Validation of the Leiden Visual Sensitivity Scale and Visual Discomfort Scale in chronic pain conditions

Short title: Validation of the L-VISS and Visual Discomfort Scale

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Abstract

Discomfort provoked by normally innocuous visual stimuli has been reported by people with chronic pain. Visual discomfort may be higher in pain conditions in which central sensitization is implicated, such as Complex Regional Pain Syndrome (CRPS) and fibromyalgia. In an online study, we validated the Leiden Visual Sensitivity Scale (L-VISS) and Visual Discomfort Scale (VDS) in people with CRPS (*n*=57), fibromyalgia (*n*=75), and general chronic pain (*n*=53); investigated whether these groups and pain-free controls (*n*=125) differed in visual discomfort; and evaluated the effect of age. The L-VISS and VDS had good internal consistency. Both scales were positively related with experimentally induced visual distortions for mid spatial frequency striped patterns, suggesting good construct validity. The scales were positively related with each other, and dissociated between the pain and pain-free groups in similar ways, suggesting good construct validity. There was no relationship between age and L-VISS scores, and a small negative relationship between age and VDS scores. Visual discomfort was highest in the fibromyalgia group, followed by the CRPS group. This research confirms the utility of the L-VISS and VDS for measuring visual sensitivity in chronic pain, and adds to evidence that central sensitization is an important mechanism of visual discomfort.

Key Words: visual stress, visual allodynia, pattern glare, Complex Regional Pain Syndrome, fibromyalgia

Introduction

Looking at repetitive striped patterns or flickering lights may lead to visual side-effects. These can be somatic (e.g. sore or tired eyes) and perceptual (e.g. flickering or shading). The collection of these side effects has been termed visual discomfort (interchangeable with the terms visual stress and visual allodynia; Wilkins et al., 1984). The presence and intensity of visual discomfort varies according to the spatial (e.g. spatial frequency and contrast level) and temporal (e.g. amplitude and phase spectra) characteristics of the stimulus (Wilkins, 2016; Wilkins et al., 1984; Yoshimoto et al., 2017), and depends on individual susceptibility. Visual discomfort may be enhanced after sleep deprivation (Dyakova et al., 2019) and might decrease with age (Evans & Stevenson, 2008). Functional impacts of visual discomfort include reduced reading speed (Conlon et al., 1999) and decreased productivity in office environments (Anshel, 2007; Hamedani et al., 2019). There are known examples of clinical populations that are more susceptible to visual discomfort, including people with brain damage such as stroke (Beasley & Davies, 2012), migraine (Evans & Stevenson, 2008; Harle et al., 2006; Shepherd, 2001), or Myalgic Encephalomyelitis/Chronic Fatigue Syndrome (Wilson et al., 2015). Altogether, it is important to be able to assess visual discomfort, especially in individuals with a higher risk of being susceptible to it.

Two questionnaires that have been developed to measure visual discomfort are the Leiden Visual Sensitivity Scale (L-VISS) and the Visual Discomfort Scale (VDS). The L-VISS was developed based on experiences of everyday light and pattern sensitivity in people with migraine. The Dutch version was validated in people with migraine and pain-free controls (Perenboom et al., 2018). The VDS was based on visual discomfort as conceptualized by Wilkins et al. (1984) and perceptual side-effects when reading (Conlon et al., 1999). The VDS was validated in students (Borsting et al., 2007, 2008) and people with migraine (Cucchiara et al., 2015). The L-VISS and VDS both aim to measure visual discomfort but take a somewhat different approach. Both scales measure possible somatic (e.g. being bothered, sore eyes), perceptual (e.g. afterimages, flickering, shimmering), and performance difficulties (e.g. worse eyesight, blurring) experienced with exposure to different light sources or patterns. The VDS has a strong focus on reading, which is not the case for the L-VISS. It is unclear whether they measure the same or different underlying concepts. Furthermore, although both scales have been validated in people with migraine, it is unknown whether they are valid in other chronic pain populations. The sensitivity for striped patterns in migraine has been suggested to relate to hyper excitability of the visual cortex (Evans & Stevenson, 2008). According to this hypothesis, visual discomfort may also be higher in other pain conditions in which central sensitization is implicated; that is, where the central nervous system is hyperactive or over sensitive.

Our first aim was to validate the L-VISS and VDS in specific chronic pain conditions that are related to central sensitization, Complex Regional Pain Syndrome (CRPS) and fibromyalgia; and general chronic pain. CRPS and fibromyalgia are associated with functional and structural changes in the central nervous system (Henry et al., 2011; Kindler et al., 2011; Littlejohn, 2015; Yunus, 2008). People with CRPS or fibromyalgia show hyperalgesia (increased responses to painful stimuli) and allodynia (pain from a normally non-painful stimulation; Littlejohn, 2015; Marinus & van Hilten, 2006), which is absent or less severe in other pain conditions such as arthritis (Palmer et al., 2019), and has been attributed to central sensitization (Adams & Turk, 2015; Ji & Woolf, 2001; Yunus, 2008). In addition to heightened sensitivity to somatosensory stimuli, it is proposed that in both CRPS and fibromyalgia sensory input across many systems is amplified by the central nervous system, leading to enhanced sensory sensitivity for non-somatic stimuli (de Klaver et al., 2007; Fleming & Volcheck, 2015). Hypersensitivity to bright light and flashing stimuli have been measured as higher in people with fibromyalgia compared to pain-free controls (Ichesco et al., 2013; Martenson et al., 2016). Anecdotally, some people with CRPS or fibromyalgia report pain and discomfort when looking at high-contrast images (Dönmez et al., 2012; Ten Brink et al., 2020). We, therefore, expected that people with CRPS or fibromyalgia would report more everyday visual discomfort than people with other pain conditions. In the present study, we computed the internal consistency of the L-VISS and VDS separately in people with CRPS, fibromyalgia, and other chronic pain conditions. Furthermore, we evaluated the construct validity of the L-VISS and VDS by assessing the relationships with experimentally induced visual distortions while viewing striped patterns. In addition, we evaluated the relationship between the L-VISS and VDS in these pain populations, to learn about the degree of similarity of the scales.

Our second aim was to investigate whether people with CRPS, fibromyalgia, other pain conditions, and age-matched pain-free controls differ in self-reported visual discomfort as measured with the L-VSS and VDS. As there are known relationships between migraine and visual discomfort (Shepherd et al., 2013; Wilkins et al., 2016), we performed secondary analyses to assess differences in visual discomfort between different pain-related medical diagnoses, including migraine.

Third, we evaluated the effects of age on visual discomfort as measured with the L-VISS and VDS. Only one prior study compared different healthy age groups regarding visual distortions for striped patterns, and they found that these distortions *decreased* with age (Evans & Stevenson, 2008). Similarly, photosensitivity was reported less in older people with migraine compared to younger people with migraine (Bigal et al., 2006). It is unknown whether everyday light and pattern sensitivity changes throughout life in a similar way.

Methods

Online study

Study distribution and procedure

This study formed part of a larger online study that we created using Qualtrics survey software (Qualtrics, 2005). We distributed the link to this study to people with CRPS, fibromyalgia, other types of pain, and no pain who had previously taken part in other research in our lab or online. Additionally, we distributed the study link to the Community Participant Panel of the Psychology Department of the University of Bath, psychology students of the University of Bath, through patient newsletters and social media groups for a number of pain conditions, via our own social media, including friends and relatives. We collected responses from December 2019 to May 2020. The study was automatically closed when respondents opened the survey on a mobile device, did not provide informed consent, were aged below 16 years, or indicated that they had a history of neurological illness/injury or epilepsy. Respondents were offered the chance to enter a £50 Amazon gift voucher prize draw. Students were offered study credits. The study took approximately 25 minutes to complete. The study was approved by the Psychology Research Ethics Committee of the University of Bath (PREC code 19-278). Survey questions that were used in the current study are described below, and presented in Appendix A.

Demographic and pain-related information

Respondents were asked to indicate their age, sex, and handedness. Respondents were asked whether they experienced pain on most days for the past 3 months or more. If this question was answered with "yes", respondents were asked questions on their pain duration (in years) and the average hours of pain they experienced per day. Using a selection of 10 predefined body parts and a free-text "other" box, respondents with chronic pain were asked to indicate in which area/part of their body they experienced pain in the past week (Supplementary Table 1). All respondents were asked whether they had received a pain-related medical diagnosis, and what this diagnosis was. We predefined 15 pain-related medical diagnoses (Supplementary Table 2), including CRPS (we did not dissociate between CRPS type I and CRPS type II, as many people do not know which type they have), fibromyalgia, and migraine. An "other" option was included with a free-text box for respondents to specify additional diagnoses. Respondents were asked to rate their current levels of pain, discomfort, and distress using separate Numerical Pain Rating Scales ranging from 0 (no pain/discomfort/distress) to 10 (worst imaginable pain/discomfort/distress; Karcioglu et al., 2018; Williamson & Hoggart, 2005). Respondents were asked whether or not they had dyslexia, as the VDS items on difficulties with reading could be affected by dyslexia. Finally, two

control questions were included instructing the participant to select a specific option, in order to confirm that respondents had read the questions.

