Assessment of trypophobia and an analysis of its visual precipitation

An T. D. Le, Geoff G. Cole, and Arnold J. Wilkins

University of Essex

Address for correspondence:

An Trong Dinh Le

Department of Psychology,

University of Essex,

Colchester CO4 3SQ, United Kingdom

E-mail: ale@essex.ac.uk. Tel: +44 (0)1206874919

Fax: +44 (0)1206873590

Abstract

We developed and validated a symptom scale that can be used to identify "trypophobia", in which individuals experience aversion induced by images of clusters of circular objects. The trypophobia questionnaire (TQ) was based on reports of various symptom types, but it nevertheless demonstrated a single construct, with high internal consistency and test-retest reliability. The TQ scores predicted discomfort from trypophobic images, but not neutral or unpleasant images, and did not correlate with anxiety. Using image filtering, we also reduced the excess energy at mid-range spatial frequencies associated with both trypophobic and uncomfortable images. Relative to unfiltered trypophobic images, the discomfort from filtered images experienced by observers with high TQ scores was less than that experienced with control images and by observers with low TQ scores. Furthermore, we found that clusters of concave objects (holes) did not induce significantly more discomfort than clusters of convex objects (bumps), suggesting that trypophobia involves images with particular spectral profile rather than clusters of holes *per se*.

Keywords: phobia, holes, questionnaire, visual stress

Assessment of trypophobia and an analysis of its visual precipitation

Specific phobias have been defined as “marked fear or anxiety about a specific object or situation” (DSM-V; American Psychiatric Association, 2013, p. 197), and are classified as anxiety disorders. A specific phobia is reliably bound to a particular object or situation (the phobic stimulus), and emerges when individuals engage the phobic stimulus in thought or action (Bruce & Sanderson, 1998). Specific phobias are the third most common psychiatric disorder among adults in the US, with a lifetime prevalence of 12.5% (Kessler et al., 2005).

Two of the most prominent theories that have been offered as explanations for phobias either involve learning (e.g., Merckelbach & Muris, 1997) or innate evolutionary mechanisms (Marks & Nesse, 1994). Seligman (1971) made the point that conditioning theory cannot explain all phobias because (1) phobias tend to be induced by a rather limited set of objects and (2) not all phobias necessarily reflect the potential danger of the object or situation. To account for these aversions within learning theory, a “biological preparedness” viewpoint was offered: phobias can develop as a result of ancient selection pressures associated with self-defence, and thus have survival value (see also McNally, 1987). Support for this view has been reported in studies of rhesus monkeys (Cook & Mineka, 1989) who watched videotapes of peer monkeys reacting fearfully to fear-relevant stimuli (e.g., toy snakes) and acquired fear. Fear-irrelevant stimuli (e.g., flowers) did not have the same effect. This suggests that although phobias can be learned, innate mechanisms may also contribute.

Among the various phobias reported, one of the most theoretically interesting is “trypophobia”, often described as the irrational fear of holes (Cole & Wilkins, 2013; Skaggs, 2014). The inducing stimuli can be any image that presents clusters of small objects in proximity to each other. The most commonly cited such image is the seed head of the lotus flower (see Figure 1), a harmless plant that has been used within Chinese herbal medicine (Ohkoshi et al., 2007) or as food in some countries (Bailey, 1975). Another example of trypophobic stimuli is the honeycomb (see Figure 1). Upon seeing such images, one individual from a trypophobia community on the web reported that "…the pictures make me feel incredibly anxious and uneasy" (S. M, personal communication, June 1, 2014). Others report that the aversion affects their daily or professional life. For example, a biology student wrote: "…learning about cells has been absolutely horrifying" (L. H, personal communication, February 22, 2014). One interesting aspect of trypophobia is that the stimuli inducing the aversion are generally innocuous images that pose no threat, making the phenomenon hard to explain in terms learning theory (Cole & Wilkins, 2013).

INSERT FIGURE 1 ABOUT HERE

Cole and Wilkins (2013) asked 91 male and 195 female adults whether they found the lotus seed head "uncomfortable or even repulsive to view". Eleven percent of males and 18% of females indicated that they did, suggesting that some 15% of the general population is sensitive to images associated with trypophobia. Despite this, the condition is rarely reported in the literature, and there currently exists no formal definition. Partly as a consequence of this, "trypophobia" does not yet represent a phobia as defined by the DSM-V (American Psychiatric Association, 2013). Rather, the term stands for the fear of holes, as described by (Cole & Wilkins, 2013; Skaggs, 2014).

Self-report scales are central to the measurement and assessment of anxiety disorders, such as arachnophobia (Szymanski & O'Donohue, 1995), ophidiophobia

(Klorman, Weerts, Hastings, Melamed, & Lang, 1974) or claustrophobia (Radomsky, Rachman, Thordarson, McIsaac, & Teachman, 2001), and the literature reports developments and refinements of numerous scales to serve this purpose (e.g., Beidel, Turner, & Morris, 1995; Cutshall & Watson, 2004; Salkovskis, Rimes, Warwick, & Clark, 2002). The initial step in developing a scale is to generate an item pool, and Glass and Arnkoff (1997) described three ways of doing so: (a) by consulting the theoretical and empirical literature, including prior measures, diagnostic criteria or clinical experience items (e.g., Turner, Johnson, Beidel, Heiser, & Lydiard, 2003); (b) structural interviews with patients (e.g., Ehlers et al., 2007); and (c) empirically investigating the client's thoughts through methods of cognitive assessment (e.g., thought listings or thinking aloud).

The first aim of the current paper was to develop and validate a self-report questionnaire for trypophobia (Trypophobia Questionnaire; TQ) that represents symptoms typically associated with the condition. The psychometric properties of the scale will be investigated by assessing the following aspects: (a) the underlying construct within a scale (factor structure; Costello & Osborne, 2005; Furr, 2011; Meyers, Gamst, & Guarino, 2012); (b) the reliability of the scale (internal consistency and test-retest; Meyers et al., 2012; Radomsky et al., 2001; Rust & Golombok, 1999); (c) how well the scale correlates with other measures that conceptually or theoretically should be related (convergent validity; Glass & Arnkoff, 1997; Mellenbergh, 2011; Radomsky et al., 2006; Salkovskis et al., 2002; Turner et al., 2003; Van Diest, Smits, Decremer, Maes, & Claes, 2010). Furthermore, one of the requirements for specific phobias outlined by the DSM-V is that "the disturbance is not better explained by the symptoms of another mental disorder, including fear, anxiety…"**.** Rachman (2004) described anxiety as "one of the most prominent and pervasive emotions, and a large number (of individuals) are distressed by inappropriate and excessive anxiety" (p. 1). It is also a recurring theme among the testimonials from individuals who report trypophobia. Here, the discriminant validity (Mellenbergh, 2011; Öst, 2007; Papageorgiou & Wells, 2002; Radomsky et al., 2001) was investigated by examining the relationship between the symptom scale for trypophobia and general anxiety.

Although trypophobia is widely regarded as the fear of holes *per se* (Cole & Wilkins, 2013; Skaggs, 2014), testimonials from individuals indicate that it is not just holes that induce this condition. For example, one individual reported symptoms upon observing "…clusters of bumps, holes, or patterns" (J. L. M., personal communication, April 20, 2014), suggesting that fear of *holes* might not be the most appropriate description. In support of this, images of skin lesions (i.e., clusters of spots) also appear on the trypophobia website (www.trypophobia.com), suggesting that clusters of objects other than holes can also induce symptoms. The second aim of this paper was to investigate whether clusters of concave objects (i.e., holes) are found more uncomfortable than clusters of convex objects (i.e., bumps).

Cole and Wilkins (2013) noted that it is the visual structure of the inducing stimulus that is aversive and contrasted this with phobias (e.g., ailurophobia) where the presence of the object is often enough to cause distress, regardless of whether it is visible. Typical images from nature tend to have consistent spatial properties that the human visual system processes efficiently, and little discomfort is induced by such stimuli (Fernandez & Wilkins, 2008). Such properties can be elucidated by Fourier analysis, which makes it possible to express any image in terms of sinusoidal variations in luminance with different spatial frequencies, phases, amplitude and orientation. When such spectral analyses are performed on images from natural scenes, it is well established (e.g., Field, 1987) that they show a characteristic feature concerning the relationship between spatial frequency and Fourier amplitude. Specifically, a slope of roughly 1/f is found (or a slope of -1 for log amplitude versus log spatial frequency), meaning that amplitude decreases as spatial frequency increases. Images that induce discomfort do not share this 1/f characteristic. For example, Juricevic, Land, Wilkins, and Webster (2010) filtered images of "visual noise", varying the slope of the amplitude spectrum. Images having Fourier amplitude spectra with slopes greater than and less than 1/f were found to be more uncomfortable to view.

