annual Meeting of the Organisation for Human Brain Mapping*. 2004.
10. Hibbard PB, O'Hare L. Uncomfortable images produce non-sparse responses in a model of primary visual cortex. *R Soc Open Sci*. 2014.
11. Field DJ. Relations between the statistics of natural images and the response properties of cortical cells. *J Opt Soc Am A*. 1987;4:2379–2394.
12. Field DJ. What is the goal of sensory coding. *Neural Comput*. 1994;6:559–601.
13. Field DJ, Brady N. Visual sensitivity, blur and the sources of variability in the amplitude spectra of natural scenes. *Vis Res*. 1997;37:3367–3383.
14. Field DJ, Olshausen B. Sparse coding with an overcomplete basis set: a strategy employed by V1. *Vis Res*. 1997;37:3311–3325.
15. Wilkins AJ, Nimmo-Smith MI. The clarity and comfort of printed text. *Ergonomics*. 1987;3012:1705–1720.

16. Jainta S, Jaschinski W, Wilkins AJ. Periodic letter strokes within a word affect fixation disparity during reading. *J Vis*. 2010;10(13:2):1–11.
17. Wilkins A, Smith J, Willison CK, et al. Stripes within words affect reading. *Perception*. 2007;36:1788–1803.
18. Hollis J, Allen PM. Screening for Meares-Irlen sensitivity in adults: can assessment methods predict changes in reading speed? *Ophthal Physiol Opt*. 2006;26:566–571.
19. Wilkins AJ, Jeanes RJ, Pumfrey PD, et al. Rate of Reading Test: its reliability, and its validity in the assessment of the effects of coloured overlays. *Ophthal Physiol Opt*. 1996;16:491–497.
20. Tyrrell R, Holland K, Dennis D, et al. Coloured overlays, visual discomfort, visual search and classroom reading. *J Res Reading*. 1995;181:10–23.
21. Wilkins AJ. Coloured overlays and their effects on reading speed: a review. *Ophthal Physiol Opt*. 2002;22:448–454.
22. Evans BJW, Stevenson SJ. The Pattern Glare Test: a review and determination of normative values. *Ophthal Physiol Opt*. 2008;28:295–309.
23. Northway N. Predicting the continued use of overlays in school children – a comparison of the Developmental Eye Movement test and the Rate of Reading test. *Ophthal Physiol Opt*. 2003;23:457–464.
24. Singleton C, Henderson L-M. Computerised screening for visual stress in children with dyslexia. *Dyslexia*. 2007;13:130–151.
25. Singleton C, Trotter S. Visual stress in adults with and without dyslexia. *J Res Reading*. 2005;28:365–378.
26. Newman WB, Wilkins AJ, Zoukos Y. Spectral filters can improve reading and visual search in patients with multiple sclerosis. *J Neurol*. 2007;254:1729–1735.
27. Allen PM, Gilchrist JM, Hollis J. Use of visual search in the assessment of pattern-related visual stress (PRVS) and its alleviation by coloured filters. *Investig Ophthal Vis Sci*. 2008;49:4210–4218.
28. Sheedy J, Hayes J, Engle J. Is all asthenopia the same? *Optom Vis Sci*. 2003;81:732–739.
29. Wilkins AJ, Lewis E. Coloured overlays, text and texture. *Perception*. 1999;28:641–650.
30. Wilkins AJ, Lewis E, Smith F, et al. Coloured overlays and their benefit for reading. *J Res Reading*. 2001;24:41–64.
31. Scott JC, McWhinnie H, Taylor L, et al. Coloured overlays in schools: orthoptic and optometric findings. *Ophthal Physiol Opt*. 2002;22:156–165.
32. Dalkey N, Helmer O. An experimental application of the Delphi Method to the use of experts. *Manag Sci*. 1963;9:458–467.
33. Shah K, Naidoo K, Loughman J. Development of socially responsive competency frameworks for ophthalmic technicians and optometrists in Mozambique. *Clin Exp Optom*. 2016;99:173–182.
34. Myint J, Edgar DF, Kotecha A, et al. Development of a competency framework for optometrists with a specialist interest in glaucoma. *Eye (Lond)*. 2010;24:1509–1514.