Leiden Visual Sensitivity Scale

The L-VISS measures the impact of light and pattern sensitivity on daily functioning (Perenboom et al., 2018). Respondents indicate for 9 items whether they experience different forms of pattern sensitivity on a scale from 0 ("Not at all"), 1 ("Moderately"), 2 ("Severely"), and 3 ("Very severely"), resulting in a total score ranging from 0-27. By mistake, we did not include the "Slightly" option that was part of the original five-point response scale (therefore our scale consisted of only four choices). Please see the discussion section for possible implications. The items are listed in Table 1. The Dutch L-VISS has a good to excellent test-retest reliability in people with migraine, and is positively related to the number of visual distortions reported on the Pattern Glare Test (Perenboom et al., 2018).

Table 1. English translation of items of the Leiden Visual Sensitivity Scale (L-VISS), adapted from Perenboom et al. (2018).

#	**Question**
1	To what extent does sunlight bother you when you are not wearing sunglasses?
2	To what extent are you bothered by artificial lighting?
3	To what extent are you bothered by flickering lights (e.g. a flickering lamp, during films, or in a nightclub)
4	When you look at a bright light, is your eyesight worse afterwards (e.g. blurred or distorted vision)
5	To what extent does looking at patterns bother you? (e.g. patterns in clothing, materials, blinds)?
6	When you look at everyday patterns, do you experience afterimages? (seeing an image of the pattern elsewhere, for instance, on a white wall)
7	When you look at patterns, is your eyesight worse? (e.g. blurred or distorted vision)
8	When you look at a computer or TV screen, do you see afterimages? (seeing an image of the pattern elsewhere, such as on a white wall)
9	When you look at a computer or TV screen, is your eyesight worse? (e.g. blurred or distorted vision)

Visual Discomfort Scale

The VDS measures visual sensitivity in daily life situations (Conlon et al., 1999). Respondents rate 23 different situations on a scale from 0 ("Event never occurs"), 1 ("Occasionally. A couple of times a year"), 2 ("Often. Every few weeks"), to 3 ("Almost always"), resulting in a total score ranging from 0-69. Subdomains that are measured are movement/fading, blur/diplopia, headache/eye soreness, glare, rereading, and slow reading. The items are listed in Table 2. The VDS has been validated in students (Borsting et al., 2007, 2008) and in people with migraine (Cucchiara et al., 2015).

Table 2. Items of the Visual Discomfort Scale (VDS), retrieved from Conlon et al. (1999).

#	**Question**
1	Do your eyes every feel watery, red, sore, strained, tired, dry, gritty, or do you rub them a lot, when viewing a striped pattern?
2	Do your eyes every feel watery, red, sore, strained, tired, dry or gritty, after you have been reading a newspaper or magazine with clear print?
3	Do your eyes every feel watery, red, sore, strained, tired, dry or gritty, when working under fluorescent lights?
4	How often do you get a headache when working under fluorescent light?
5	Do you ever get a headache from reading a newspaper or magazine with clear print.
6	When reading, do you ever unintentionally reread the same words in a line of text?
7	Do you have to use a pencil or your finger to keep from losing your place when reading a page of text in a novel or magazine?
8	When reading do you ever unintentionally reread the same line?
9	When reading do you ever have to squint to keep the words on a page of clear text from going blurry or out of focus?
10	When reading, do the words on a page of clear text ever appear to fade into the background then reappear?
11	Do the letters on a page of clear text ever go blurry when you are reading?
12	Do the letters on a page ever appear as a double image when you are reading?
13	When reading, do the words on the page ever begin to move or float?
14	When reading, do you ever have difficulty keeping the words on the page of clear text in focus?

15	When you are reading a page that consists of black print on white letters, does the background ever appear to overtake the letters making them hard to read?
16	When reading black print on a white background, do you ever have to move the page around, or continually blink to avoid glare which seems to come from the background?
17	Do you ever have difficulty seeing more than one or two words on a line in focus?
18	Do you ever have difficulty reading the words on a page because they begin to flicker or shimmer?
19	When reading under fluorescent lights or in bright sunlight, does the glare from bright white glossy pages cause you to continually move the page around so that you can see the words clearly?
20	Do you have to move your eyes around the page, or continually blink or rub your eyes to keep the text easy to see when you are reading?
21	Does the white background behind the text ever appear to move, flicker, or shimmer making the letters hard to read?
22	When reading, do the words or letters in the words ever appear to spread apart?
23	As a result of any of the above difficulties, do you find reading a slow task?

Pattern Glare Test

We used an adapted version of the Pattern Glare Test, an optometric test developed to measure susceptibility to perceptual distortions and discomfort from patterns (Wilkins & Evans, 2010). The original Pattern Glare Test includes three striped patterns that differ in spatial frequency. The recommended viewing distance is 40 cm, but it is not necessary to precisely control viewing distance and the participant can view the patterns at their usual reading distance. For ease of reading, we report the cycles per degree (cpd) as though viewed at a distance of 40 cm. Of the three patterns, viewing distance has a large effect on the number of visual distortions only for pattern 3 (i.e. stripes of 9.4cpd at 40 cm, to 14.2cpd at 60 cm; Conlon et al., 2001; Wilkins et al., 2016). Because we could not control for viewing distance in this study, we did not use pattern 3. That is, we included only pattern 1 (i.e. stripes of 0.3cpd at 40 cm) and pattern 2 (i.e. stripes of 2.3cpd at 40 cm; Figure 1). The 2.3cpd striped pattern is likely to induce distortions, and these effects are not influenced by viewing distance (Monger et al., 2016; Wilkins et al., 2016). Visual distortions are rarely reported for the 0.3cpd striped pattern, and the pattern can be used to account for the person's acquiescence to suggestion in reporting symptoms. We included a filled grey circle as an additional control image, to evaluate potential differences for striped versus non-striped circles (i.e. both geometric shapes). The Pattern Glare Test has been validated in people with migraine (Evans & Stevenson, 2008).

The three images were shown in a fixed order, as was done in the original Pattern Glare Test. Respondents were asked to view a fixation dot at the centre of each image for 10 seconds. Next, they were asked to answer a series of seven questions about any distortions they perceived (e.g. shimmering, fading, blurring); and whether these distortions were absent (0), mild (1), moderate (2), or strong (3). The image remained on screen so respondents could view the image again if they wished. A total visual distortion score was computed by taking the sum of all seven distortion items (ranging from 0 to 21).

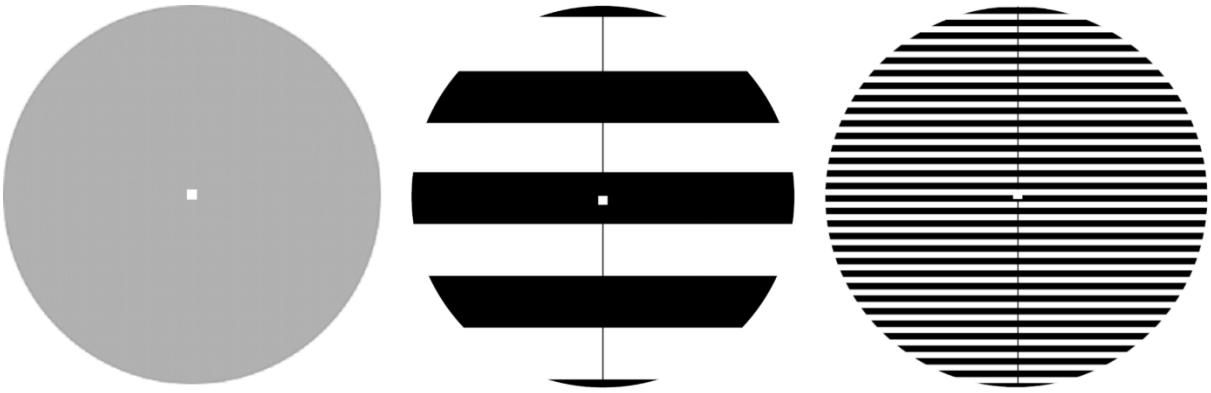

Figure 1. The three images used for the Pattern Glare Test. From left to right: filled grey circle, 0.3cpd striped pattern, and 2.3cpd striped pattern.