In complex images, Fernandez and Wilkins (2008) reported that discomfort was related to the extent to which the images contained excess energy at mid-range spatial frequencies, i.e., a "bump" relative to the 1/f slope. Prompted by this, Cole and Wilkins (2013) performed a spectral analysis of the images obtained from a trypophobia website (www.trypophobia.com), and found that they too contained greater energy at mid-range spatial frequencies when compared with a set of control images of holes. This suggests that trypophobic images possess a particular low-level visual characteristic that is known to be associated with discomfort among both clinical groups (e.g., Shepherd, 2001; Wilkins, Andermann, & Ives, 1975) and the general population (e.g., Fernandez & Wilkins, 2008; O'Hare & Hibbard, 2011; Wilkins et al., 1984). Hence, the third and final aim of the present paper was to further investigate the role of the spectral composition of images that induce trypophobia.

Study 1. Construction of a scale and initial psychometric properties

The condition called "trypophobia" has not yet been recognised as a disorder in DSM-V, and there are no formal methods of selecting participants other than by their participation in a website support group. In order to generate an item pool for the scale development, the most common symptoms induced by trypophobic images were obtained from testimonials provided by individuals in this support group. This was one of the methods proposed by Glass and Arnkoff (1997). The data obtained were then corroborated by data from a group of participants recruited more conventionally.

Initial psychometric properties of the scale were investigated by assessing the underlying construct within the scale (factor structure; Costello & Osborne, 2005; Furr, 2011; Meyers et al., 2012) and the reliability of the scale (internal consistency and test-retest; Meyers et al., 2012; Radomsky et al., 2001; Rust & Golombok, 1999). In order to find a criterion that best distinguished between individuals who report trypophobia and a more general sample, a sensitivity and specificity analysis was conducted.

Method

Participants

In the first experiment the testing was based on the web. Two samples were recruited. One sample included 155 volunteers (28 males, 127 females) who used the trypophobia Facebook page (the ‘web-based’ trypophobic cohort), aged from 18 to 73 years (M = 30.1, SD = 11.3). The second sample (to corroborate the ‘web-based’ trypophobic cohort) included 117 individuals (33 males, 84 females) recruited from a panel of University of Essex student and staff volunteers (the ‘university’ group), aged from 18 to 50 years (M = 23.1, SD = 5.81).

Materials

Symptoms were derived from testimonials provided by individuals who used the internet-based supporting group for trypophobia (https://www.facebook.com/groups/3318322299/, accessed 15th April 2013).

Comments from two hundred individuals were collected, dating from 19th September 2012 to 15th April 2013, in which symptoms induced by viewing trypophobic images were reported. For example, comments such as "I was so uneasy and itchy and disturbed…" were coded as "uneasy", "itchy" and "disturbed". Comments that did not involve any descriptions of symptoms were disregarded.

Nineteen similar symptoms were merged together to create six items. Comments about feeling sick were coded as "Feel sick or nauseous", whereas comments about being sick were coded as "vomit". "Aversion", "disgust" and "repulsion" were combined to form the item "Feel aversion, disgust or repulsion"; "uncomfortable" and "uneasy" were combined to form the item "Feel uncomfortable or uneasy"; "panic" and "screaming" became "Panic or scream"; "anxious", "dreadful" and "fearful" became "Feel anxious, full of dread or fearful"; "butterflies in stomach", "heart pound", "clammy hands", "sweating" and "stomach ache" were considered as subcategories of "nervous", and were combined to form the item "Feel nervous (e.g., heart pounding, butterflies in stomach, sweating, stomach ache, etc.)" In addition, eleven symptoms that we considered not to resemble others were regarded as discrete (e.g. itchiness). Symptoms that were reported less than five times (2.5%) were removed from the item pool, unless they were combined with other symptoms to form an item. In total, seventeen items reflected the most common symptoms as a result of viewing trypophobic images and comprised a preliminary scale. The item pool consisted of three categories of items:

1. Cognitive-related symptoms, such as "Uneasy" or "Aversion". Six items were included for this category.
2. Skin-related symptoms, such as "Itchiness" or "Skin crawl". Four items were included for this category.

3. Physiological symptoms, such as “Nausea” or “Have trouble breathing”. Seven items were included for this category.

In addition, two foil items were included in the item pool, “Feel at peace” and “Want to laugh”. The purpose of the foil items was to include aspects that were not expected to relate to the other items, which should be apparent in a factor analysis.

Procedure

A web-based software survey tool, Qualtrics (www.qualtrics.com), was used to present the questionnaire. Participants were presented with a welcome screen informing them about the procedure. They were informed that the illustrative images included might be found aversive. Consent was obtained by choosing either “Agree” or “Disagree”, the former indicating that the information had been read, that participation was voluntarily and that the participant was 18 years or older. The next section involved viewing images that appeared on a trypophobia website (www.trypophobia.com). Two images were presented at the outset of the questionnaire, illustrating a lotus seed head and a honeycomb. The version distributed to the ‘web-based’ trypophobic cohort included an option to skip the images if necessary. It was expected that the individuals who were members of a trypophobia group and report trypophobia were familiar with such images.

Each symptom in the scale (see Table 1) was rated according to the extent that the reaction to which it referred occurred when observing trypophobic images, using a 5-point Likert scale: 1 (Not at all), 2 (Slightly), 3 (Moderately), 4 (Considerably) and 5 (Extremely).

Results

Construct validity

The data for the two samples of participants were initially combined in order to reach a sample size described as “good” (i.e., 300 subjects) by Comrey (1988). The seventeen preliminary items and two foil items were subjected to a principal axis factoring with promax rotation (Furr, 2011). Two factors were identified with eigenvalues greater than 1, but the scree plot indicated a single-factor model as the two other factors fell under the “elbow” (Floyd & Widaman, 1995). The foil item “Feel at peace” had the weakest (negative) loading at -.460, whereas the foil item “Want to laugh” did not load above .3 with the factor. As expected, both the foil items showed little or no relationship to the unitary structure.

When the foil items were removed, the remaining items were again subjected to a principal axis factoring with promax rotation, and a single-factor solution was again obtained. The factor yielded an eigenvalue of 10.8 and explained 63.3% of the total variance. Table 1 summarises the items within the factor and their respective loadings. Separate factor analyses for the trypophobic and university samples yielded broadly similar findings: there remained a single factor with overall good factor loadings, shown in the final columns of Table 1. Although one item (“Have an urge to destroy the holes”) had a weaker loading with the factor for the ‘web-based’ trypophobic group, Costello and Osborne (2005) argued that sample sizes could significantly affect how items are classified, which suggests that the strengths of the factor loadings for low sample sizes should be interpreted with caution.

INSERT TABLE 1 ABOUT HERE

The results suggested that the scores from the seventeen items (excluding the foil items) could be averaged in order to obtain a composite score. This score will be referred to as the TQ score, which can range from 17 to 85.

Internal consistency

Cronbach´s Alpha was 0.96 for the scale (all participants). The item-total correlations ranged from .57 to .85.

Test-retest reliability

Fifty-three individuals (10 males, 43 females) from the ‘web-based’ trypophobic cohort, aged from 18 – 61 (M = 32.4, SD = 10.3), agreed to be contacted at a later stage, and after four weeks they were sent the TQ by e-mail to complete a second time. A paired-samples t-test indicated that the TQ score did not significantly differ over the 4-week interval, initial test (M = 52.5, SD = 13.2) and re-test (M = 51.2, SD = 13.2), $t(52) = 1.31$, $p = .195$, $d = .1$. The Pearson’s correlation was $r(51) = .85$, $p < .001$, suggesting a good test-retest reliability.

Sensitivity and specificity

Sensitivity and specificity refer to the ability of a diagnostic test to detect individuals with and without disease (Akobeng, 2007). Lalkhen and McCluskey (2008) described sensitivity as the proportion of true positives correctly identified (i.e., the probability of correctly diagnosing patients with the condition), and specificity as the proportion of false negatives correctly identified (i.e., the probability of correctly rejecting patients without the disease).

Prior to the sensitivity and specificity analysis, a criterion for outliers (in terms of TQ score) was defined in order to make the results more representative. Tukey’s method (Tukey, 1977) uses the lower quartile (Q1; 25th percentile) and the upper quartile (Q3; 75th percentile) of the data, in addition to the inter-quartile range, which is defined as the interval between Q1 and Q3. Outliers are described as values outside a range, which is defined as Q1-(r*IQR) and Q3+(r*IQR). Common r factors have been reported as 1.5 or 2.2 (e.g., Hoaglin, Iglewicz, & Tukey, 1986; Joaquim & Marques, 2007; Tukey, 1977). In order to remain conservative, the r factor of 1.5 was used in the current study. The method revealed 14 outliers in the ‘university’ group (TQ scores above 34), which were excluded from subsequent analyses (Study 1 and Study 2). No outliers were detected for the ‘web-based’ trypophobic cohort.

All the outliers were high scores (above 34), indicating a positive skew, and suggesting that the ‘university’ group included a few individuals with trypophobia, as might be expected. These individuals were excluded from subsequent analyses, although we performed analyses in which the outliers were included, and reported those occasions on which their inclusion changed the results.

