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Low correlation between visual discomfort image ratings and hypersensitivity questions is improved with functional questions☆

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ABSTRACT

To assess visual discomfort, researchers can use questionnaires that require people to self-reflect on their real-world experiences, or researchers can present images and ask for ratings of discomfort while they are viewed. These two methods are conceptualised to measure a similar construct, but they tend to show surprisingly low correlation. A possible reason is that, when viewing the images, people do not know how to calibrate their answers on a standard discomfort scale, because it requires implicit comparison of one's own perception with others (e.g., *is my perception unusually uncomfortable?)*. Here we compared standard discomfort ratings with functional questions that aimed to aid calibration (e.g. *I would need to immediately look away; I could tolerate it as a poster; I could live with it as wallpaper*). We found correlation with questionnaire questions about stripes and patterns improved with the functional style of question. We conclude that functional questions are helpful for assessing visual discomfort.

1. Introduction

Visual discomfort is challenging to measure. Researchers and clinicians would often prefer to have objective psychophysical measures, but visual discomfort is an intrinsically perceptual experience and generally does not correlate with detection or discrimination thresholds (Schulz & Stevenson, 2021; Ward, 2019). Therefore, various measures involving questionnaires or rating images have been developed across multiple disciplines (neurodevelopment, neurology, occupational therapy, psychiatry and mental health). If a general concept of visual discomfort is warranted, then we should expect the correlations between measures to be consistently high where they are used in the same sample, even if they use different stimulus examples or specific questions. However, they do not always do so.

The approaches to measuring visual discomfort fit into two broad categories. The first approach is that of questionnaires, requiring people to self-reflect on general sensitivity or experience with specific stimuli or environments (e.g., Baranek et al., 2006; Brown & Dunn, 2002; Dixon et al., 2016; Perenboom et al., 2018; Price, 2023; Robertson & Simmons, 2013; Schoen et al., 2008; Tavassoli et al., 2014). These questionnaires, while having the known drawbacks of questionnaires in general, tend to show high reliability, internal consistency, and correlate reasonably well with each other (in the range r = 0.6 to 0.9; Horder et al., 2014; Price, 2023; Wang et al., 2022), supporting a general concept of visual hyper-sensitivity. This is also consistent with the factor structure reported by Price (2023) where the four factors of visual hypersensitivity were accompanied by a strong general factor.

The second approach is to show people specific stimuli or images and ask them to rate their discomfort or visual disturbances. For example, the Pattern Glare Test (Evans & Stevenson, 2008; Wilkins, 1995) asks individuals to rate the discomfort and distortions they experience in response to three achromatic gratings of different spatial frequency (e.g., Braithwaite et al., 2013). More specifically for visual discomfort, researchers have asked people to rate their discomfort in response to images with different features and spatial frequency distributions (e.g., Cole & Wilkins, 2013; Fernandez & Wilkins, 2008; Penacchio et al., 2021; Penacchio & Wilkins, 2015). These images include those known to elicit higher discomfort due to their statistical properties, which deviate from those found in natural scenes with an over-representation of mid-high spatial frequencies (Penacchio & Wilkins, 2015). For example, Powell et al. (2021) found individuals with visually-induced dizziness reported heightened discomfort to these static images. Likewise, trypophobia (an irrational fear of holes, argued to be mechanistically related to visual hypersensitivity) is measured by participants rating their

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cognitive, physiological, and skin-related symptoms in response to triggering images (Cole & Wilkins, 2013; Le et al., 2015). Exposure to aversive stimuli is similarly used in investigation of photophobia, where visual discomfort thresholds are determined by the lowest luminance level needed to induce discomfort (Pinheiro et al., 2020).

However, scrutiny of the literature and our own previous data reveals a surprising pattern: the correlation between questionnaires and ratings of discomfort when viewing images or gratings is often surprisingly low. In other words, discomfort ratings to images show low convergent validity (relation to other measures which theoretically assess the same construct) when questionnaires are used as the benchmark. For example, Ward et al. (2017) reported a maximum correlation of r = 0.33 for reported distortions in the pattern glare (mid frequency) with the Glasgow Sensory Questionnaire (GSQ; Robertson & Simmons, 2013), with almost no correlation of discomfort ratings with GSQ, even though both GSQ and discomfort ratings distinguished between synaesthetes and controls.