Statistical analyses

The alpha level was set at 0.05 and we used the Holm-Bonferroni method to correct for multiple post-hoc comparisons (Holm, 1978). All data, analysis scripts, and output files can be found at https://osf.io/td93k/.

Respondents

We assigned respondents to one of four groups based on their declared diagnosis or lack thereof: CRPS, fibromyalgia, other pain, and pain-free. Respondents who reported not to have had pain on most days for 3 months or more were allocated to the pain-free group. The pain-free group was further split into two subgroups: respondents aged 30 years or older were allocated to the age-matched pain-free group, respondents younger than 30 years were allocated to the younger pain-free group. The cut-off of 30 years was based on the age of the pain groups. The age-matched pain-free group served as a control group. The younger pain-free group was only included in the analysis on age effects and the regression analyses. The allocation of respondents to the CRPS or fibromyalgia groups was based on a respondent indicating one of these diagnoses, regardless of whether they

indicated other pain diagnoses. Respondents were allocated to the other pain group if they indicated having had pain on most days for 3 months or more, and if they did not indicate the diagnosis CRPS or fibromyalgia. Eight respondents who reported as having received a diagnosis of CRPS and fibromyalgia were excluded, because this would add noise to the comparison of the CRPS versus fibromyalgia groups.

Demographic and pain-related characteristics

We conducted one-way ANOVAs and Chi-square tests (when more than 20% of cells had expected frequencies below 5, we used Fisher's exact test) to compare the groups (i.e. CRPS, fibromyalgia, other pain, pain-free age-matched, pain-free younger) regarding demographic and pain-related characteristics.

Internal consistency of the L-VISS and VDS

Per pain group (i.e. CRPS, fibromyalgia, other pain), we computed the internal consistency of the L-VISS and VDS. A Cronbach's alpha of ≥0.70 was considered acceptable. Per item, we computed the item-total correlations, for which values ≥0.30 are recommended (Field, 2013).

Relationships between the L-VISS, VDS, and Pattern Glare Test

Per pain group (i.e. CRPS, fibromyalgia, other pain), we computed Spearman correlation coefficients between the L-VISS, VDS, and the visual distortion score for each image of the Pattern Glare Test. Spearman's rho was interpreted as small (>.10), moderate (>.30), large (>.50), or very large (>.70; Dancey & Reidy, 2004).

Comparison of L-VISS and VDS scores between pain conditions and age-matched pain-free controls

We compared L-VISS and VDS scores between people with CRPS, fibromyalgia, other pain, and age-matched pain-free controls using one-way ANOVAs. Effect sizes were computed with the Pearson correlation coefficient, and were considered to reflect a small (>.10), a medium (>.30), or a large effect (>.50; Field, 2013).

Effects of different pain-related medical diagnoses on L-VISS and VDS scores

As secondary analysis, we assessed effects of different pain-related medical diagnoses on L-VISS and VDS scores, independent of age. We performed linear regression analyses including all respondents (i.e. CRPS, fibromyalgia, other pain, age-matched pain-free, and younger pain-free). Pain-related medical diagnoses for whom at least 10%

of participants indicated to have the diagnosis were included as potential predictors. The dependent variable was the L-VISS or VDS score.

Effects of age on L-VISS and VDS scores

To evaluate effects of age on L-VISS and VDS scores, we included all pain-free respondents and computed Spearman correlation coefficients between the L-VISS and VDS scores, and age.

Results

Demographic and pain-related characteristics

We received 401 responses, of which 69 were excluded because respondents did not finish any part of the study, 8 because they reported as having received a diagnosis of CRPS and fibromyalgia, and 14 because they did not provide correct answers on one or both control question(s). Of the 310 included responses, 57 were assigned to the CRPS group, 75 to the fibromyalgia group, 53 to the other pain group, 59 to the age-matched pain-free group (≥30 years), and 66 to the younger pain-free group (<30 years; Table 3).

The younger pain-free group was, as expected, younger than the other groups, and consisted of more men than the CRPS and fibromyalgia groups. The other groups did not differ regarding age or sex. Groups did not differ regarding handedness or having received a diagnosis of dyslexia.

Respondents who reported as having received a diagnosis of fibromyalgia reported the highest number of (comorbid) pain-related medical diagnoses of all groups. Respondents who reported as having received a diagnosis of CRPS and pain controls did not differ from each other regarding the number of pain-related medical diagnoses. Migraine was present in all groups, but most often (40%) in the respondents with fibromyalgia. Other (comorbid) medical diagnoses are depicted in Supplementary Table 2. In the three pain groups, back pain (24.6% to 49.1%) and osteoarthritis (17.5% to 24.5%) were the most common (comorbid) pain-related medical diagnoses. In respondents who reported as having received a diagnosis of fibromyalgia, irritable bowel syndrome (53.3%), chronic fatigue syndrome (24%), and plantar fasciitis (14.7%), were more often reported as (comorbid) medical diagnoses than in the other groups. People with other pain more often reported to have been diagnosed with rheumatoid arthritis (17%) and degenerative disc disease (20.8%) compared to the other groups.

In Supplementary Table 3, we assessed relationships between the number of pain-related medical diagnoses and scores on the L-VISS and VDS. In the CRPS group, fibromyalgia group, and younger pain-free group there were no relationships between visual discomfort as measured with the L-VISS and VDS, and the

number of pain-related medical diagnoses. In the other pain group, there were moderate positive relationships between the L-VISS and VDS, and the number of pain-related medical diagnoses. In the age-matched pain-free group, there was a small positive relationship between the number of pain-related medical diagnoses and the VDS, which was absent for the L-VISS. It should be noted that, in the current study, the only criterion to be labelled pain-free was the absence of *chronic* pain. Therefore, the pain-free groups could still report experiencing headaches or migraine that was *not* present most days for the last three months, or even pain on the day of testing. The pain-free control group is, therefore, not comparable with control groups from the original studies (Cucchiara et al., 2015; Perenboom et al., 2018), in which people who experienced headaches or migraine were excluded. It is likely that for this reason, the pain-free control group in our study obtained higher scores on the L-VISS and VDS compared to the control groups of the original studies (Supplementary Table 4).

The pain duration in years did not differ between the pain groups. Respondents who reported as having received a diagnosis of CRPS or fibromyalgia reported to have pain more hours per day than the other pain group. All pain groups reported to have higher levels of baseline pain, discomfort, and distress than the pain-free groups. The pain intensity was highest for respondents who reported as having received a diagnosis of CRPS or fibromyalgia.

The body parts that were reported to be painful in the past week are listed in Supplementary Table 1. For all pain groups, the most frequently mentioned body parts were the leg/foot (CRPS: 87.7%; fibromyalgia: 98.7%; other pain: 79.2%), the arm/hand (CRPS: 64.9%; fibromyalgia: 96%, other pain: 56.6%), and the back (CRPS: 50.9%; fibromyalgia: 92%; other pain: 67.9%). For all body parts, more respondents who reported as having received a diagnosis of fibromyalgia reported to have experienced pain in that body part in the past week compared to respondents who reported as having received a diagnosis of CRPS or other pain conditions.

Table 3. Demographic and pain-related characteristics, means (SD) and frequencies (%), split per group.

	CRPS	Fibromyalgia	Other pain	Pain-free age-matched	Pain-free younger	Statistical comparison between groups
N	57	75	53	59	66	
Age	52.16 (13.46)[5]	49.44 (13.54)[5]	47.79 (19.69)[5]	50.86 (11.87)[5]	20.92 (2.91)[1,2,3,4]	$F(4) = 64.82$, $p < .001$
Sex, % female	52 (91.2%)[5]	68 (90.7%)[5]	42 (79.2%)	43 (72.9%)	46 (69.7%)[1,2]	$\chi^2(4) = 16.52$, $p = .002$
Handedness[a]						$\chi^2(4) = 2.17$, $p = .704$
- Left	7 (12.3%)	7 (9.3%)	5 (9.4%)	9 (15.3%)	8 (12.3%)	
- Right	47 (82.5%)	65 (86.7%)	48 (90.6%)	49 (83.1%)	58 (87.9%)	
- Ambidextrous	3 (5.3%)	3 (4.0%)	0	1 (1.7%)	0	
Dyslexia[a]						$\chi^2(4) = 5.28$, $p = .260$
- No	48 (84.2%)	63 (84.0%)	38 (76.0%)	47 (81.0%)	48 (73.8%)	
- Maybe/don't know	7 (12.3%)	7 (9.3%)	9 (18.0%)	8 (13.8%)	12 (18.2%)	
- Yes	2 (3.5%)	5 (6.7%)	3 (6.0%)	3 (5.2%)	6 (9.2%)	
Number of pain-related medical diagnoses	2.12 (1.44)[2,4,5]	3.77 (1.88)[1,3,4,5]	2.32 (1.62)[2,4,5]	0.54 (0.97)[1,2,3,5]	0.18 (0.43)[1,2,3,4]	$F(4) = 75.39$, $p < .001$
(Comorbid) migraine	8 (14.0%)[2]	30 (40.0%)[1,4,5]	11 (20.8%)	7 (11.9%)[2]	3 (4.5%)[2]	$\chi^2(4) = 33.38$, $p < .001$
Pain duration, in years	10.10 (10.12)	14.53 (11.21)	10.75 (10.17)	-	-	$F(2) = 3.42$, $p = .035$
Hours of pain per day	17.95 (7.86)[3]	17.21 (6.45)[3]	9.89 (7.43)[1,2]	-	-	$F(2) = 21.51$, $p < .001$
Pain, 0-10	6.35 (2.25)[3,4,5]	5.80 (1.70)[3,4,5]	4.79 (1.99)[1,2,4,5]	0.83 (1.66)[1,2,3]	0.70 (1.20)[1,2,3]	$F(4) = 151.83$, $p < .001$