To find the optimal score that separated those who report trypophobia (the ‘web-based’ trypophobic cohort) and a general sample (the ‘university’ group), the (a) sensitivity, (b) specificity and (c) the average of a and b was calculated for various cut-points in the TQ score. This is summarised in Table 2.

INSERT TABLE 2 ABOUT HERE

The highest average sensitivity and specificity was obtained at TQ score above 31, represented in bold letters in Table 2. The Receiver Operating Characteristics (ROC) curve showed that the area under curve (AUC) was 0.987. This AUC value exceeds the 0.80 criterion suggested by Meyers et al. (2012), indicating that the TQ provides an excellent basis for identifying trypophobia.

Discussion

A factor analysis revealed that the seventeen symptoms most commonly reported by individuals self-diagnosed with trypophobia show a single construct, despite the heterogeneous nature of the questionnaire items, and regardless of the group from which the data were obtained, whether web-based or students recruited to the study. All the items satisfied the criterion for acceptable loadings suggested by Kline (1994). The scale also had a strong internal consistency, and acceptable item-total correlations above .4, as suggested by Kline (1986). Good test-retest reliability after four weeks was demonstrated, notwithstanding the fact that in this sample all the respondents reported symptoms, and in consequence the number of symptoms had a relatively small range. The sensitivity and specificity analysis suggested that a score above 31 is likely to be drawn from the cohort of individuals who report trypophobia. It is recommended that this criterion should be applied when using the TQ as an initial measurement for trypophobia.

Study 2. Convergent and discriminant validity

Further psychometric properties of the scale developed in Study 1 were investigated by asking the participants to rate images that have been reported to induce trypophobia, in addition to neutral (non-trypophobic) images of holes and images of unpleasant objects (convergent validity; Glass & Arnkoff, 1997; Mellenbergh, 2011; Radomsky et al., 2006; Salkovskis et al., 2002; Turner et al., 2003; Van Diest et al., 2010). A spectral analysis of the images was performed in order to compare the images to the ones reported in Cole and Wilkins (2013). Furthermore, the relationship between the TQ and general trait anxiety, using the trait version of the Spielberger State-Trait Anxiety Inventory (STAI; Spielberger & Gorsuch, 1983), was investigated in order to demonstrate the discriminant validity (Mellenbergh, 2011; Öst, 2007; Papageorgiou & Wells, 2002; Radomsky et al., 2001).

Method

Participants

The same two groups (the ‘web-based’ trypophobic cohort and the ‘university’ group) from Study 1 were used. The outliers detected in Study 1 were also removed from the current study using the same criteria as used before.

Materials

Visual stimuli

Twenty images from three categories were obtained:

a) *Trypophobic images*: These images were taken from www.trypophobia.com and an internet-based supporting group (https://www.facebook.com/groups/3318322299/, accessed 15th April 2013). All the images were of different objects and none was artificially manipulated. Google was used to find the high-resolution versions of the images.

b) *Non-trypophobic images* (neutral images): A Google search for "objects with holes" provided a list of objects such as guitar case, trumpet, etc., and the images illustrating those objects were obtained from a Google image search. These images were not present on the trypophobia websites, and comprised the neutral images.

c) *Images of unpleasant objects/scenes* (unpleasant images) obtained from a Google search for images of items listed on the web as "unpleasant objects". The list included: mould, sewage, rubbish, dirt, blood, worms, vomit, cockroaches, naked mole rat, rat colony, dry skin and varicose veins.

Using MATLAB©, the images were cropped to obtain the largest central square image and resized to 512 x 512 pixels (using the nearest neighbour algorithm).

Anxiety questionnaire

The trait version of the STAI was used as a measure of anxiety. The instrument asks the subject to read twenty statements such as "I feel pleasant" and then circle the appropriate response from a given scale ("Almost never", "Sometimes", "Often" and "Almost always").

Procedure

After completing the symptom questionnaire in Study 1, the participants were asked to rate images. Participants from the ‘web-based’ trypophobic cohort were given the choice to opt out of this task since some of the images were from the trypophobia website. The images were presented in a random order. Beneath each image, a 9-point scale was provided which ranged from “extremely repulsive” through “repulsive”, “very unpleasant”, “unpleasant”, “neither unpleasant or pleasant”, “pleasant,” “very pleasant”, “attractive” to “extremely attractive”, and the participants were asked to rate the images in terms of the scale.

In the last part of the survey, the participants were asked to complete the STAI. All the participants were asked to do this, including those who opted out from the image-rating task.

Results

Convergent validity

Seventeen participants from the ‘web-based’ trypophobic cohort decided to opt out of the image-rating task. Two images from the group of trypophobic images were similar to the illustrative images in the TQ (the lotus seed head and the honeycomb), and were excluded from the analysis. The responses for the ratings of unpleasantness were coded numerically from -4 through 0 to +4, a low score indicating unpleasantness (i.e., -4 = *extremely repulsive*; +4 = *extremely attractive*).

Figure 2 shows, for each participant, the average unpleasantness rating of images and the TQ score. In Figure 2a, a relationship between the unpleasantness rating of trypophobic images and TQ score was evident. Pearson’s correlation coefficients were $r(136) = -.53$, $p < .001$ and $r(101) = -.54$, $p < .001$ for the ‘web-based’ trypophobic cohort (diamonds) and the ‘university’ group (squares), respectively. In Figure 2b (neutral images) and Figure 2c (unpleasant images), little relationship was found: Pearson's correlation coefficient for neutral images was $r(136) = -.011$, $p = .894$ ('web-based' trypophobic cohort) and $r(101) = -.14$, $p = .175$ ('university' group). For the unpleasant images, Pearson's $r(138) = -.14$, $p = .093$ ('web-based' trypophobic cohort) and $r(101) = -.02$, $p = .862$ ('university' group). Including the outliers did not change the results, except for the correlation between TQ score and rating of unpleasant images for the 'university' group, which was significant ($r(115) = .21$, $p < .05$).

INSERT **FIGURE 2** ABOUT HERE

Discriminant validity

There were no significant differences between the 'web-based' trypophobic cohort ($M = 45.1$, $SD = 12.9$) and the 'university' group ($M = 45.1$, $SD = 11.3$), $t(256) = 0.02$, $p = .982$, $d < .01$, in terms of STAI score. For the former and the latter groups, the relationship between TQ score and STAI showed Pearson's correlation coefficients of $r(153) = .216$, $p < .05$ and $r(101) = .018$, $p = .853$, respectively. This demonstrated that there was little correlation between the TQ and STAI. Similar results were obtained when the outliers were included in the analysis.

Spectral analysis of the images

An analysis of the images was conducted according to the methods described by Cole and Wilkins (2013). The 512 x 512 images were rendered in grey level using the rbg2gray function in MATLAB©. The mean pixel grey level was set to 128 and the standard deviation to 50. The power spectra of neutral images, unpleasant images and trypophobic images are illustrated in Figure 3.

INSERT **FIGURE 3** ABOUT HERE

The power function (linear on log-log axes) accounted for more than 99% of the variance for both neutral images and unpleasant images. For trypophobic images, however, the power function accounted for only 96.5% of the variance. A one-way ANOVA revealed a statistically significant difference between image category, $F(2, 57) = 12.31$, $p < .001$, $\eta^2 = .298$. Three pairwise comparisons with Bonferroni correction were conducted to investigate the differences between the image categories in terms of variance explained by the power function. For trypophobic images, the fit explained 93.3% ($SD = 7.62$) of the variance, which was significantly less than for both neutral images ($M = 99.4$, $SD = 0.63$), $t(19) = 3.61$, $p < .01$, $d = 1.5$, and unpleasant images ($M = 99.3$, $SD = 1.31$), $t(19) = 3.36$, $p < .01$, $d = 1.3$. Furthermore, there was no significant difference between neutral and unpleasant images in terms of the variance explained by the power function, $t(19) = 0.54$, $p = .597$, $d = .1$.

Discussion

In order to investigate the convergent validity of the instrument, the TQ was correlated with the unpleasantness ratings trypophobic, neutral and unpleasant images. For both the ‘web-based’ trypophobic cohort and the ‘university’ group, and for trypophobic images only, the TQ score was found significantly to predict the unpleasantness ratings. Given the prevalence of trypophobia, the ‘university’ group inevitably included a small proportion of individuals who experienced trypophobia. Evidently, the symptoms experienced by individuals when viewing trypophobic images were specifically related to the unpleasantness induced by those images and not other images. A Fourier analysis of the images also suggested that the amplitude spectra of trypophobic images deviated from a power law more than those of control images, a finding consistent with Cole and Wilkins (2013).

The weak relationship between the TQ and STAI demonstrated that the TQ has discriminant validity. Although the correlation was significant for the ‘web-based’ trypophobic cohort, it was small. Taylor (1990) argued that even small correlation coefficients (*r*=0.20) can reach significance, given a sufficiently large sample size (*n*>100), but provide little practical importance. Based on this, there was little evidence to suggest that general anxiety accounted for trypophobia.

