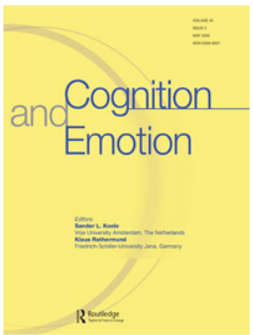

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What causes trypophobia?

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ABSTRACT

Trypophobia is the phenomenon in which individuals report a range of aversive responses when seeing clusters of small holes. Since the phenomenon was first described in the peer-reviewed literature in 2013, approximately 60 papers have appeared directly concerned with the condition. There have also been hundreds of news articles in both online and print media. In the present review of the literature, we examine why trypophobia is likely to occur. Four explanations have been posited in the past decade. These state that the stimuli (1) induce cortical hyperexcitability via the image statistics they possess, (2) signal the presence of a dangerous/poisonous animal, (3) cue the observer to the presence of disease and (4) are aversive due to a form of social learning. We argue that the available evidence points to the disease avoidance hypothesis as the most likely account of the phenomenon.

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Trypophobia; anxiety; aversion; visual stress; visual discomfort

In 2013, Cole and Wilkins (2013) described the phenomenon in which approximately 10–15% of adults experience a number of negative reactions when viewing clusters of small holes. More recent work, based on sample sizes of 2548 (Cole et al., 2024) and 2065 (Wong et al., 2023), more accurately places this prevalence at between 10% and 18%. "Trypophobia" can be induced by a large variety of stimuli and objects, including ones that are naturally occurring (e.g. honeycomb) or human-made (e.g. aerated chocolate). The most commonly cited example is the head of the lotus seed flower. This is particularly interesting because the object is semantically attractive (i.e. a flower). Although the Cole and Wilkins article was the first peer-reviewed description and assessment of the phenomenon, trypophobia had already been discussed within professional practice (Rufo, 1998) and on various internet forums during the early part of the century.

The condition can be debilitating for many people (Cole, 2024). For example, Robakis (2018) described a case study in which an adult sufferer was unable to drive because she found the light-emitting diode arrays in traffic lights "particularly upsetting". Similarly, Martínez-Aguayo et al. (2018) described a young girl who had "uncontrollable fears" that included choking, nausea, sweating and agitation. Reactions and symptoms to trypophobic stimuli are usually classified as skin-related, cognitive and/or physiological (Le et al., 2015). For example, a feeling of nausea or "skin crawling" is often reported. In the last decade or so, approximately 60 peer-reviewed papers have appeared directly concerned with the phenomenon. These have assessed a range of issues such as what critical features induce the aversion (Sasaki et al., 2017), its physiological correlates (Pipitone et al., 2017), the extent to which images modulate eye movements (Shirai et al., 2019) and its relationship to other measures (Imaizumi et al., 2016; Mayor et al., 2021). A commonly used trypophobia scale has also been developed (i.e. the Trypophobia Questionnaire, TQ; Le et al., 2015).

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After commenting on the condition's name, we describe and evaluate the four main accounts that have been put forward to explain why trypophobia occurs. To summarise, the *cortical hyperexcitability* account (Le et al., 2020) argues that the phenomenon is due to the inducing images possessing excess energy within particular spatial frequency ranges. This, in turn, induces hyperexcitability of the cortex. The *poisonous animals* account (Cole & Wilkins, 2013) suggests that trypophobic stimuli cue the observer to the potential presence of a poisonous or dangerous animal. The *disease avoidance* hypothesis (Imaizumi et al., 2016; Kupfer & Le, 2018) argues that the images signal the presence of ectoparasites and skin-transmitted pathogens. The *social learning* explanation (Smith, 2018) argues that trypophobia is no more than a particularly successful internet meme. The present article thus represents the first comprehensive review assessing why the phenomenon occurs (see Thiebaut et al., 2024, for a brief review that is not solely concerned with aetiology).