Distress, 0-10	4.51 (3.08)[4,5]	3.89 (2.64)[4,5]	3.49 (2.74)[4,5]	0.71 (1.44)[1,2,3]	0.48 (1.15)[1,2,3]	$F(4) = 40.87$, $p < .001$
Discomfort, 0-10	6.46 (2.20)[3,4,5]	6.31 (1.90)[4,5]	5.32 (2.49)[1,4,5]	1.14 (1.66)[1,2,3]	1.21 (1.51)[1,2,3]	$F(4) = 119.48$, $p < .001$

Abbreviation: Complex Regional Pain Syndrome, CRPS. [a]As cells had few counts, for handedness we combined the "left" and "ambidextrous" categories, and for dyslexia the "Maybe/don't know" and "Yes" categories for statistical comparisons. Groups were compared using one-way ANOVAs and Chi-square tests. Post-hoc tests showed that groups differ from [1]CRPS, [2]fibromyalgia, [3]other pain, [4]pain-free age-matched, [5]pain-free younger.

Internal consistency of the L-VISS and VDS

Internal consistency of the L-VISS

Cronbach's alpha for the L-VISS was 0.85 or higher in all three pain groups (Table 4), which is considered good. The item-total correlations were all higher than 0.30, suggesting that all items measured a similar construct. There were no floor (0.3% reported the lowest score) or ceiling effects (1.0% reported the highest score).

Table 4. The internal consistency of the Leiden Visual Sensitivity Scale (L-VISS): Cronbach's alpha and the item-total correlation per item, split per group

	CRPS (*N* = 57)	**Fibromyalgia (*N* = 75)**	**Other pain (*N* = 53)**
Cronbach's alpha	0.89	0.85	0.85
Item-total correlations			
Q1	0.54	0.39	0.43
Q2	0.56	0.52	0.59
Q3	0.54	0.51	0.64
Q4	0.64	0.51	0.53
Q5	0.70	0.62	0.46
Q6	0.69	0.65	0.61
Q7	0.69	0.69	0.62
Q8	0.71	0.63	0.64
Q9	0.75	0.67	0.53

Abbreviation: Complex Regional Pain Syndrome, CRPS.

Internal consistency of the VDS

Three respondents in the other pain group did not finish the VDS and were excluded from the analysis. Cronbach's alpha was 0.94 or higher for all three pain groups, which is considered excellent (Table 5). The item-total correlations were all higher than 0.30, suggesting that all items measured a similar construct. There were no floor (1.9% reported the lowest score) or ceiling effects (0.3% reported the highest score).

Table 5. The internal consistency of the Visual Discomfort Scale (VDS): Cronbach's alpha and the item-total correlation per item, split per group

	CRPS (*N* = 57)	**Fibromyalgia (*N* = 75)**	**Other pain (*N* = 50)**
Cronbach's alpha	0.96	0.94	0.95
Item-total correlations			
Q1	.61	.46	.56
Q2	.73	.50	.56
Q3	.54	.49	.68
Q4	.50	.47	.45
Q5	.64	.67	.57
Q6	.62	.56	.70
Q7	.77	.58	.74
Q8	.61	.53	.74
Q9	.77	.73	.72
Q10	.74	.66	.77
Q11	.81	.74	.74
Q12	.73	.72	.53
Q13	.75	.64	.70
Q14	.80	.75	.75
Q15	.70	.77	.74
Q16	.72	.74	.77
Q17	.66	.72	.54
Q18	.78	.78	.61
Q19	.69	.59	.67
Q20	.83	.63	.80
Q21	.80	.77	.68
Q22	.74	.37	.51
Q23	.60	.68	.74

Abbreviation: Complex Regional Pain Syndrome, CRPS.

Relationships between the L-VISS, VDS, and Pattern Glare Test

There was a moderate positive correlation between the L-VSS and VDS for the fibromyalgia group (r = 0.38, p < .001), and large positive correlations between the L-VISS and VDS for the CRPS (r = 0.65, p < .001) and other pain group (r = 0.68, p < .001; Figure 2). This suggests that the L-VISS and VDS measure similar constructs in people who reported as having received a diagnosis of CRPS or other chronic pain conditions, whereas this is less the case for people who reported as having received a diagnosis of fibromyalgia.

Across groups, there were small to moderate positive relations between L-VISS and VDS scores and visual distortion scores for the 2.3cpd striped pattern of the Pattern Glare Test, which was not always seen for the grey circle and 0.3cpd striped pattern (Table 6). This suggests that, in all groups, the L-VISS and VDS are mostly related to distortions for patterns with a mid spatial frequency.

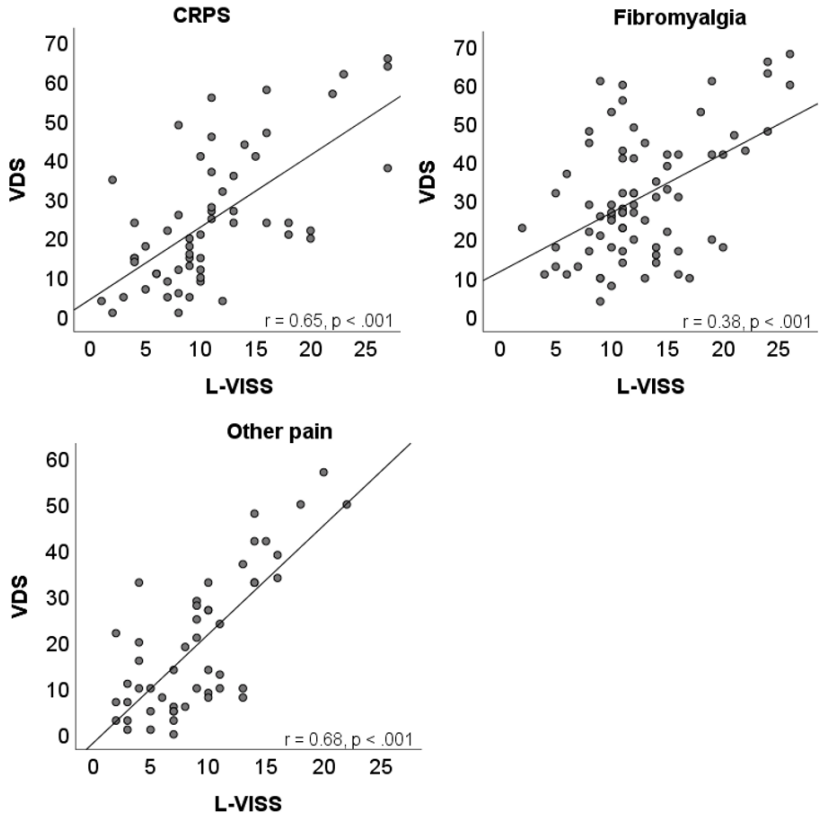

Figure 2. Scatterplots of the Leiden Visual Sensitivity Scale (L-VISS, range 0-27) and Visual Discomfort Scale (VDS, range 0-69) scores, for the Complex Regional Pain Syndrome (CRPS; N = 57), fibromyalgia (N = 75), and other pain group (N = 50).

Table 6. Spearman correlation coefficients between the Leiden Visual Sensitivity Scale (L-VISS), Visual Discomfort Scale (VDS), and the visual distortion scores for each image of the Pattern Glare Test (three respondents in the other pain group did not fill out the VDS).