Does this mean that questionnaires and image ratings tap dissociable aspects of visual discomfort? This is possible given that most questionnaires either do not have any questions relating to stripes or spatial frequencies (e.g., Brown & Dunn, 2002; Robertson & Simmons, 2013), or would not weight such answers highly in the overall score.

An alternative potential reason for the low correlations is that responders do not know how to calibrate their answers and therefore interpret the scale differently (Hartley & Betts, 2010). Discomfort is a perceptual experience and reporting it relies on introspection. The most straightforward calibration for an individual to perform is to compare what they experience across the stimuli or images presented to them. For example, someone experiencing medium discomfort could give the same top rating to a certain 'high discomfort image' as someone with high discomfort, because for both participants that particular image represents the most discomfort of their own personal experience. This would mean the within-participant comparison between images with different properties remains highly robust (as is always found), but between-participant differences in experience would be less apparent – they would be calibrated out. This would dilute correlations with other measures.

In order for someone experiencing medium discomfort (when compared to other people) to give a rating in the middle of the scale, even though they have never experienced higher discomfort themselves, they would have to implicitly compare their experience to the perceptual experience of others – *is my response to this stimulus 'normal' or more uncomfortable than 'normal'*? How would one know how to do this? It is known that large perceptual differences between people can go unnoticed. For example, children, and even adults, who are colour-blind (and their parents) often do not realise their perceptual experience differs from others until they are formally tested (Cole, 1991; Pickford, 1972; Spalding, 1999). Likewise, synaesthesia or dyslexia probably emerge in children much earlier than they become aware that their experience diverges from other people's (Bazen et al., 2020; Chun & Hupé, 2016; Simner et al., 2009).

To test if this explanation contributes to the low correlations, and to attempt to provide a partial remedy, we designed a new 'functional' question that attempted to calibrate responses against hypothetical real-life situations. Instead of asking for a discomfort rating from -5 to 5, we asked, for example, whether people would need to immediately look away from the image, or whether they could live with wallpaper like the image shown. Similar approaches which anchor response scales to functional impairment have been adopted in pain literature (Adeboye et al., 2021; Buckenmaier et al., 2013), but not yet in visual discomfort. To address a similar issue, cognitive, physiological, and skin-related symptoms, rather than only discomfort ratings, are used in assessing trypophobia (Cole & Wilkins, 2013; Le et al., 2015). We compared our new scale to the traditional numeric rating scale, to see if correlations, and therefore construct validity, improved with questionnaire questions about mid-high spatial frequency stripes and patterns, based on the Cardiff Hypersensitivity Scale (CHYPS; Price, 2023).

2. Methods

2.1. Participants

Participants were recruited in two groups of psychology students at Cardiff University, who completed the online survey in exchange for course credit. Group 1 consisted of 525 students, although 6 participants had missing data for this analysis. Mean age was 19.6 (SD = 2.8), 84.7 % reported female gender, 12.6 % male, and 2.3 % non-binary. Group 2 consisted of 417 students, although 88 had missing data for the image ratings (which were optional at the end of a longer survey). Mean age was 19.4 (SD = 1.5), 85.6 % reported female gender, 11.5 % male, and 2.6 % non-binary. Cardiff University's School of Psychology ethics committee provided ethical approval for all procedures [EC.10.03.02.2441G]. Informed consent was obtained from all participants, and experiments were carried out in accordance with the World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects.

2.2. Image ratings

Participants were shown six images and asked to rate their visual discomfort. Three of the images (Fig. 1) were selected from a previous battery of images (Penacchio & Wilkins, 2015; Powell et al., 2021) as those with highest reported discomfort in pilot testing. The other three images were selected as those eliciting the lowest discomfort. Group 1 were simply asked to rate their visual discomfort or comfort, on a scale from −5 ("*Extremely uncomfortable*") to +5 ("*Extremely comfortable*"), as has been used in previous research (Braithwaite et al., 2013; Penacchio et al., 2021; Wilkins, 1995). Group 2 were instead asked the following 'functional' question:

Which of these statements best describes how you feel about this image:

- *I find this image so uncomfortable to look at I would need to look away immediately*
- *I find this image uncomfortable to look at but could tolerate it for very short periods*
- *I find this image a bit uncomfortable, but could tolerate it as a poster if I was sitting opposite it in a café*
- *This image is comfortable enough to look at that it could be hung up as a poster in my home*
- *This image is comfortable enough that I could live in a house where it had been used to wallpaper the living room*