Study 3. Replication using a student sample

Kraut et al. (2004) raised some concerns regarding research based on Internet sites. For example, due to anonymity, individuals can participate with unknown intentions. Factors that can undermine the integrity of the research, such as multiple submissions from a single individual, may not be controlled for using on-line methods. Hence, the purpose of the present experiment was to replicate the convergent and discriminant validity reported in Study 2 by using a non-internet-based sample.

Method

Participants

Eight male and 34 female psychology undergraduate students, age ranged from 18 – 36 years (*M* = 20.5, *SD* = 4.1) from the University of Essex took part for course credit. None of these individuals participated in Study 1 and 2.

Materials and procedure

The TQ, STAI and images from Study 2 were included. The participants were presented the TQ, the rating task of images (using the same scale as Study 2), followed by the STAI. Prior to the experimental procedures, the participants were asked to read and sign a consent form, which informed them about the experiments and the potentially aversive images included.

Results

Similarly to Study 2, Tukey's method (Tukey, 1977) was used to detect outliers in the sample in terms of TQ score, again using an r factor of 1.5. One outlier was revealed (score above 48) and excluded from further analysis, however similar results were obtained when the outlier was included.

Convergent validity

The relationship between the unpleasantness rating of trypophobic images and TQ score showed a moderate Pearson's correlation coefficient of $r(39) = -.52$, $p < .01$. No relationship was found between the unpleasantness rating of neutral/unpleasant images and TQ score: Pearson's correlation coefficient for neutral images was $r(39) = -.148$, $p = .482$. For the unpleasant images, Pearson's $r(39) = -.134$, $p = .404$. This suggested that, as previously, the TQ score significantly predicted the unpleasantness ratings only for trypophobic images.

Discriminant validity

The relationship between TQ score and STAI showed a weak Pearson's correlation coefficient of $r(39) = .235$, $p = .140$, suggesting that there was little relationship between the two measurements.

Study 4. The role of holes versus clusters in trypophobia

Lighting generally reaches objects from above, resulting in shadowing of convex objects on their lower surface and shadowing of concave objects on their upper surface. The next experiment used circular objects that were shaded so as to appear as hemispherical convex bumps or concave dips depending on their orientation, see Figure 4a. Clusters of such objects were used, see Figures 5b-f. The objects either all had the same orientation and were perceived as dips (Figure 4b, 4e and 5f) or as bumps (Figure 4c), or the orientation varied within the cluster (Figure 4d). If it is in fact clusters of holes that affect individuals with trypophobia, then the images of dips should be more uncomfortable than the images of bumps.

Clusters were of a small (16), medium (64) and large (256) number of objects. The spectral properties of these clusters differed significantly with their size, as the small clusters conformed best to 1/f. Object category, whether bumps, dips or mixed, did not affect the spectral properties. Based on the findings by Fernandez and Wilkins (2008), it was hypothesised that images with power functions that are *least* explained by a linear fit (1/f) should be reported as more uncomfortable. More specifically, it was expected that an increase in cluster size would increase the discomfort. Furthermore, object category was expected to not affect discomfort, hence clusters of bumps, dips or mixed objects should be rated similarly.

Method

Participants

One hundred and two (20 males and 82 females) naïve students from the University of Essex, in addition to 19 student and staff volunteers (three males and 16 females) who were invited on the basis of their TQ score (M = 46.4, SD = 15.7, range = 32, 76), participated in the current experiment for course credit or reimbursement. They were aged from 18 to 49 years (M = 21.6, SD = 6.1). None of the participants had previously participated in the preceding experiments.

Stimuli

Small clusters: Stimuli were created using 128 x 128 pixel grey squares with a circular object (see Figure 4a). The images of holes comprised 4 x 4 of the squares, resulting in 512 x 512 images with 16 objects. The object was randomly offset from the centre of the square it occupied without touching the edge so as to create asymmetrical clusters, while preventing overlap of the objects. Figure 4b illustrates an example of images of holes. Subsequently, all objects within the images of holes were turned 180 degrees, comprising the images of bumps (Figure 4c). Patterns were also created in which the orientations of the objects were randomly determined, comprising the images of mixed objects (Figure 4d). For each category (holes, bumps and mixed objects), four versions were created.

Medium clusters: Each image from the small cluster category was reduced in size by 50%, and reproduced four times in a contiguous two by two matrix to create a new image (see Figure 4e). The images in this category therefore contained 64 objects each.

Large clusters: The above procedure was undertaken with the medium clusters category, increasing the number of objects to 256 (see Figure 4f).

INSERT **FIGURE 4** ABOUT HERE

The Fourier spectra of each image were fit by a power function and the percentage of variance explained by the fit was subjected to a 3 (object category) x 3 (cluster size) ANOVA. There was a significant main effect of cluster size, $F(2, 27) = 1211.99$, $MSE = .001$, $p < .001$, $\eta^2 = .064$, no main effect of object category, $F(2, 27) = 1.895$, $MSE = .001$, $p = .170$, $\eta^2 < .001$, and no significant interaction, $F(4, 27) = .927$, $MSE = .001$, $p = .463$, $\eta^2 < .001$. For images with large clusters, the fit explained 50.0% (SD = 4.2%) of the variance, significantly less than for images with medium clusters, for which the fit explained 88.4% (SD = 1.4%) of the variance, $t(22) = 29.9$, $p < .001$, $d = 13.6$. The power function explained 97.6% (SD = 0.2%) of the variance for images with small clusters, significantly more than for images with medium clusters, $t(22) = 23.0$, $p < .001$, $d = 11.5$. Evidently, with these stimuli, increasing the size of the cluster, whether holes, bumps or a mixture of the two, increased the deviation from the statistical norms of natural images.

Procedure

Before beginning the task, the participants were informed that the images in the experiment might be found uncomfortable to observe, and consent was obtained. The images were presented in random orders, and below each image was a rating scale, from 1-10 (1 = "Not at all uncomfortable", 10 = "Extremely uncomfortable").

Results

Overall, 81 individuals did not meet the criterion for trypophobia and comprised the control group, whereas 40 individuals did and formed the trypophobic group. The first analysis was conducted to investigate whether the images induced more discomfort among individuals who met the criterion for trypophobia compared to the control group, so as to verify that the images resemble other trypophobic images. For each individual, the average rating of all the images was obtained. An independent-samples t-test revealed that the trypophobic group ($M = 4.03$, $SD = 1.84$) rated the images as significantly more uncomfortable compared the control group ($M = 2.96$, $SD = 2.01$), $t(119) = 2.82$, $p < .01$, $d = .6$. This suggests that the images created were of trypophobic nature.

INSERT TABLE 3 ABOUT HERE

The subsequent analyses were conducted to investigate the differences between object category and cluster sizes, and only included the individuals from the trypophobic group. The means and standard deviations for the ratings for all object categories and cluster sizes are presented in Table 3. An ANOVA with the object category (hole, bumps and mixed objects) and cluster size (small, medium and large) as within-subjects factors revealed a significant main effect of object category, $F(2, 78) = 3.63$, $p < .05$, $MSE = 0.68$, $\eta^2 = .005$, and a significant main effect cluster size, $F(1.24, 48.50) = 6.84$, $MSE = 12.5$, $p < .01$, $\eta^2 = .129$. There was no significant interaction, $F(3.03, 118.28) = .763$, $MSE = .464$, $p = .518$, $\eta^2 = .001$.

Three pairwise comparisons with Bonferroni correction were conducted to investigate the main effect of cluster size. Three composite scores were created for each cluster size (i.e., small, medium and large) by averaging across the score for the images with holes, bumps and mixed objects. The results indicated that the average rating of images of large clusters ($M = 4.75$, $SD = 2.47$) was significantly higher than the average rating of images of medium clusters ($M = 3.87$, $SD = 2.04$), $t(39) = 2.16$, $p < .01$, $d = .4$, and images of small clusters ($M = 3.45$, $SD = 2.26$), $t(39) = 2.73$, $p < .01$, $d = .4$. The average ratings for images of medium clusters and small clusters were not significantly different, $t(39) = 1.71$, $p = .096$, $d = .2$. Overall, the ratings of discomfort increased with the size of the cluster and the departure from the properties of natural images, as assessed by the extent to which the spectrum conformed to 1/f.

Two *a priori* pairwise comparisons were conducted to investigate the main effect of object category. The aim was to examine whether images of holes were reported to be more uncomfortable to observe compared to images of bumps or images of mixed objects. Three composite scores were created for each object category by averaging across the score for the images of small, medium and large clusters. It was found that the average rating of images of holes ($M = 3.94$, $SD = 1.78$) was not significantly different from the average rating of images of bumps ($M = 3.95$, $SD = 1.96$), $t(39) = 0.06$, $p = .954$, $d < 0.01$. The average rating of images of holes was significantly lower than the average rating of images of mixed objects ($M = 4.19$, $SD = 1.92$), $t(39) = 2.50$, $p < .05$, $d = .1$. There was therefore nothing to suggest that images of holes were worse than images of bumps or images of mixed categories.