	CRPS (*N* = 57)	**Fibromyalgia (*N* = 75)**	**Other pain (*N* = 50/53)**
L-VISS and visual distortions			
• Grey circle	0.16	0.34*	0.28*
• 0.3cpd stripes	0.34*	0.43**	0.35*
• 2.3cpd stripes	0.42*	0.33*	0.36*
VDS and visual distortions			
• Grey circle	0.20	0.24*	0.17
• 0.3cpd stripes	0.47**	0.18	0.32*
• 2.3cpd stripes	0.39*	0.25*	0.35*

Abbreviation: Complex Regional Pain Syndrome, CRPS; Leiden Visual Sensitivity Scale, L-VISS; Visual Discomfort Scale, VDS. * $p < .05$, ** $p < .001$.

Comparison of L-VISS and VDS scores between pain conditions and people without pain

Groups differed regarding L-VISS score, $F(3) = 19.17$, $p < .001$, and VDS score, $F(3) = 25.76$, $p < .001$ (Figure 3). The group differences followed the same pattern for both scales. Respondents who reported as having received a diagnosis of CRPS or fibromyalgia did not differ from each other regarding visual discomfort (L-VISS: $r = 0.14$; VDS: $r = 0.18$). Respondents who reported as having received a diagnosis of fibromyalgia obtained higher scores than respondents with other pain, which was a medium effect (L-VISS: $r = 0.35$; VDS: $r = 0.34$), and higher than respondents without pain, which was a large effect (L-VISS: $r = 0.60$; VDS: $r = 0.69$). Respondents who reported as having received a diagnosis of CRPS obtained higher scores than respondents without pain with medium to large effect sizes (L-VISS: $r = 0.47$; VDS: $r = 0.57$), but did not differ from respondents with other pain (L-VISS: $r = 0.19$; VDS: $r = 0.16$). Respondents with other pain obtained higher scores than respondents without pain, which was a medium effect (L-VISS: $r = 0.32$; VDS: $r = 0.46$).

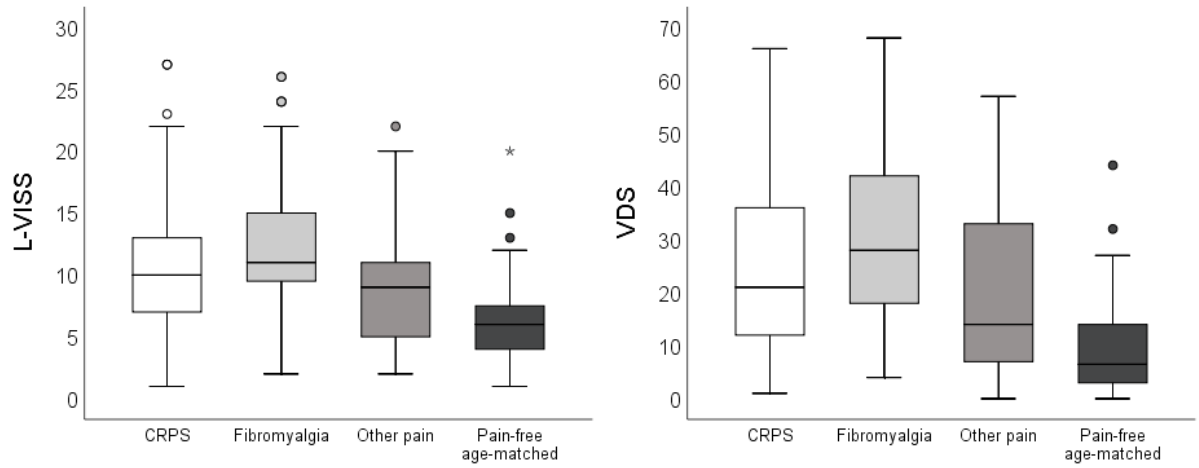

Figure 3. Boxplots depicting the Leiden Visual Sensitivity Scale (L-VISS; left panel) and Visual Discomfort Scale (VDS; right panel) scores, split for Complex Regional Pain Syndrome (CRPS; *N* = 57), fibromyalgia (*N* = 75), other pain (*N* = 53/50), and age-matched pain-free (*N* = 58). The thick line in the middle is the median. The top and bottom box lines show the first and third quartiles. The whiskers show the maximum and minimum values, with the exceptions of outliers (circles) and extremes (asterisks).

Effects of different pain-related medical diagnoses on L-VISS and VDS scores

Results of the regression analyses are depicted in Table 7. For both the L-VISS and VDS, having chronic pain was positively related with more visual discomfort. Having a pain-related medical diagnosis in itself did not predict visual discomfort. Specific pain-related medical diagnoses, however, were related with higher visual discomfort: CRPS, fibromyalgia, and irritable bowel syndrome/inflammatory bowel disease. Migraine predicted L-VISS scores, but was no significant predictor of VDS scores. Osteoarthritis and back pain were no predictors of visual discomfort as measured with the L-VISS nor the VDS.

Table 7. Results of linear regression analyses including all respondents (i.e. CRPS, fibromyalgia, other pain, age-matched pain-free, and younger pain-free) to assess the independent contribution of a given pain-related medical diagnosis on visual discomfort. Only diagnoses for whom at least 10% of participants indicated to have received the diagnosis were included, those percentages are depicted in between the brackets. The depend variables were the Leiden Visual Sensitivity Scale (L-VISS; *N* = 310) and the Visual Discomfort Scale (VDS; *N* = 306).

	L-VISS[1]		**VDS[2]**	
	B (95% CI)	*p*	B (95% CI)	*p*

Age	-0.01 (-0.05 to 0.20)	.408	-0.08 (-0.18 to 0.02)	.112
Chronic pain (59.7%)	2.41 (0.48 to 4.34)	.015*	8.89 (3.11 to 14.68)	.003*
No diagnosis (31.9%)	0.33 (-1.54 to 2.21)	.727	-2.05 (-7.63 to 3.53)	.470
CRPS (18.4%)	2.61 (0.84 to 4.39)	.004*	5.75 (0.39 to 11.12)	.036*
Fibromyalgia (24.5%)	2.65 (0.93 to 4.37)	.003*	8.51 (3.33 to 13.68)	.001*
Osteoarthritis (14.2%)	-0.77 (-2.44 to 0.90)	.366	-2.16 (-7.12 to 2.80)	.392
Back pain (25.8%)	0.36 (-1.01 to 1.72)	.606	-1.40 (-5.46 to 2.66)	.498
Migraine (19%)	2.99 (1.56 to 4.43)	< .001**	4.22 (-0.03 to 8.47)	.052
Irritable bowel syndrome/inflammatory bowel disease (19.0%)	1.70 (0.09 to 3.30)	.038*	5.39 (0.65 to 10.14)	.026*

[1]The model for the L-VISS was significant, $F(9) = 13.00$, $p < .001$, and the explained variance was 30% (R^2). [2]The model for the VDS was significant, $F(9) = 14.91$, $p < .001$, and the explained variance was 31% (R^2). * $p < .05$, ** $p < .001$.

Effects of age on L-VISS and VDS scores

For the L-VISS, there was no correlation with age ($r = -0.04$, $p = .646$; Figure 4). For the VDS, there was a small negative correlation with age ($r = -0.18$, $r = .049$), indicating that visual discomfort slightly decreased with age.

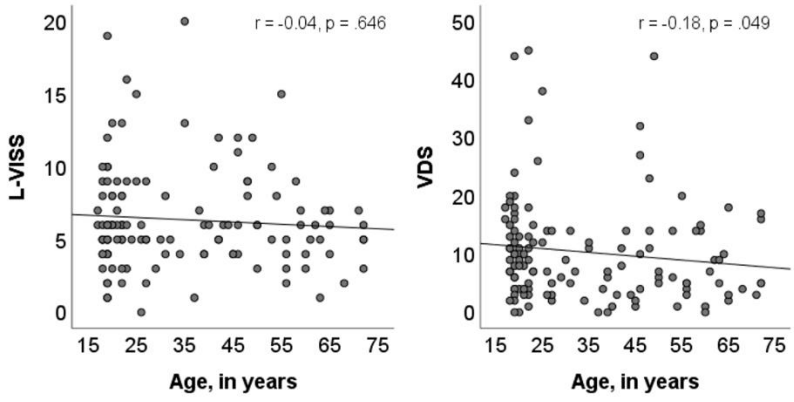

Figure 4. Scatterplots of age and the Leiden Visual Sensitivity Scale (L-VISS, range 0-27; left panel) and Visual Discomfort Scale (VDS, range 0-69; right panel) scores, for pain-free controls ($N = 125$ for the L-VISS and $N = 124$ for the VDS).