As the images were presented online (Qualtrics survey), spatial frequency (viewing distance) could not be fully controlled. We accepted this source of variability in order to recruit large samples. All participants were required to use a laptop or desktop computer to participate. Viewing distance and screen size data was collected for 475 participants in Group 1 using a virtual chinrest (Li et al., 2020); from this data, we calculated the approximate horizontal visual angle of the images to be 22°, based on a 66 cm average viewing distance. Due to technical issues, similar data was not collected in Group 2. However, participants in both groups received the same instructions regarding positioning themselves at arm's length from the computer. The image size across participants is therefore expected to be comparable.

2.3. Visual (pattern) hypersensitivity questions

As part of a wider survey, we asked three questions about perceptual hypersensitivity to stripes and patterns, based on the CHYPS (Price, 2023). These were: "*Looking at repeating or stripey patterns (*e.g., *patterned flooring, wallpaper, buildings, striped clothing) makes my eyes or head feel so uncomfortable I need to look away from them*"; "*Stripey and repeating*

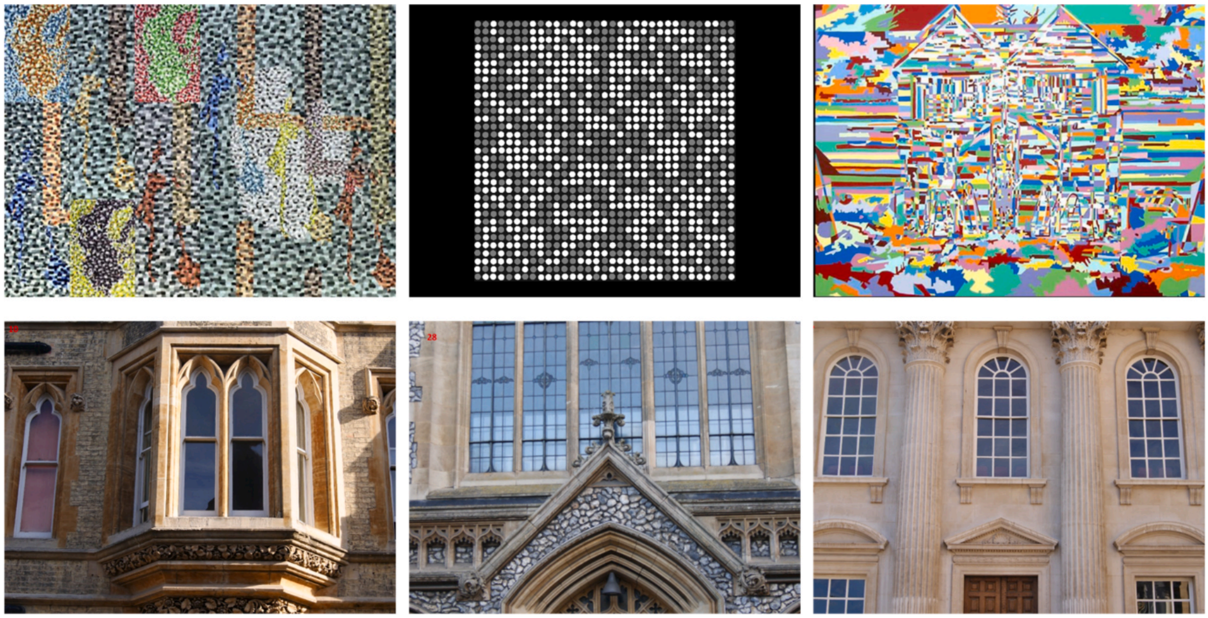

Fig. 1. The three high discomfort (top row) and low discomfort (bottom row) images rated by participants (from Penacchio & Wilkins, 2015, Powell et al., 2021). *Alt Text*: Two rows of images, three for high discomfort and three for low. The top row (high discomfort) includes abstract images with high contrast and mid-high spatial frequencies. The bottom row (low discomfort) includes images of buildings that are stone coloured and relatively low contrast.

patterns and pictures seem to shimmer, flicker, or move when I look at them;" "*Looking at repeating or stripey patterns triggers a headache*". The questions refer to looking away, shimmering, and headaches, rather than simple discomfort or dislike, in order to minimise the same type of calibration problem discussed for the images. Participants answered using a 4-point Likert frequency scale (0 = Almost Never, 1 = Occasionally, 2 = Often, 3 = Almost Always).