Discussion

Given the large number of images associated with trypophobia, some of which do not contain clusters of holes but clusters of other objects, these results suggest that holes alone are unlikely to be the only cause for this condition. We consider that the fear of *holes* does not accurately reflect the condition. Individuals who met the criterion for trypophobia rated clusters of holes, bumps and mixed objects (i.e., both holes and bumps) in terms of discomfort, which demonstrated that images of clusters of holes did not induce a greater level of discomfort than images of clusters of bumps. Furthermore, it was found that images of clusters of mixed objects were relatively more uncomfortable to observe than images of clusters of holes. As anticipated, the images that conformed *least* to the linear fit, namely the images of large clusters, also received the highest average discomfort rating. This finding suggests a necessary (but not sufficient) condition for trypophobia may be unnatural image statistics.

Study 5. The role of unnatural image statistics in trypophobia

As stated previously, the deviation from the statistical norm of natural images has been shown to cause discomfort (Fernandez & Wilkins, 2008; O'Hare & Hibbard, 2011; Shepherd, 2001; Wilkins et al., 1975; Wilkins & Nimmo-Smith, 1984). Furthermore, Cole and Wilkins (2013) reported that images responsible for trypophobia differed from other natural images in respect of this norm, i.e., they possessed an excess of energy at mid-range spatial frequencies, as shown in the spectral analysis reported in Study 2. Study 4 has confirmed this observation in so far as the least comfortable images were those with the greatest departure from 1/f. It follows therefore that for individuals with trypophobia, removing the excess energy may render the images less aversive (Cole & Wilkins, 2013). In the present experiment therefore trypophobic and neutral images were filtered to have a 1/f amplitude spectrum, removing the excess contrast at mid-range spatial frequencies, and giving the image a statistical characteristic of natural images.

Method

Participants

The participants in Study 3 also served in the current study. In addition, 18 volunteers (one male) were invited to take part in the current experiment on the basis of their TQ score (*M* = 38.6, *SD* = 5.26, range = 32, 48), aged 18 – 26 (*M* = 20.4, *SD* = 2.36). Fifteen of the invited participants had previously taken part in Study 4.

Apparatus

Stimuli were presented on a 13” Apple MacBook Pro with a screen resolution of 1280 x 800 pixels. A chin rest was used to ensure the distance of 0.5 m was maintained between participants and the display. The screen was calibrated using a Minolta LS-100 photometer and nine grey-scale images, and a polynomial used to provide for a linear relationship between image grey level and luminance. The luminance of the mid-grey background was 168 $cd.m^{-2}$, with a range from 0.50 to 276 $cd.m^{-2}$.

Materials

The 20 images associated with trypophobia and 20 non-trypophobic images of holes (neutral images) from Study 2 were rendered in grey level using the rbg2gray function in MATLAB®. The mean pixel grey level was set to 128 and the standard deviation to 50. These images comprised the unfiltered set. The Fourier amplitude spectra of the images were then obtained and given a slope of -1. This was achieved by performing a fast Fourier transform of the images and adjusting the amplitude spectrum to be 1/f. The inverse Fourier transform was then obtained and the images that resulted from this transformation were then re-normalised so that the mean pixel grey level was 128 and the standard deviation 50. These images comprised the filtered set, saved as TIFF files. In total, 40 unfiltered images and 40 filtered images were obtained (see Figure 5).

INSERT FIGURE 5 ABOUT HERE

Design

Images were presented as a slideshow. In total, 80 images (40 unfiltered, 40 filtered) were included in a fixed random order. The first 40 trials included one version (unfiltered or filtered) of each image, which was randomly determined. The last 40 trials (second half) included the versions of the images that were not included in the first half. As a result of this, the minimum separation between presentations of two versions of an image was three slides.

Procedure

Participants were seated facing away from the experimenter and use a chin-rest in front of the screen. The room was otherwise dark. Each image was presented for three seconds, after which a 9-point scale (same as Study 2) on a grey background replaced the image. Participants were asked to give their response verbally.

Results

In total, 25 students met the criterion for trypophobia (i.e., TQ score > 31; trypophobic group), whereas 35 students did not (control group). The ratings of unpleasantness were coded numerically from -4 through 0 to +4, a low score indicating unpleasantness (i.e., -4 = *extremely repulsive*; +4 = *extremely attractive*). The average ratings are illustrated in Figure 6.

INSERT **FIGURE 6** ABOUT HERE

Two repeated-measures ANOVAs, separated by groups, were conducted to investigate the effect of image type (trypophobic versus neutral) and filtering (filtered versus unfiltered) on the rating of images.

Control group

There was no statistically significant interaction between image type and filtering, $F(1, 34) = 1.41$, $p = .243$, $MSE = 0.03$, $\eta^2 < .001$. A main effect was found for image type, $F(1, 34) = 30.43$, $p < .001$, $MSE = 0.09$, $\eta^2 = .049$, and filtering, $F(1, 34) = 51.99$, $p < 001$, $MSE = 0.57$, $\eta^2 = .530$. This suggested that image type and filtering had an effect on the ratings, which was investigated further. Two composite scores were obtained by averaging the scores for all filtered and unfiltered images (across image type), as to investigate the main effect of filtering. A paired-samples t-test revealed that filtered images ($M = -0.29$, $SD = 0.52$) overall received a lower (more unpleasant) score compared to their unfiltered ($M = -0.02$, $SD = 0.45$) counterparts, $t(34) = 5.52$, $p < .001$, $d = .6$. Furthermore, two composite scores were obtained by averaging the scores for all trypophobic and neutral images (across image type), so as to investigate the main effect of image type. As expected, a paired-samples t-test revealed that trypophobic images ($M = -0.62$, $SD = 0.73$) overall received a lower (more unpleasant) score compared to neutral images ($M = 0.30$, $SD = 0.42$), $t(34) = 7.21$, $p < .001$, $d = 1.6$.

The results suggested that, for control participants, filtering the images had a negative effect. Manipulating the images decreased the overall rating of the images, indicating more unpleasantness. Presumably, the reduction of pleasantness for filtered images was due to the degradation of the images as a result of the manipulation (Figure 5 illustrates the loss of images quality). As there was no significant interaction, it was suggested that filtering images had the same effect for both trypophobic and neutral images. Hence, excess energy in images did not seem to have a negative effect on control participants, as they showed a preference for those images compared to the images where excess energy was removed.

Trypophobic group

There was a statistically significant interaction between image type and filtering, $F(1, 24) = 19.78$, $p < .001$, $MSE = 0.03$, $\eta^2 = .004$. To investigate the interaction, two paired-samples t-test were conducted to examine the differences between filtered and unfiltered images in terms of rating, separated by image type. For neutral images, a paired-samples t-test revealed that filtered images ($M = 0.34$, $SD = 0.68$) overall received a significantly lower (more unpleasant) score compared to unfiltered images ($M = 0.76$, $SD = 0.78$), $t(24) = 5.06$, $p < .001$, $d = .6$. For trypophobic images, however, a paired-samples t-test revealed that there was *no significant difference* between filtered ($M = -1.51$, $SD = 0.34$) and unfiltered ($M = -1.38$, $SD = 0.74$) images, $t(24) = 1.93$, $p = .066$, $d = .2$.

The results shows that, for the trypophobic group, filtering neutral images had a negative effect whereas filtering trypophobic images did not, as indicated by the significant interaction. Thus, it was evident that the trypophobic group behaved in the same manner as the control group when it came to neutral images, as the filtered versions of the images were rendered less pleasant compared to the unfiltered versions. Importantly, there was a difference between the two groups in terms of trypophobic images. Control participants significantly disliked the degraded images compared to the images with excess energy at mid-range spatial frequencies (unfiltered images), whereas the trypophobic participants did not. The absence of such an effect of degradation for the trypophobic group in respect of the trypophobic images suggests that the excess energy in such images did indeed have an effect on these particular individuals. The current experiment therefore demonstrated that visual characteristics could be partially responsible for trypophobia. The spectral characteristics of the images cannot be a sufficient explanation, however: there are many images that are not trypophobic, but nevertheless have an excess energy at mid-spatial frequencies.

General discussion

Although trypophobia is relatively common, only one peer-reviewed paper has described the condition. As Cole and Wilkins (2013) point out, one of the unique aspects of trypophobia is the innocuous nature of the stimuli. For example, visual stimuli representing honeycomb or barnacles have been reported to induce symptoms among individuals. The current paper developed a self-report questionnaire to measure trypophobia in terms of the most common symptoms reported. A single construct was evident despite the heterogeneous nature of the symptoms, which can be broadly described as cognitive (e.g., feel uncomfortable or uneasy), skin-related (e.g., itchiness) or physiologically–related symptoms of anxiety (e.g., having trouble breathing).