Discussion

The L-VISS and VDS have a good internal consistency in people who reported as having received a diagnosis of CRPS, fibromyalgia, or other chronic pain conditions. In addition, the L-VISS and VDS are positively related with experimentally induced visual distortions while viewing striped patterns, which is evidence for good construct validity. Both scales seem to measure similar constructs, as they were positively related with each other, and they discriminated between the different pain and pain-free groups in a very similar way. As both questionnaires are valid and measure similar constructs, there is no reason to use both scales in future studies. The L-VISS (9 items) is shorter than the VDS (23 items), which could be a reason to choose the L-VISS over the VDS. Another reason to prefer the L-VISS over the VDS is that having dyslexia might increase VDS scores due to the strong focus on reading. Although some relationships between dyslexia and visual discomfort have been found in previous studies, dyslexia and visual discomfort are not the same and it is important to differentiate between them (Wilkins et al., 2016). Finally, there was no relationship between age and visual discomfort as measured with the L-VISS, whereas a small negative relationship was seen between age and VDS scores. This finding is in line with the lower number of perceived visual distortions for striped patterns in an older versus younger group of people consulting the optometric practice (Evans & Stevenson, 2008) and the lower reports of photophobia in older versus younger people with migraine (Bigal et al., 2006). This suggests that the VDS is a better questionnaire to use when age differences are relevant.

In people with migraine, visual distortions are especially pronounced for patterns with a higher (e.g. 2.3cpd) versus lower (e.g. 0.3cpd) spatial frequency (Conlon et al., 2001; Wilkins et al., 1984), whereas this difference was not that clear in our chronic pain groups. All groups showed positive relationships either for the L-VISS and/or the VDS with the 0.3cpd pattern and/or the grey circle. In other words, the 0.3cpd pattern and the grey circle also induced visual distortions, and to a greater extend in respondents who reported visual discomfort in daily life. This could be due to the contrast of the 0.3cpd stripes and grey circle, and their presentation on a bright computer screen. Thus, although striped patterns with higher spatial frequencies most likely induce more visual distortions, striped patterns and geometric figures in general can induce visual distortions in people with chronic pain, which are related with visual discomfort in daily life.

Comparing scores on the L-VISS and VDS between groups showed that, in line with our expectations, people with chronic pain reported more everyday visual discomfort compared to age-matched people without chronic pain. Furthermore, people who reported as having received a diagnosis of fibromyalgia obtained highest visual discomfort scores, followed by people who reported as having received a diagnosis of CRPS. This adds to

the evidence that central sensitization is an important mechanism of visual discomfort, as hypothesized based on migraine studies.

The regression analyses showed positive relationships between visual discomfort and having received a diagnosis of CRPS, fibromyalgia, irritable bowel syndrome/inflammatory bowel disease, or migraine; whereas no such relationships were seen with the diagnoses of osteoarthritis and back pain. Although this was a secondary analysis and not hypothesis-driven, it is notable that the pain conditions that showed a positive relationship with visual discomfort are those in which central sensitisation plays the largest role (i.e. CRPS, fibromyalgia, irritable bowel syndrome/inflammatory bowel disease, and migraine; e.g. Adams & Turk, 2015; Littlejohn & Guymer, 2019; Moshiree, 2006; Nijs et al., 2019; Verne & Price, 2002; Yunus, 2008). However, there is also evidence of central sensitisation in subgroups of people with osteoarthritis and chronic lower back pain, and chronic pain in general (e.g. Arendt-Nielsen et al., 2018; Nijs et al., 2017; O'Neill & Felson, 2018). A direction for future research is to compare scores on the L-VISS and VDS in people with chronic pain (regardless of diagnosis) to metrics that are thought to reflect central sensitization (e.g. from Quantitative Sensory Testing, questionnaires, or (f)MRI; den Boer et al., 2019). Nevertheless, our results comparing groups of patients with different conditions are in line with previous studies in which it was stated that deep somatic or visceral chronic conditions have the most profound effect on the development of central sensitisation, which is less the case for other chronic pain conditions (Arendt-Nielsen et al., 2018; Nijs et al., 2019).

Limitations

We conducted an online survey in order to include people who live distant from our lab and/or are not able to travel. To maximise sample size, we distributed the survey internationally. We did not confirm English language comprehension in our respondents. A first limitation is therefore that some of the English terms might not be consistent across countries or fully understood by non-native speakers.

Second, we had less control over the testing environment than is possible for in-person laboratory studies (e.g. the type of computer used, viewing distance, distractions, and whether respondents understood the instructions). To partially overcome these issues, we blocked participation through mobile devices, included a CAPTCHA test to block robotic responses, included images for which the effects were not dependent on viewing distance, and included control questions to measure participant engagement.

Third, groupings (e.g. of CRPS, fibromyalgia, and migraine) were based on self-reported diagnoses rather than independent clinical evaluation, and we did not dissociate between subtypes (e.g. CRPS type 1 and 2, migraine

with and without aura). However, in previous research using a similar recruitment strategy, most respondents reported having received their pain-related diagnoses from an appropriately qualified clinician (Ten Brink et al., 2020). Furthermore, the patterns of demographic and pain-related characteristics in our study are consistent with those found in previous research. For example, respondents who reported as having received a diagnosis of CRPS most frequently reported their limb(s) as being most painful, whereas respondents with fibromyalgia reported widespread pain (Wurtman, 2010). There was also a higher proportion of females in the pain groups than the pain-free control groups (Borchers & Gershwin, 2015; Marinus & van Hilten, 2006; Mills et al., 2019; Van Hecke et al., 2013).

Fourth, dyslexia was assessed with only one question. There are different definitions of dyslexia (Wilkins et al., 2016), and a dyslexia questionnaire could have provided a clearer definition of the measured construct. Furthermore, we did not perform additional analysis including dyslexia as a factor, since groups were too small.

Fifth, we omitted the response category "Slightly" for the L-VISS, resulting in a four-point response scale rather than the five-point response sale used in the original version. This means that each item had a maximum score of 3 rather than 4, and the overall maximum score was 27 rather than 36. The omission of the "Slightly" response category could have resulted in some people choosing either "Not at all" or "Moderately" where they might have chosen "Slightly" if that option had been available. It seems more likely that people who otherwise would have chosen "Slightly" would select "Moderately" in this study, as this is the response that reflects the least symptoms out of the responses available. Since the scoring shifted as well (1 point for "Moderately" instead of 1 point for "Slightly"), the effect of the omission of the "Slightly" category on the total score is hard to predict and, most likely, affects all groups in a similar way. Therefore, omitting this response category is unlikely to have affected the results of this study because this relied on comparisons between groups. Despite this omission, the L-VISS appeared valid and yielded group differences as expected. In future studies, the "Slightly" option should be included.

Finally, alternative explanations for differences between groups could be differences in pain intensity, medication, or sleep deprivation. About 67-88% of people with chronic pain report that their sleep is disrupted (Finan et al., 2013), and a night of sleep loss enhances visual discomfort (Dyakova et al., 2019).

Conclusions

The L-VISS and VDS have good internal consistency and construct validity in people who reported as having received a diagnosis of CRPS, fibromyalgia, or other chronic pain conditions, and measure the same construct.

VDS scores are slightly lower in older versus younger people. People who reported as having received a diagnosis of fibromyalgia or CRPS self-report more everyday visual discomfort than people with other chronic pain conditions or people without chronic pain. This adds to the evidence that central sensitization is an important mechanism of visual discomfort, as hypothesized based on studies in people with migraine. The results show that it is valuable to have valid measures of visual sensitivity that could be administered in a variety of situations (e.g. clinic, online, lab). Remote tools that can be delivered online are particularly useful given the current concerns about healthcare access and social distancing.

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Appendix A. Study material

Demographic and pain-related information

Do you have a history of neurological illness or injury such as epilepsy, brain damage, multiple sclerosis, or stroke? (CRPS and fibromyalgia are not considered a neurological illness for this study)

- Yes
- No

What is your sex?

- Male
- Female
- Other

What is your dominant hand?

Please choose the hand that would be your dominant hand naturally (that is, the hand you write with), and not the hand you use for example due to pain in the dominant hand.

- Left
- Right
- Ambidextrous (two-handed)

What is your age in years? _____

Have you been experiencing pain on most days for three months or more?

- Yes
- No

Please select any medical diagnoses that you have received for your pain condition. You can select as many responses as you like so please select all that apply.