2.4. Analysis

For analysis, we simply averaged across the three high discomfort images (reversing the scale for Group 1 so that discomfort was positive in both groups) and averaged across the three hypersensitivity questions. Data preparation and analyses was completed in JASP (version 0.19.1; JASP Team, 2024). Note that one can also subtract the ratings for low discomfort images from those for high discomfort images (e.g. Evans & Stevenson, 2008), but there are known statistical drawbacks of subtraction (e.g., Hedge et al., 2018). Here, however, it made no difference if we had used this subtraction instead of the simple average (see Results). The data and materials necessary to reproduce the findings reported in this manuscript are available at https://osf.io/7x9ar/.

3. Results

As Fig. 2 shows, the correlation between discomfort image ratings using the traditional numeric rating scale and questionnaire answers was relatively low for Group 1 ($r(517) = 0.26$, 95% CI 0.18 to 0.34). The correlation was significantly improved for Group 2 using the new functional questions ($r(327) = 0.47$, 95% CI 0.38 to 0.55). The difference between these correlations was also found to be significant ($z = -3.70$, $p < 0.001$).

Ratings for the three discomfort images were reasonably consistent

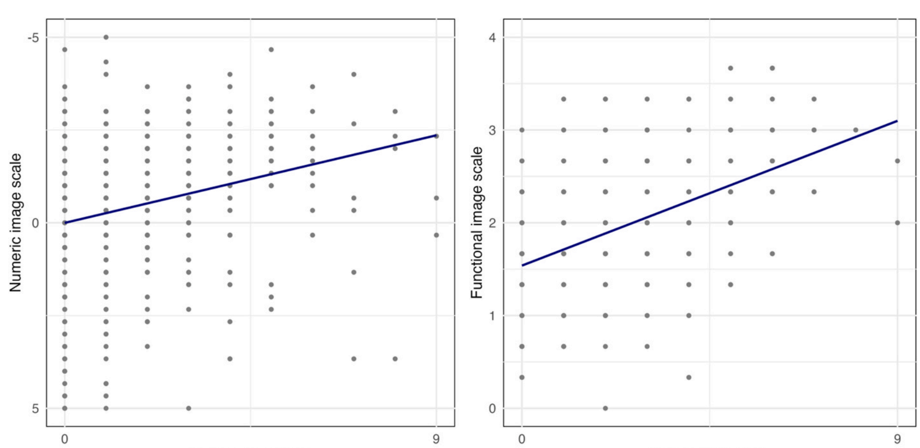

Fig. 2. The correlation between hypersensitivity (pattern) questions and image ratings was low for standard discomfort ratings (A, Group 1n = 519) and improved for the functional question (B, Group 2n = 329). (2A) Uses standard discomfort ratings (Scale = -5 to + 5) and thus has more levels than (2B), which uses functional question ratings (Scale = 0–4). Due to the number of participants and quantised scales, many participants may be plotted at the same location on the plots. *Alt Text*: Two scatterplots of response data, one for numeric scale (2A) and one for functional scale (2B). (2A) shows a weaker correlation when compared to (2B), where the correlation line and associated data points form a steeper pattern.

with each other for both numeric and functional scales (Cronbach alpha = 0.82 and 0.70, respectively). Ratings for the three stripe or pattern questionnaire items were also consistent with each other (Cronbach alpha = 0.78 for Group 1 and 0.81 for Group 2).

Results did not materially alter – in fact the improvement was larger – if we used a subtraction between ratings for high and low discomfort images, rather than a simple average for the high discomfort images (numeric scale $r(517) = 0.08$, 95% CI 0.0 to 0.17; functional scale $r(327) = 0.47$, 95% CI 0.40 to 0.54).

Results also did not alter when the scale used for Group 1 was binned to provide the same number of possible levels as Group 2 (i.e., reducing from 11 levels to 5 levels; $r(517) = 0.24$, 95% CI 0.15 to 0.32).