The scale was able to predict individual differences in discomfort from a wide range of images and in doing so supported the notion that trypophobia is a cohesive entity with consequences for the perception of certain categories of images. The scale was ratified in respect of aversion to specific images, namely images associated with trypophobia, and not for other unpleasant images or neutral images (convergent validity). Furthermore, the TQ and a measurement for general anxiety (STAI) showed little correlation, which demonstrated discriminant validity. A cut-off score of 31 was reported to discriminate well between the cohort of specific individuals who report trypophobia and a more general sample.

The present work investigated a particular mediating mechanism for trypophobia. Cole and Wilkins (2013) reported that the inducing stimuli possess ‘low-level’ visual characteristics associated with discomfort, and suggested that this may explain why trypophobia occurs. Here, trypophobic and neutral images were manipulated so that they both had a Fourier amplitude spectrum similar to that from natural scenes (Field, 1987). It was found that such manipulation degraded the images, resulting in lower (more unpleasant) ratings overall. The interesting point was that when individuals with trypophobia rated trypophobic images, they did not give the filtered images lower ratings than their unfiltered counterparts. This suggested that individuals with trypophobia were indeed sensitive to the images' spectral properties, but only when they were present in trypophobic images.

Furthermore, although holes comprise the majority of the images associated with trypophobia, the clustering nature of objects plays an important role in the discomfort induced by these images. The present Study 4 showed that clusters of bumps was as effective as holes in generating the aversion. Thus, the nature of the objects themselves may be relatively unimportant. This supports the assertion made by Cole and Wilkins (2013); although the aversion is known as the 'fear of holes', it is a particular property possessed by the images that is the driving phenomenon. Finally, since it has been reported that both clinical groups (e.g., Shepherd, 2001; Wilkins et al., 1975) and the general population (e.g., Fernandez & Wilkins, 2008; O'Hare & Hibbard, 2011; Wilkins et al., 1984) are susceptible to certain visual patterns, it can be argued that sensitivity to such characteristics is on a continuum, and a matter of degree. It is suggested that individuals with trypophobia are more sensitive to those visual characteristics, and that trypophobia arises partly as a function of this exaggerated sensitivity.

Acknowledgements

We are grateful to Dr. Paul Hibbard for his contribution to the filtering of images.

References

Akobeng, A. K. (2007). Understanding diagnostic tests 1: sensitivity, specificity and predictive values. *Acta Paediatrica, 96*(3), 338-341.

American Psychiatric Association. (2013). *The Diagnostic and Statistical Manual of Mental Disorders: DSM 5*: bookpointUS.

Bailey, L. H. (1975). *Manual of Cultivated Plants* (15 ed.). NYC: MacMillian Publishing Co., Inc.

Beidel, D. C., Turner, S. M., & Morris, T. L. (1995). A new inventory to assess childhood social anxiety and phobia: The Social Phobia and Anxiety Inventory for Children. *Psychological assessment, 7*(1), 73.

Bruce, T. J., & Sanderson, W. C. (1998). *Specific phobias: Clinical applications of evidence-based psychotherapy*: Jason Aronson.

Cole, G. G., & Wilkins, A. J. (2013). Fear of Holes. *Psychological science, 24*(10), 1980-1985.

Comrey, A. L. (1988). Factor-analytic methods of scale development in personality and clinical psychology. *Journal of consulting and clinical psychology, 56*(5), 754.

Cook, M., & Mineka, S. (1989). Observational conditioning of fear to fear-relevant versus fear-irrelevant stimuli in rhesus monkeys. *Journal of abnormal psychology, 98*(4), 448.

Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation, 10*(7).

Cutshall, C., & Watson, D. (2004). The phobic stimuli response scales: A new self-report measure of fear. *Behaviour Research and Therapy, 42*(10), 1193-1201.

Ehlers, A., Taylor, J. E., Ehring, T., Hofmann, S. G., Deane, F. P., Roth, W. T., & Podd, J. V. (2007). The driving cognitions questionnaire: Development and preliminary psychometric properties. *Journal of anxiety disorders, 21*(4), 493-509.

Fernandez, D., & Wilkins, A. J. (2008). Uncomfortable images in art and nature. *Perception, 37*(7), 1098.

Field, D. J. (1987). Relations between the statistics of natural images and the response properties of cortical cells. *Journal of the Optical Society of America A, 4*(12), 2379-2394.

Floyd, F. J., & Widaman, K. F. (1995). Factor analysis in the development and refinement of clinical assessment instruments. *Psychological assessment, 7*(3), 286.

Furr, M. (2011). *Scale construction and psychometrics for social and personality psychology*: SAGE Publications Ltd.

Glass, C. R., & Arnkoff, D. B. (1997). Questionnaire methods of cognitive self-statement assessment. *Journal of consulting and clinical psychology, 65*(6), 911.

Hoaglin, D. C., Iglewicz, B., & Tukey, J. W. (1986). Performance of some resistant rules for outlier labeling. *Journal of the American Statistical Association, 81*(396), 991-999.

Joaquim, P., & Marques, S. (2007). Applied statistics using SPSS, statistica, Matlab and R. *Springer Company USA*, 205-211.

Juricevic, I., Land, L., Wilkins, A., & Webster, M. A. (2010). Visual discomfort and natural image statistics. *Perception, 39*(7), 884.

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of general psychiatry, 62*(6), 593-602.

Kline, P. (1986). *A handbook of test construction: Introduction to psychometric design*: Methuen.

Kline, P. (1994). *An Easy Guide to Factor Analysis*: Psychology Press.

Klorman, R., Weerts, T. C., Hastings, J. E., Melamed, B. G., & Lang, P. J. (1974). Psychometric description of some specific-fear questionnaires. *Behavior Therapy, 5*(3), 401-409.

Kraut, R., Olson, J., Banaji, M., Bruckman, A., Cohen, J., & Couper, M. (2004). Psychological research online: report of Board of Scientific Affairs' Advisory Group on the Conduct of Research on the Internet. *American psychologist, 59*(2), 105.

Lalkhen, A. G., & McCluskey, A. (2008). Clinical tests: sensitivity and specificity. *Continuing Education in Anaesthesia, Critical Care & Pain, 8*(6), 221-223.

Marks, I. M., & Nesse, R. M. (1994). Fear and fitness: An evolutionary analysis of anxiety disorders. *Ethology and sociobiology, 15*(5), 247-261.

McNally, R. J. (1987). Preparedness and phobias: a review. *Psychological Bulletin, 101*(2), 283.

Mellenbergh, G. J. (2011). *A Conceptual Introduction to Psychometrics: Development, Analysis and Application of Psychological and Educational Tests*: Eleven International.

Merckelbach, H., & Muris, P. (1997). The etiology of childhood spider phobia. *Behaviour Research and Therapy, 35*(11), 1031-1034.

Meyers, L. S., Gamst, G., & Guarino, A. (2012). *Applied Multivariate Research: Design and Interpretation*: SAGE.

O'Hare, L., & Hibbard, P. B. (2011). Spatial frequency and visual discomfort. *Vision research, 51*(15), 1767-1777.

Ohkoshi, E., Miyazaki, H., Shindo, K., Watanabe, H., Yoshida, A., & Yajima, H. (2007). Constituents from the leaves of Nelumbo nucifera stimulate lipolysis in the white adipose tissue of mice.

Öst, L.-G. (2007). The claustrophobia scale: a psychometric evaluation. *Behaviour Research and Therapy, 45*(5), 1053-1064.

Papageorgiou, C., & Wells, A. (2002). Positive beliefs about depressive rumination: Development and preliminary validation of a self-report scale. *Behavior Therapy, 32*(1), 13-26.

Rachman, S. (2004). *Anxiety*: Psychology Press.

Radomsky, A. S., Ouimet, A. J., Ashbaugh, A. R., Paradis, M. R., Lavoie, S. L., & O'Connor, K. P. (2006). Psychometric properties of the French and English versions of the Claustrophobia Questionnaire (CLQ). *Journal of anxiety disorders, 20*(6), 818-828.

Radomsky, A. S., Rachman, S., Thordarson, D. S., McIsaac, H. K., & Teachman, B. A. (2001). The claustrophobia questionnaire. *Journal of anxiety disorders, 15*(4), 287-297.

Rust, J., & Golombok, S. (1999). *Modern psychometrics: The science of psychological assessment*: Psychology Press.

Salkovskis, P. M., Rimes, K. A., Warwick, H., & Clark, D. (2002). The Health Anxiety Inventory: development and validation of scales for the measurement of health anxiety and hypochondriasis. *Psychological medicine, 32*(05), 843-853.

Seligman, M. E. P. (1971). Phobias and preparedness. *Behavior Therapy, 2*(3), 307-320.

Shepherd, A. J. (2001). Increased visual after-effects following pattern adaptation in migraine: a lack of intracortical excitation? *Brain, 124*(11), 2310-2318.

Skaggs, W. (2014). Fear of Holes. *Scientific American Mind, 25*(2), 12-12.

Spielberger, C. D., & Gorsuch, R. L. (1983). *State-Trait Anxiety Inventory for Adults: Manual and Sample: Manual, Instrument and Scoring Guide*: Consulting Psychologists Press.