Although distinct, the four accounts are not entirely independent. For example, the cortical excitability explanation may adequately describe the "proximate" mechanisms and processes that occur in trypophobia, whilst the disease avoidance account could also adequately provide the "distal", or evolutionary, explanation. Furthermore, proximate mechanisms will have been shaped by any distal causes. If one knows what the function of a trait is (e.g. disease avoidance), one can gain a greater understanding of its "design" features, i.e. its psychological mechanisms. Similarly, more than one of the explanations is based on the fact that the inducing stimuli tend to possess a relatively unique visual property. Moreover, with the sole exception of the social learning account, no explanation can be refuted with a single piece of evidence. As often occurs with any attempt to explain a phenomenon via empirical data, one can only posit the most likely explanation.

Trypophobia as a term

Before any peer-reviewed papers were published on the phenomenon, trypophobia was given its name in 2005 by a user of an online forum (Aminuddin & Lotfi, 2016); the term being based on the Greek word for hole, "Trypa". Although it is not uncommon in experimental psychology for an effect to be given a name that presupposes its cause (e.g. *Inhibition of Return, Attentional Blink*), the trypophobia term is somewhat unfortunate because it suggests that any adverse reaction to hole clusters renders the individual as having the phobia. Although it is clear that many individuals do indeed have a phobia of hole clusters, others are best described as being averse because they, for instance, feel uncomfortable or nauseous when viewing the stimuli. For these reasons, the present authors use "aversion" when writing about the phenomenon because this is a literal description and neutral. As problematic as the term may be, we do, however, use "trypophobia" when referring to its name and, of course, refer to other phobias as phobias. The present article is therefore agnostic as to whether individual reactions reach the definition of a phobia.

The *cortical hyperexcitability* account

It is well-established that the simple act of viewing particular types of visual stimuli can have negative health consequences for many people (e.g. Bickford et al., 1953). Perhaps the most well-known example is photosensitive epilepsy, a susceptibility to lights that flicker at particular frequencies (Harding & Jeavons, 1994). Another example is the effect in which migraine can be induced when sufferers look at images that contain high-contrast stripes (Wilkins et al., 1984). Such conditions are associated with cortical excitability, often characterised as the strength of a neural response given a particular stimulation (Ly et al., 2016). It has also been linked with a number of other health conditions, including Alzheimer's (Casula et al., 2023), chronic pain (see Tegeder et al., 2022) and epilepsy (Badawy et al., 2009). The cortical hyperexcitability account of trypophobia suggests that neural responses in visual areas peak when hole clusters are viewed. This explanation can be viewed as the visual equivalent of the uncomfortable feeling often experienced when hearing a noise that possesses particular frequencies, such as when fingernails scrape on a blackboard (see Alimohammadi et al., 2013). Unlike the two evolutionary explanations reviewed in the following sections, the hyperexcitability hypothesis is solely concerned with "immediate" mechanisms.

The account relies on trypophobic stimuli possessing a specific kind of spectral property. That is, relatively high contrast, particularly at mid-range spatial frequencies. Being related to image statistics, the hypothesis has its basis in the seminal work of Barlow (1961; see also Atick, 1992; Field, 1987;

Ruderman, 1997), who argued that to fully understand the functioning of the visual system, one has to consider the statistical structure of the natural environment. One of the fundamental features of a scene/image is the relationship between spatial frequency and luminance contrast. In natural scenes, contrast decreases as spatial frequency increases in a systematic way. On a logarithmic scale, natural images create a straight line with a slope close to −1 (i.e. 1/*f*; Field & Brady, 1997). This partly reflects the fact that the small details on the surface of natural objects are more similar in luminance than the object's overall luminance (averaged across these details) is to other objects. If this were not the case, and instead contrast *increased* with increasing spatial frequency, adjacent blades of grass might, for instance, possess larger differences in luminance than the garden lawn (possessing the blades) compared with the sky. As Barlow (1961) argued, the visual system has evolved to take advantage of these natural image statistics, and there are now thought to be a number of channels that are maximally sensitive at different spatial frequencies (Campbell & Robson, 1968). For example, high frequency channels are dedicated to computations that enable the perception of fine detail and low frequency channels average across these fine contrasts and instead compute broader contrasts.