- Complex Regional Pain Syndrome (also known as Reflex Sympathetic Dystrophy, Causalgia, or Sudeck's syndrome)
- Fibromyalgia
- Rheumatoid Arthritis
- Osteoarthritis
- Plantar fasciitis
- Hypermobility
- Back pain
- Migraine

- ○ Cluster Headache
- ○ Chronic Fatigue Syndrome (also known as Myalgic Encephalomyelitis or ME)
- ○ Neuralgia
- ○ Oesteoporosis
- ○ Endometriosis
- ○ Irritable bowel syndrome/inflammatory bowel disease
- ○ Degenerative Disc Disease
- ○ Other. Please specify _____
- ○ I have not received any diagnosis for my pain condition

For approximately how long have you been experiencing pain? Please answer in years and months. For example, 6 months would be “0" years and "6" months.

Years: _____

Months: _____

Approximately how many hours per day do you experience pain?

▼ 0-1 ... 24

Where in your body have you felt pain over the last week? Please indicate whether this pain was on the left or right hand side of your body or equally spread across both. You can select as many responses as you like so please select all that apply.

	More pain on the left side than the right side	About the same amount of pain on both sides	More pain on the right side than the left side
Arm/hand (including shoulder, elbow, wrist, fingers)	○	○	○
Leg/foot (including hip, knee, ankle, toes, foot sole)	○	○	○
Back	○	○	○
Head	○	○	○
Face (including ears, eyes, jaw, teeth)	○	○	○
Neck	○	○	○
Chest/ribs	○	○	○
Stomach/abdomen	○	○	○

Groin/genitals	○	○	○
Whole body	○	○	○
Other. Please specify.	○	○	○
I have not felt pain in my body in the past week	○	○	○

Dyslexia question

Do you have dyslexia?

- ○ Yes
- ○ Maybe/I don't know
- ○ No

Pain, discomfort, and distress ratings

Please rate your current level of pain, distress and discomfort with regard to how you feel in your body. *Please try to answer only with regard to how you feel about your body, and not other things. For example, this question is NOT about any pain, distress, or discomfort that you might be feeling related to emotional events or circumstances, such as a death of a loved one.*

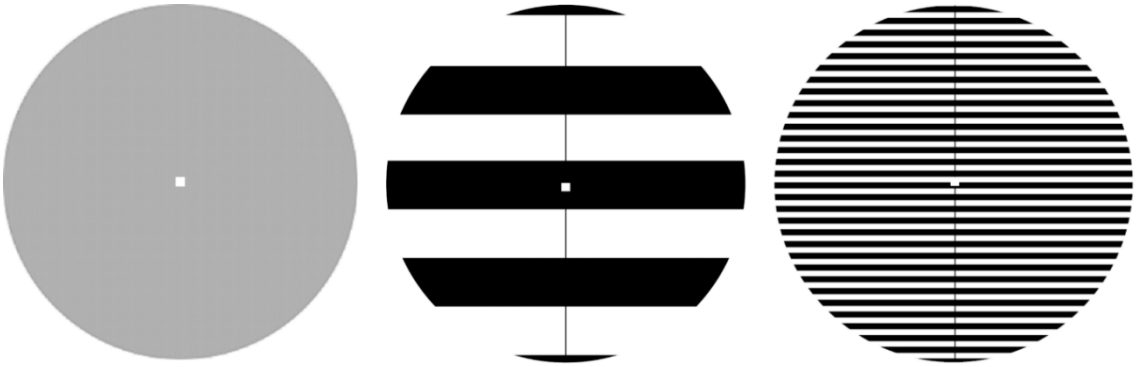
	0 (None)	1	2	3	4	5	6	7	8	9	10 (Worst imaginable)
Pain	○	○	○	○	○	○	○	○	○	○	○
Distress	○	○	○	○	○	○	○	○	○	○	○
Discomfort	○	○	○	○	○	○	○	○	○	○	○

Pattern Glare Test

For this part of the study, you will be shown three different images, one at a time. Please try to look at the dot in the centre of the image for 10 seconds. After 10 seconds, you will be asked a series of questions about the image and any perceptions or sensations you experienced while looking at it. We will ask whether you perceived:

- Colours (other than grey, black and white)
- Bending of lines
- Blurring of lines
- Shimmer/flicker
- Fading
- Shadowy shapes
- Other effects (please specify)

And we will ask at which side you saw the effects (mainly left, both sides, or mainly right?). Note that you might not see any of these effects. When the image is presented, please keep your eyes focused on the central fixation dot (see example below). Click 'next' to view the first image.



[Each of the above images was presented one. The instructions and questions were the same for all three images.]

Please try to answer the following questions based on the first thing that comes to mind. You may look at the image again if you wish. To what extent did you perceive the following:

	Not present	Mild	Moderate	Strong
Colours (other than grey, black and white)	○	○	○	○
Bending of lines	○	○	○	○
Blurring of lines	○	○	○	○
Shimmer/flicker	○	○	○	○
Fading	○	○	○	○
Shadowy shapes	○	○	○	○
Other effects	○	○	○	○

Please specify what other effects you perceived _____

	Mainly left	Both sides	Mainly right
Colours (other than grey, black and white)	○	○	○
Bending of lines	○	○	○
Blurring of lines	○	○	○
Shimmer/flicker	○	○	○
Fading	○	○	○
Shadowy shapes	○	○	○
Other effects	○	○	○

Leiden Visual Sensitivity Scale

Please answer the following questions. For all following questions, choose the answer that is most appropriate with regards to a situation that is normal for you (e.g. if you have glasses, answer them with respect to when you would wear glasses). If in doubt, tick which ever feels like the truest answer.

	Not at all	Moderately	Severely	Very severely
To what extent does sunlight bother you when you're not wearing sunglasses?	○	○	○	○
To what extent are you bothered by artificial lighting?	○	○	○	○
To what extent are you bothered by flickering lights? (e.g. a flickering lamp, during films or in a nightclub)	○	○	○	○
When you look at a bright light, is your eyesight worse afterwards? (e.g. blurred or distorted vision)	○	○	○	○
For this statement, please choose 'Very severely' (this is a control question)	○	○	○	○
To what extent does looking at patterns bother you? (e.g. patterns in clothing, materials, blinds)?	○	○	○	○
When you look at everyday patterns, do you experience afterimages? (seeing an image of the pattern elsewhere, for instance, on a white wall)	○	○	○	○
When you look at patterns, is your eyesight worse? (e.g. blurred or distorted vision)	○	○	○	○
When you look at a computer or TV screen, do you see afterimages? (seeing an image of the pattern elsewhere, such as on a white wall)	○	○	○	○
When you look at a computer or TV screen, is your eyesight worse? (e.g. blurred or distorted vision)	○	○	○	○

Visual Discomfort Scale

Please answer the following questions. For all following questions, choose the answer that is most appropriate with regards to a situation that is normal for you (e.g. if you have glasses, answer them with respect to when you would wear glasses). If in doubt, tick which ever feels like the truest answer.

	Event never occurs	Occasionally, a couple of times a year	Often, every few weeks	Almost always
Do your eyes ever feel watery, red, sore, strained, tired, dry, gritty, or do you rub them a lot, when viewing a striped pattern?	○	○	○	○
Do your eyes ever feel watery, red, sore, strained, tired, dry or gritty, after you have been reading a newspaper or magazine with clear print?	○	○	○	○
Do your eyes ever feel watery, red, sore, strained, tired, dry or gritty, when working under fluorescent lights?	○	○	○	○
How often do you get a headache when working under fluorescent lights?	○	○	○	○
Do you ever get a headache from reading a newspaper or magazine with clear print?	○	○	○	○
When reading, do you ever unintentionally re-read the same words in a line of text?	○	○	○	○
Do you have to use a pencil or your finger to keep from losing your place when reading a page of text in a novel or magazine?	○	○	○	○
When reading, do you ever unintentionally re-read the same line?	○	○	○	○
When reading, do you ever have to squint to keep the words on a page of clear text from going blurry or out of focus?	○	○	○	○

	Event never occurs	Occasionally, a couple of times a year	Often, every few weeks	Almost always
When reading, do the words on a page of clear text ever appear to fade into the background then reappear?	○	○	○	○
Do the letters on a page of clear text ever go blurry when you are reading?	○	○	○	○
Do the letters on a page ever appear as a double image when you are reading?	○	○	○	○
When reading, do the words on the page ever begin to move or float?	○	○	○	○
When reading, do you ever have difficulty keeping the words on the page of clear text in focus?	○	○	○	○
When you are reading a page that consists of black print on white background, does the background ever appear to overtake the letters making them hard to read?	○	○	○	○
When reading black print on a white background, do you ever have to move the page around, or continually blink to avoid glare which seems to come from the background?	○	○	○	○
Do you ever have difficulty seeing more than one or two words on a line in focus?	○	○	○	○
For this statement, choose 'Often, every few weeks' (this is a control question)	○	○	○	○
Do you ever have difficulty reading the words on a page because they begin to flicker or shimmer?	○	○	○	○

	Event never occurs	Occasionally, a couple of times a year	Often, every few weeks	Almost always
When reading under fluorescent lights or in bright sunlight, does the glare from the bright white glossy pages cause you to continually move the page around so that you can see the words clearly?	○	○	○	○
Do you have to move your eyes around the page, or continually blink or rub your eyes to keep the text easy to see when you are reading?	○	○	○	○
Does the white background behind the text ever appear to move, flicker, or shimmer making the letters hard to read?	○	○	○	○
When reading, do the words or letters in the words ever appear to spread apart?	○	○	○	○
As a result of any of the above difficulties, do you find reading a slow task? (If you have no difficulties, choose 'Event never occurs')	○	○	○	○

Supplementary Table 1. Numbers and percentages of body parts that were painful in the past week, split by group. Note that respondents could report multiple body parts, thus percentages do not sum to 100.