Szymanski, J., & O'Donohue, W. (1995). Fear of spiders questionnaire. *Journal of Behavior Therapy and Experimental Psychiatry, 26*(1), 31-34.

Taylor, R. (1990). Interpretation of the correlation coefficient: a basic review. *Journal of diagnostic medical sonography, 6*(1), 35-39.

Tukey, J. W. (1977). *Exploratory data analysis*. Reading: MA: Addison-Wesley.

Turner, S. M., Johnson, M. R., Beidel, D. C., Heiser, N. A., & Lydiard, R. B. (2003). The Social Thoughts and Beliefs Scale: a new inventory for assessing cognitions in social phobia. *Psychological assessment, 15*(3), 384.

Van Diest, I., Smits, D., Decremer, D., Maes, L., & Claes, L. (2010). The Dutch Claustrophobia Questionnaire: Psychometric properties and predictive validity. *Journal of anxiety disorders, 24*(7), 715-722.

Wilkins, A. J., Andermann, F., & Ives, J. (1975). Stripes, complex cells and seizures. An attempt to determine the locus and nature of the trigger mechanism in pattern-sensitive epilepsy. *Brain, 98*(3), 365-380.

Wilkins, A. J., & Nimmo-Smith, I. (1984). On the reduction of eye‐strain when reading. *Ophthalmic and Physiological Optics, 4*(1), 53-59.

Wilkins, A. J., Nimmo-Smith, I., Tait, A., McManus, C., Della Sala, S., Tilley, A., . . . Scott, S. (1984). A neurological basis for visual discomfort. *Brain, 107*(4), 989-1017.

Table 1. *Factor loadings for items in the Trypophobia Questionnaire (TQ)*

Item	Factor loading		
	a	b	c
Feel skin crawl	0.905	0.407	0.541
Feel aversion, disgust or repulsion	0.860	0.470	0.545
Feel uncomfortable or uneasy	0.850	0.554	0.539
Shiver	0.840	0.403	0.718
Feel freaked out	0.832	0.618	0.571
Feel itchiness	0.830	0.310	0.528
Chills	0.825	0.371	0.583
Have goosebumps	0.823	0.358	0.757
Feel nervous (e.g., heart pounding, butterflies in stomach, sweating, stomach ache, etc.)	0.726	0.764	0.775
Feel anxious, full of dread or fearful	0.720	0.742	0.740
Feel sick or nauseous	0.714	0.518	0.662
Feel like going crazy	0.647	0.778	0.899
Feel like panicking or screaming	0.643	0.918	0.913
Have an urge to destroy the holes	0.632	0.221	0.588
Have trouble breathing	0.580	0.760	0.903
Feel like crying	0.567	0.771	0.822
Vomit	0.504	0.428	0.839

Note. a = all participants, b = ‘web-based‘ trypophobic cohort, c = ‘university’ group

Table 2. *Summary of the sensitivity, specificity and the average sensitivity and specificity at different TQ score criterion.*

TQ score	(a) Sensitivity	(b) Specificity	(c) Average a and b
> 26	0.97	0.90	0.94
> 27	0.96	0.91	0.94
> 28	0.96	0.91	0.94
> 29	0.95	0.95	0.95
> 30	0.94	0.95	0.95
> 31	**0.94**	**0.98**	**0.96**
>32	0.91	0.98	0.95

Table 3. *Mean (SD) rating of the images*

Cluster size	Holes	Bumps	Mixed objects
Small	**3.45 (2.23)**	**3.31 (2.36)**	**3.59 (2.23)**
Medium	**3.73 (2.06)**	**3.88 (2.24)**	**4.03 (2.07)**
Large	**4.65 (2.49)**	**4.66 (2.55)**	**4.96 (2.58)**

Figure captions

Figure 1. Examples of trypophobic stimuli; lotus seed head (left) and honeycomb (right).

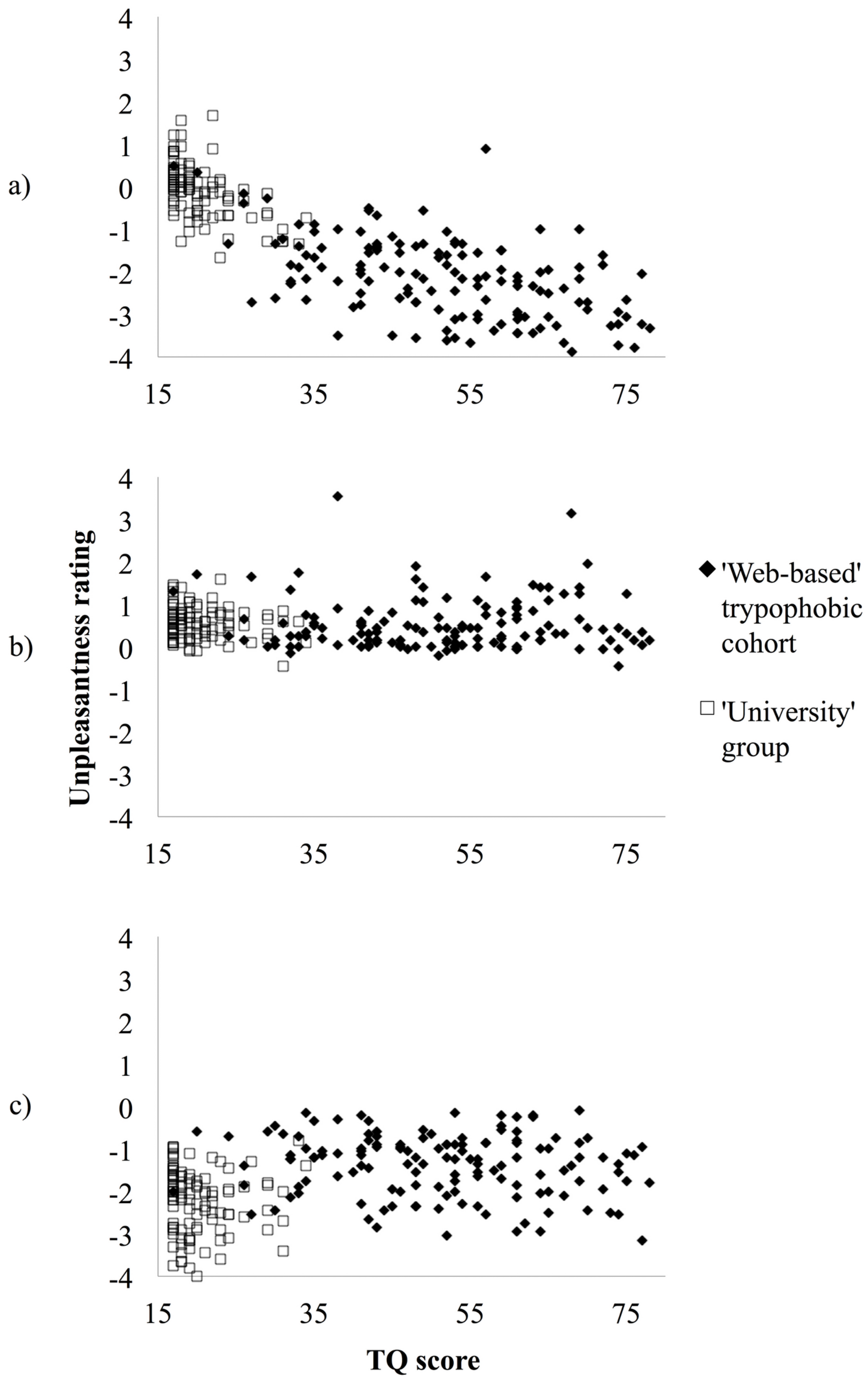

Figure 2. Scatterplot showing the average image rating for each participant as a function of their TQ score: (a) trypophobic images, (b) neutral images and (c) unpleasant images.