This central characteristic of the natural world mentioned above (i.e. 1/*f*) does not, however, occur with some images that are uncomfortable to view. Fernandez and Wilkins (2008; see also O'Hare & Hibbard, 2011; Shepherd, 2001) presented participants with a range of images (e.g. paintings, photographs, random noise) and asked them to rate how comfortable each was to view. The results showed that uncomfortable images tend to possess relatively high contrast at mid-range spatial frequencies. In other words, these images cycled between bright and dark approximately 3–9 times per degree of visual angle (with one degree being 10 mm in width viewed at 57 cm, or 20 mm at 114 cms, etc). These results concur with a number of studies showing that stimuli possessing this feature can induce migraine (Marcus & Soso, 1989) and seizures (Funatsuka, Fujita, Shirakawa, Oguni, & Osawa, 2001).

Given this property of uncomfortable images, Cole and Wilkins (2013) examined the degree to which, if at all, a sample of trypophobic stimuli (e.g. lotus seed pods) varied from natural image statistics compared with non-trypophobic images of holes. Results found that the former possessed significantly more contrast energy at mid-range spatial frequencies (but also including some high spatial frequencies). This property of trypophobic images has been confirmed by Le et al. (2015), Sasaki et al. (2017), Shirai et al. (2019), Shirai and Ogawa (2019) and Pipitone and DiMattina (2020). Shirai and Ogawa (2019) additionally found that trypophobic images differ from the 1/*f* slope to a greater degree than even fear-inducing images (e.g. spiders).

These data thus support the notion that trypophobic stimuli differ from natural images and are associated with a visual statistic known to induce aversion. Cole and Wilkins (2013) additionally made a generalisability argument, suggesting that any hole cluster stimulus has the potential to be aversive if it happens to possess the critical image statistic. This would explain why a large variety of (innocuous) stimuli can induce trypophobia, from aerated chocolate to the brake lights on some models of Peugeot. Furthermore, although viewing trypophobic stimuli can be, by definition, aversive, *visual discomfort* is considered a specific condition induced when viewing striped patterns and flickering lights (Sheedy et al., 2003). Symptoms include eyestrain, headache, squinting, diplopia and blurring (O'Hare et al., 2023). It is also thought to induce cortical hyperexcitability (Bargary et al., 2015). Importantly, in this context is the fact that Imaizumi et al. (2016) also found that trypophobia was significantly correlated with scores on the Conlon et al. (1999) *visual discomfort scale*.

The finding that trypophobic stimuli differ from natural images at mid-range spatial frequencies is significant because humans are known to be particularly sensitive to contrasts at these spatial scales (Campbell & Robson, 1968). In standard contrast sensitivity paradigms, in which participants are required to detect/discriminate a stimulus (e.g. a grating) that typically varies in spatial frequency and luminance contrast, thresholds for correct responses steadily decrease as spatial frequency increases. Thresholds then steadily increase as spatial frequency increases past mid-range frequencies. The classic contrast sensitivity function shows a point of maximum sensitivity at around 2–6 cycles per degree. It follows, therefore, that particularly high contrasts at spatial frequencies that humans are already sensitive to could peak neural activity and so lead to cortical hyperexcitability.

Although high contrasts are an important property of trypophobic stimuli, as it is with pattern-induced migraine, the cortical excitability account clearly

requires this feature to play a *causal* role in the aversion. This issue has been examined using the paradigm in which contrasts are experimentally manipulated, and participants perform comfort/aversion ratings for both the manipulated and unaltered stimuli. Sasaki et al. (2017) filtered trypophobic and control images such that low, mid-range and high spatial frequency contrasts were eliminated. Results showed that although trypophobic images were consistently judged to be less comfortable than control images, filtering did not influence ratings. In a second experiment, Sasaki et al. presented images that *only* contained either low, mid-range or high spatial frequencies. Results again showed no influence of this manipulation on responses. The exception to this was in the high spatial frequency condition, where no difference in aversion was observed for the trypophobic stimulus when compared with the (high frequency) control images. The authors thus concluded that only mid-range and low spatial frequencies contribute to trypophobia. These data did, however, come from a small number of images ($n = 20$) and a small number of participants ($n = 15$). In an earlier study, Le et al. (2015) eliminated the medium and high spatial frequency contrasts present in a sample of trypophobic and neutral images so that they resembled natural image statistics (i.e. $1/f$ slope). A group of trypophobic and non-trypophobic individuals then rated the images for aversion. Although filtering had the unexpected effect of lowering overall comfort levels for both image types in both groups of participants, this effect did not occur for trypophobic participants when viewing trypophobic stimuli. In other words, eliminating the high contrasts at mid and high spatial frequencies reduced aversion.