4. Discussion

Rating the level of internal perceptions and sensations, such as pain or discomfort, is difficult. It often carries implicit comparison with what is normal and what is unusual, which are concepts involving beliefs about the perceptions or sensations of others. One way to help reduce this problem in rating scales is to provide examples of functional responses or behaviours in the real world to help to calibrate responses. For instance, there is growing awareness in pain literature of the need to standardize definitions of pain by considering how it affects function (Adeboye et al., 2021), with corresponding measures anchoring pain ratings to limitations caused by that pain (e.g., "interrupts some activities"; Buckenmaier et al., 2013).

In the case of rating visual discomfort, participants could be asked to rate the extent to which they could tolerate the stimuli in real world settings. This is what we attempted here, and it close to doubled the correlation of discomfort ratings for images with questionnaire questions about hypersensitivity to stripes and patterns. Therefore, we concluded that introspective calibration contributes to the low correlations often seen between discomfort ratings and other measures of sensory hypersensitivity (e.g., Ward et al., 2017).

The correlation remained lower than we might expect, however, if the two measures tap the same sensory experience – the same visual discomfort factor. It is lower, for example, than the correlations of 0.61–0.69 between the previously defined four different factors of visual hypersensitivity: brightness, pattern, strobing and intense visual environments (Price, 2023). Given the extensive range of questions used to elucidate these four factors, and how repeatable the factor solutions were across five cohorts in Price (2023), we do not believe that discomfort ratings to images reflect a fifth distinct type of visual sensitivity. Why, then, should questions about different visual features, delivered in the same questionnaire format, correlate better than questions about similar visual features, delivered in different formats (image ratings vs questionnaire)? Clearly the self-calibration problem that we partially addressed is only part of the issue.

One possibility is that the questions were about distortions as well as discomfort, and distortions elicited by stripes may be dissociable from discomfort. For example, the distortion question here correlated less well with the two stripe questions (r = 0.54 - 0.57 across the groups) than the stripe questions did with each other (r = 0.61 - 0.64 for the two groups). Similarly, distortions perceived with gratings in The Pattern Glare Test do not always correlate highly with comfort ratings for the same stimuli (for example, r = 0.28 for 3 cycles per degree in unpublished data from our lab). However, dropping the distortion question did not improve the correlation between the image ratings and the stripe questions in our results (r = 0.48, 95% CI 0.4 – 0.56).

A second possibility is that the images evoking discomfort are highly abstract and unfamiliar (see Fig. 1), while the questions are about real-life experiences. We only included three high discomfort images, so we cannot assess the difference between abstract images and pictures of real environments that are rated highly for discomfort, though previous research does not give us any reason to expect such a difference (Penacchio & Wilkins, 2015). We used three images partly to offset fatigue and partly because pilot data showed these three images to have the highest discomfort ratings and to be highly correlated with ratings to other discomforting images. An important limitation is that we presented the images on participants' own devices rather than on calibrated screens with controlled size and viewing distance. We ensured that they could only use laptops or computer screens, rather than tablets or phones, but even so there would be some variability associated with the viewing environment. However, the relationship between discomfort and spatial frequency is broad, so exact calibration of spatial frequency should not be necessary.

A related possibility concerning familiarity is that responders (especially students) who are used to filling in questionnaires for research do so quickly and may not pay as much attention as we would like to instructions. Questions in an unfamiliar format – such as rating discomfort to displayed images – may get answered in a slightly different way to questions in a familiar format (such as a Likert scale from never to always). Also, the questions were included in a longer survey addressing other questions, so there is always the risk of fatigue and inattention (Price, 2023). To partially address this, we included comprehension questions and catch questions (see Price, 2023), but this problem remains a limitation of cohorts that are familiar with questionnaires and motivated to complete them quickly.

Finally, it would have been useful to have qualitative feedback from participants about how they interpreted the scales in order to confirm or refute our intuition that calibration is difficult, and people settle on different solutions.

In conclusion, the experience of visual discomfort is difficult to calibrate across individuals and asking functional questions can help with this problem and improve the assessment of visual discomfort. However, there remain issues to address and understand, given that the correlation with questionnaires remains lower than we would expect for two measures of the same construct.

CRediT authorship contribution statement

Alice Price: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Georgina Powell:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Petroc Sumner:** Writing – original draft, Visualization, Supervision, Methodology, Conceptualization.

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Data availability

The data and materials necessary to reproduce the findings reported in this manuscript are available at https://osf.io/7x9ar/.

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