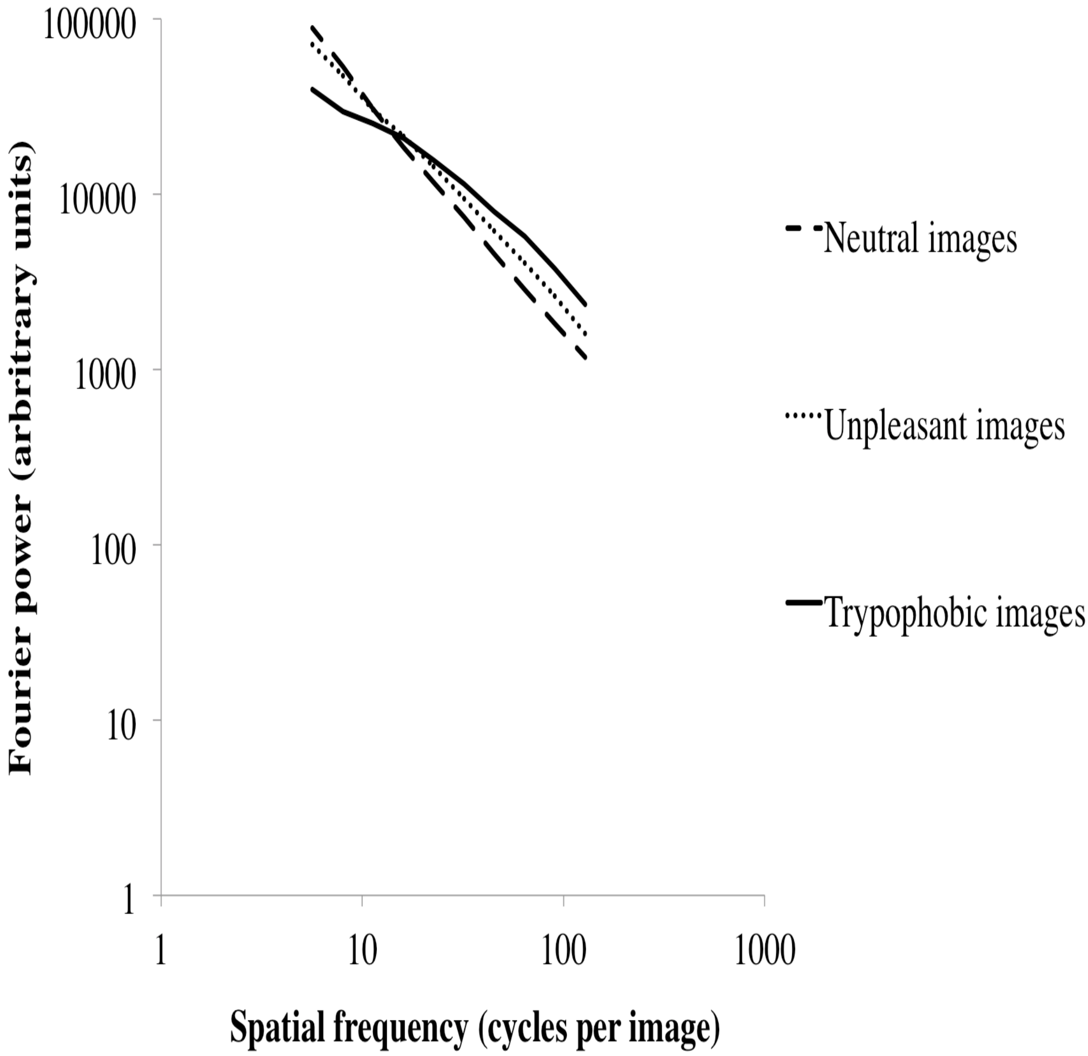

Figure 3. Power spectra of trypophobic images (solid line), neutral images (broken line) and unpleasant images (dots).

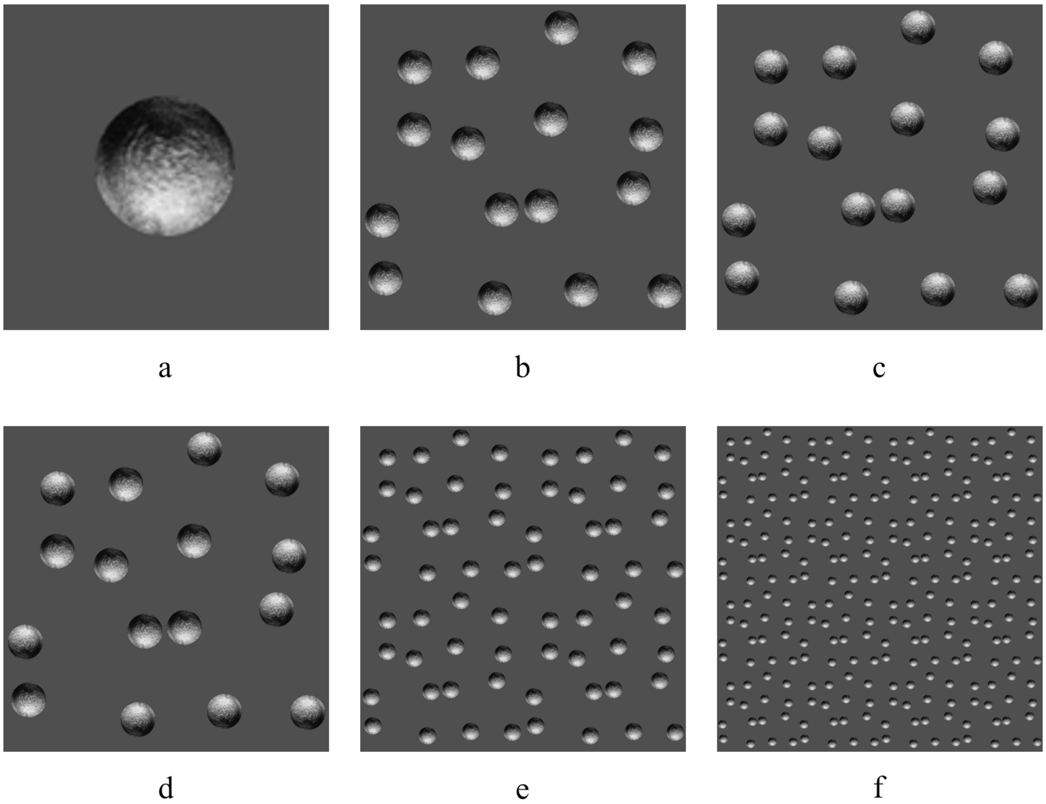

Figure 4. The 128 x 128 grey square with a circular object (a) was used to create 512 x 512 (pixels) images of clusters of holes (b), bumps (c) and mixed objects (d). To increase the number of objects, clusters with medium (e) and large (f) number of objects were subsequently created.

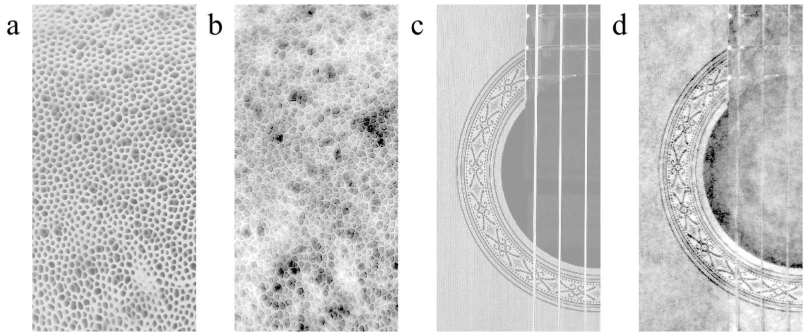

Figure 5. Illustration of unfiltered (a) and filtered (b) versions, both for trypophobic (1) and neutral (2) images.

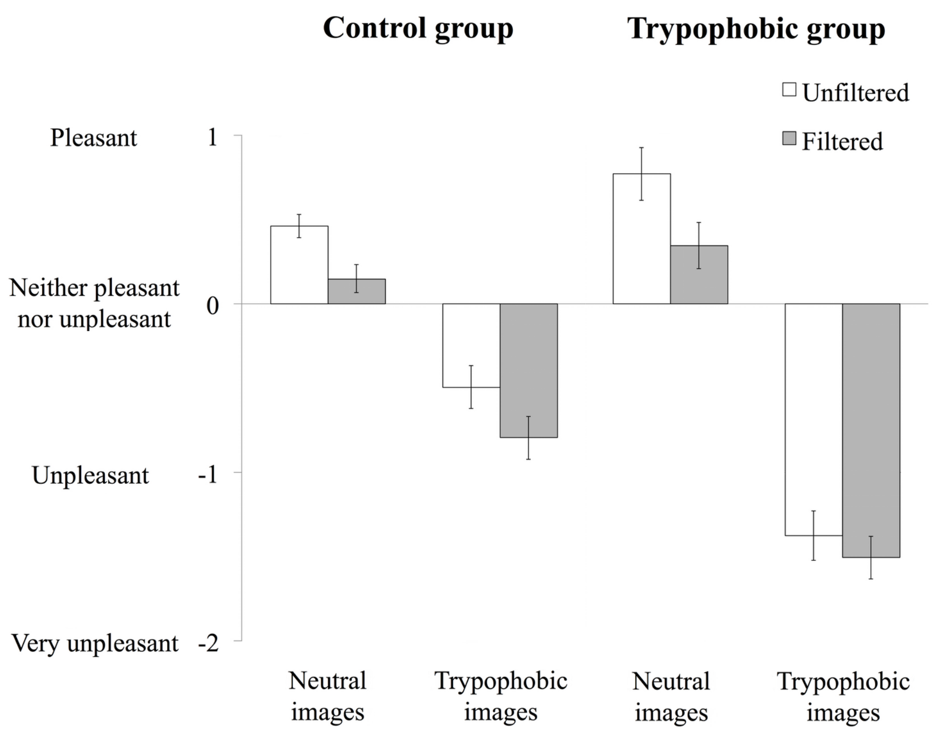

Figure 6. Mean ratings for images. Error bar represent 1 standard error.