	CRPS (N = 57)	Fibromyalgia (N = 75)	Other pain (N = 53)	Statistical comparison between groups
Arm/hand (including shoulder, elbow, wrist, fingers)	37 (64.9%)[2]	72 (96%)[1,3]	30 (56.6%)[2]	$\chi^2(2) = 30.41$, $p < .001$
Leg/foot (including hip, knee, ankle, toes, foot sole)	50 (87.7%)[2]	74 (98.7%)[1,3]	42 (79.2%)[2]	$\chi^2(2) = 13.07$, $p = .001$
Back	29 (50.9%)[2]	69 (92%)[1,3]	36 (67.9%)[2]	$\chi^2(2) = 28.18$, $p < .001$
Head	20 (35.1%)[2]	58 (77.3%)[1,3]	15 (28.3%)[2]	$\chi^2(2) = 37.46$, $p < .001$
Face (including ears, eyes, jaw, teeth)	18 (31.6%)[2]	53 (70.7%)[1,3]	14 (26.4%)[2]	$\chi^2(2) = 31.33$, $p < .001$
Neck	28 (49.1%)[2]	59 (78.7%)[1,3]	19 (35.8%)[2]	$\chi^2(2) = 25.52$, $p < .001$
Chest/ribs	17 (29.8%)[2]	52 (69.3%)[1,3]	11 (20.8%)[2]	$\chi^2(2) = 35.90$, $p < .001$
Stomach/abdomen	13 (22.8%)[2]	52 (69.3%)[1,3]	14 (26.4%)[2]	$\chi^2(2) = 36.71$, $p < .001$
Groin/genitals	10 (17.5%)[2]	31 (41.3%)[1,3]	8 (15.1%)[2]	$\chi^2(2) = 14.36$, $p < .001$
Whole body	7 (12.3%)[2]	50 (66.7%)[1,3]	10 (18.9%)[2]	$\chi^2(2) = 51.15$, $p < .001$
Other	3 (5.3%)	8 (10.7%)	5 (9.4%)	$\chi^2(2) = 1.25$, $p = .534$

Abbreviation: Complex Regional Pain Syndrome, CRPS.

Groups were compared using Chi-square tests. Post-hoc tests showed that group means differed significantly from [1]CRPS, [2]fibromyalgia, and [3]other pain, after applying the Holm-Bonferroni correction for multiple comparisons.

Supplementary Table 2. Numbers and percentages of pain-related medical diagnoses split by group. Note that respondents could report multiple diagnoses, thus percentages do not sum to 100.

	CRPS (*N* = 57)	Fibromyalgia (*N* = 75)	Other pain (*N* = 53)	Pain-free age-matched (*N* = 59)	Pain-free younger (*N* = 66)	Statistical comparison between groups
CRPS	57 (100%)	0	0	0	0	-
Fibromyalgia	0	75 (100%)	0	0	0	-
Rheumatoid Arthritis	1 (1.8%)	3 (4%)	9 (17%)[4,5]	0[3]	0[3]	$p < .001$
Osteoarthritis	10 (17.5%)[5]	17 (22.7%)[5]	13 (24.5%)[5]	4 (6.8%)	0[1,2,3]	$p < .001$
Plantar fasciitis	3 (5.3%)	11 (14.7%)[5]	1 (1.9%)	5 (8.5%)	0[2]	$p = .002$
Hypermobility	5 (8.8%)	9 (12%)	8 (15.1%)	1 (1.7%)	3 (4.5%)	$p = .048$
Back pain	14 (24.6%)[3,5]	32 (42.7%)[4,5]	26 (49.1%)[1,4,5]	7 (11.9%)[2,3]	1 (1.5%)[1,2,3]	$p < .001$
Migraine	8 (14%)[2]	30 (40%)[1,4,5]	11 (20.8%)	7 (11.9%)[2]	3 (4.5%)[2]	$p < .001$
Cluster Headache	1 (1.8%)	5 (6.7%)	3 (5.7%)	2 (3.4%)	1 (1.5%)	p = .489
Chronic Fatigue Syndrome	1 (1.8%)[2]	18 (24%)[1,3,4,5]	2 (3.8%)[2]	0[2]	0[2]	$p < .001$
Neuralgia	3 (5.3%)	7 (9.3%)	3 (5.7%)	0	0	$p = .012$
Osteoporosis	2 (3.5%)	4 (5.3%)	2 (3.8%)	1 (1.7%)	0	$p = .351$
Endometriosis	2 (3.5%)	7 (9.3%)	1 (1.9%)	1 (1.7%)	1 (1.5%)	$p = .143$
Irritable bowel syndrome/inflammatory bowel disease	4 (7%)[2]	40 (53.3%)[1,3,4,5]	9 (17%)[2]	3 (5.1%)[2]	3 (4.5%)[2]	$p < .001$
Degenerative Disc Disease	2 (3.5%)[3]	10 (13.3%)[4,5]	11 (20.8%)[1,4,5]	0[2,3]	0[2,3]	$p < .001$
None	0[4,5]	0[4,5]	4 (7.5%)[4,5]	40 (67.8%)[1,2,3]	55 (83.3%)[1,2,3]	$p < .001$
Other	8 (14%)[3]	15 (20%)[3]	24 (45.3%)[1,2]	-	-	$p < .001$

Abbreviation: Complex Regional Pain Syndrome, CRPS.

Groups were compared using Fisher Exact tests. Post-hoc tests showed that group means differed significantly from [1]CRPS, [2]fibromyalgia, [3]other pain, [4]pain-free age-matched, and [5]pain-free younger, after applying the Holm-Bonferroni correction for multiple comparisons.

Supplementary Table 3. Spearman correlation coefficients between the Leiden Visual Sensitivity Scale (L-VISS), Visual Discomfort Scale (VDS), and the total number of pain-related medical diagnoses, split per group.

	CRPS (*N* = 57)	**Fibromyalgia (*N* = 75)**	**Other pain (*N* = 50/53)**	**Pain-free age-matched (*N* = 59)**	**Pain-free young (*N* = 66)**
L-VISS and number of pain-related medical diagnoses	0.04	-0.04	0.37*	0.09	0.16
VDS and number of pain-related medical diagnoses	0.10	-0.04	0.32*	0.26*	0.19

Abbreviation: Complex Regional Pain Syndrome, CRPS; Leiden Visual Sensitivity Scale, L-VISS; Visual Discomfort Scale, VDS.

* $p < .05$, ** $p < .001$.

Supplementary Table 4. Inclusion criteria, demographic characteristics, and scores on the Leiden Visual Sensitivity Scale (L-VISS) and Visual Discomfort Scale (VDS) in the control groups of the original studies, and the control groups of the current study.

	Cucchiara et al. (2015)	Perenboom et al. (2018)	Pain-free age-matched	Pain-free younger
General inclusion criteria	25-50 years old (matched by age and sex with the migraine cohort), no history of cerebrovascular or cardiovascular disease or other neurologic illness.	18-65 years old, no psychiatric or neurological disorder.	≥16 years old, no history of neurological illness/injury or epilepsy.	
Pain-related inclusion criteria	Headache-free	No migraine, no other form of headache on more than 1 day per month. No chronic medication use, no history of malignancy.	No chronic pain (i.e. pain on most days for the past 3 months or more)	
N	45	86	59	66
Age, mean (SD)	32.5 (5.6)	38.9 (12.5)	50.86 (11.87)	20.92 (2.91)
Sex, % female	73%	64%	72.9%	69.7%
VDS, median (IQR)	3 (1-6)	-	6.5 (11)	10 (10)
L-VISS, mean (SD)	-	5-option scale (0-36): 3.6 (2.8)	4-option scale (0-27): 6.38 (3.49)	4-option scale (0-27): 6.36 (3.57)