35. Ball G. Symptomatology. In: Edwards K, Llelwellyn R, eds. *Optometry*. London: Butterworths; 1988:70–80.
36. McKeon A, Matsumoto JY, Bower JH, et al. The spectrum of disorders presenting as adult-onset focal lower extremity dystonia. *Parkinson Relat Disord*. 2008;14:613–619.
37. Spira A. Diving and marine medicine review part II: diving diseases. *J Travel Med*. 1999;6:180–198.
38. Cianci P, Slade JB Jr. Delayed treatment of decompression sickness with short, no-air-break tables: review of 140 cases. *Aviat Space Environ Med*. 2006;77:1003–1008.
39. International Headache Society. The International Classification of Headache Disorders. 2nd edition. *Cephalalgia*. 2004;24(suppl 1):1–151.
40. Kriss I, Evans BJW. The relationship between dyslexia and Meares-Irlen Syndrome. *J Res Reading*. 2005;28:350–364.
41. Wilkins AJ. *Reading Through Colour. How Coloured Filters Can Reduce Reading Difficulty, Eye Strain, and Headaches*. Chichester: John Wiley and Sons; 2003.
42. Evans BJW, Joseph F. The effect of coloured filters on the rate of reading in an adult student population. *Ophthal Physiol Opt*. 2002;22:535–545.
43. Ludlow AK, Wilkins AJ, Heaton P. The effect of coloured overlays on reading ability in children with autism. *J Autism Dev Disord*. 2006;36:507–516.
44. Allen PM, Dedi S, Kumar D, et al. Accommodation, pattern glare, and coloured overlays. *Perception*. 2012;41:1458–1467.
45. Wilkins AJ, Allen P, Monger LJ, et al. Visual stress and dyslexia for the practising optometrist. *Optom Pract*. 2015;17:103–112.
46. Monger LJ, Wilkins AJ, Allen PM. Pattern glare: the effects of contrast and color. *Front Psychol*. 2015;6:1651.
47. Monger LJ, Shah D, Wilkins AJ, et al. The effect of viewing distance on responses to the pattern glare test. *Clin Exp Optom*. 2016;99:47–50.
48. Critchley M. *Developmental Dyslexia*. London: Whitefriars Press; 1964.
49. Irlen H. Reading problems and Irlen Colored Lenses. *Dyslexia Rev*. 1997;Summer:4–7.
50. Evans BJW, Cook A, Richards IL, et al. Effect of pattern glare and colored overlays on a stimulated-reading task in dyslexics and normal readers. *Optom Vis Sci*. 1994;71:619–628.
51. Jordan I. *Visual dyslexia. Dispensing Optics*; 2002, August/September:9–10.
52. Griffiths G. Change your life with a Schoolvision diplopia. *Optom Today*. 2011;(suppl):8–9.
53. Harle DE, Shepherd AJ, Evans BJW. Visual stimuli are common triggers of migraine and are associated with pattern glare. *Headache*. 2006;46:1431–1440.
54. Wilkins AJ, Patel R, Adjamian P, et al. Tinted spectacles and visually sensitive migraine. *Cephalalgia*. 2002;22:711–719.
55. Huang J, Zong X, Wilkins A, et al. fMRI evidence that precision ophthalmic tints reduce cortical hyperactivation in migraine. *Cephalalgia*. 2011;31:925–936.
56. Coutts L, Cooper C, Elwell C, et al. Time course of the hemodynamic response to visual stimulation in migraine, measured using near infrared spectroscopy. *Cephalalgia*. 2012;32:621–629.
57. Wilkins AJ, Nimmo-Smith I, Jansons JE. Colorimeter for the intuitive manipulation of hue and saturation and its role in the study of perceptual distortion. *Ophthal Physiol Opt*. 1992;12:381–385.
58. Wilkins AJ, Sihra N. A colorizer for use in determining an optimal ophthalmic tint. *Color Res Appl*. 2000;26:246–253.
59. Waldie M, Wilkins A. How big does a coloured overlay have to be. *Ophthal Physiol Opt*. 2004;24:57–60.
60. Wilkins AJ, Sihra N, Myers A. Increasing reading speed by using colours: issues concerning reliability and specificity, and their theoretical and practical implications. *Perception*. 2005;34:109–120.
61. Wilkins A, Sihra N, Nimmo-Smith I. How precise do precision tints have to be and how many are necessary? *Ophthal Physiol Opt*. 2005;25:269–276.

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