The most comprehensive assessment of how spatial frequency contrasts modulate aversion ratings was undertaken by Pipitone and DiMattina (2020). One hundred and forty-seven participants rated 31 tyrpophobic images for comfort. The stimuli, taken from the web (e.g. trypophobia.com), were presented either in their original form or filtered to possess natural image statistics. This eliminated the high contrast at mid-range spatial frequencies that the images happened to possess. Uniquely, the authors also manipulated the phase of the images, which has the effect of abolishing edges and textures. Pipitone and DiMattina found a main effect of both amplitude (i.e. contrasts at different spatial scales) and phase. However, the effect of the latter was considerably larger than the former. Results showed that this manipulation accounted for 25% of the variation with respect to comfort compared to 9% for amplitude. Furthermore, the authors observed a significant interaction. Importantly, this was primarily driven by the absence of an amplitude effect on phase-unaltered images. Although the main effect of amplitude supports previous work showing that contrasts at different spatial frequencies play a role in image aversion (e.g. Fernandez & Wilkins, 2008), the interaction does not support the view that contrasts contribute to trypophobia. Moreover, Pipitone and DiMattina observed significant correlations between comfort levels and TQ score for amplitude-manipulated but not phase-manipulated images. Additionally, there are many images (e.g. textures) that possess relatively high contrasts at mid-spatial frequencies that do not induce trypophobia (see DiMattina et al., 2024). Overall, results from Pipitone and DiMattina (2020) and DiMattina et al. (2024) challenge the notion that trypophobia solely results from excess energy at different spatial scales. We will, however, note that phase-scrambled images of trypophobic stimuli eliminate all *perception* of holes, clustered or otherwise. Such stimuli are reminiscent of patchy clouds in which there are no discernible features anywhere in the image. As noted by Pipitone and DiMattina (2020), the perception of holes, or clusters of disc-like structures, is a necessary condition of the aversion.

Trypophobia, cortical hyperexcitability and the hemodynamic response

Although the role of neural activity in modulating hemodynamic signals is controversial (O'Herron et al., 2016), the strength and location of this activation are known to be associated with an increase in local blood flow (see Heeger & Ress, 2002). Furthermore, a number of studies have shown that a relatively large hemodynamic response is a reliable marker of discomfort and visual stress. For instance, neuroimaging work in individuals who suffer from migraine consistently shows that those who additionally experience visual discomfort or photophobia exhibit a relatively large hemodynamic response to the stimuli inducing the stress (Wilkins, 2016). Le et al. (2020) reasoned that if trypophobia is also a form of visual stress associated with cortical hyperexcitability, one should observe increased hemodynamic activity in visual areas of the cortex in trypophobic individuals when they view hole clusters; an effect that should

not be observed in nontrypophobic individuals. The authors presented 14 trypophobic and 28 non-trypophobic individuals with images of hole clusters and neutral images for 16 s each. Hemodynamic activity was measured with functional Near Infrared Spectroscopy. Results showed that relative to the neutral condition, the trypophobic images induced an oxyhaemoglobin response in the trypophobic group, but not in the control group. Furthermore, the increased blood flow was predominantly observed in occipital, as opposed to frontal, regions of the cortex adjacent to the visual cortex. These data patterns can be seen as a necessary condition of the cortical hyperexcitability account of trypophobia.

In sum, the cortical hyperexcitability account suggests that image statistics of hole clusters induce neural activity associated with aversion. This explanation effectively argues that the response is a form of visual stress, the visual equivalent of an uncomfortable noise. The property said to induce trypophobia is high contrast at different spatial frequencies. Results from experiments in which images are filtered at different spatial scales and then rated for aversion have, however, been mixed. At best, image statistics cannot be the sole explanation of trypophobia; the aversion can still occur when contrasts are controlled and equated. Furthermore, the fact that contrast manipulation effects are small additionally shows that other factors contribute to the phenomenon in addition to image statistics. As reviewed in the disease avoidance hypothesis section below, the context in which hole clusters occur is also important to the levels of aversion experienced.

The *poisonous animals* account

The idea that many aversions, or phobias, largely result from an innate predisposition to fear potentially dangerous stimuli (e.g. Marks & Nesse, 1994) is often attributed to Seligman (1970) and the "biological preparedness" hypothesis. This suggests that during the Pleistocene period of history, humans were selected for this trait via Darwinian principles. The theory has been used to explain the fact that many potentially dangerous objects that humans do not typically interact with, but were ancestrally threatening (e.g. snakes, spiders, heights, water), are more likely to induce aversion and phobia than recently designed objects that are far more dangerous (e.g. guns, cars, electricity).

The poisonous animals explanation of trypophobia was initially based on the observation that trypophobia-inducing stimuli and a range of poisonous/venomous animals both happen to possess the mid-range spatial frequency feature described in the previous section, a feature that is rare in the natural world. As Cole and Wilkins (2013) noted, this explanation was motivated by an individual who stated that their trypophobia would be induced by a number of animals. The animals they described happened to be highly poisonous. In Experiment 3 of Cole and Wilkins, the authors took the first 10 images from 10 species that a *Google* search deemed to be the "most poisonous animals" (e.g. the *Blue-ringed Octopus*) and performed a spectral analysis on each. The same analysis was performed on images of similar but nonpoisonous species (e.g. nontoxic frogs). Results showed that the poisonous animals possessed approximately 15% more contrast energy at mid-range spatial frequencies. Furthermore, this excess energy occurred for both colour and greyscale images.

Cole and Wilkins (2013) additionally noted that many snakes and spiders on their own are poisonous and are particularly phobia-inducing (e.g. Öhman et al., 2001). Images of these animals are also known to increase performance on a range of cognitive tasks. For example, LoBue and DeLoache (2008) found that snakes were more rapidly detected in a variant of a standard visual search paradigm. In a separate experiment/analysis, Cole and Wilkins (2013) performed a spectral analysis on images of snakes and spiders. Again, the power spectra revealed that such images possessed particularly high contrast energy at mid-range spatial frequencies compared with controls.

Based on these findings, Cole and Wilkins suggested that humans may have been subject to a Darwinian process in which they have been selected for their ability to *rapidly detect* poisonous organisms (see Marks & Nesse, 1994). Conscious object recognition is a relatively slow process, taking up to 350 ms (Johnson & Olshausen, 2003). Responding to potential threats using slow conscious recognition could, of course, be costly to the organism. A more effective process would be one that enables the discrimination of objects via a fast-acting visual mechanism that can discriminate some fundamental feature common to dangerous animals. Of course, the *motion* detection system is likely to have evolved for precisely this reason; any organism that was not able to rapidly orient attention to the onset of an object will have been selected out and the luminance-dedicated magnocellular channel is known to

perform this function (Steinman et al., 1997). Visual channels that compute contrasts at different spatial scales could provide a similar function, i.e. rapid, rudimentary object processing. Evidence for such mechanisms comes from work showing that, for example, the efficiency of attentional orienting to objects (e.g. faces) is modulated by contrasts they possess at different spatial frequencies (e.g. Bannerman et al., 2012).

Processing priority of trypophobic stimuli

One approach to assessing the poisonous animals hypothesis is to examine whether trypophobic stimuli are considered special by visual cognition mechanisms. According to the *behavioural urgency hypothesis* (Franconeri & Simons, 2003), the only stimuli that receive processing priority, in the absence of a goal-directed action, are those that signal an event that could require urgent action. Only one article has examined attentional capture by trypophobic stimuli. Shirai et al. (2019) asked participants to make a saccade to a peripheral target based on the direction of a centrally located arrow. Three types of irrelevant, but distracting, stimuli were also present in each display: trypophobic, fearful and neutral images. Results showed that although response latencies did not differ between stimuli, eye movement trajectories were influenced by the trypophobic stimuli and not by the fearful or neutral stimuli. Furthermore, these trajectories were biased *towards* the whole clusters, illustrating a form of attentional capture. Because Shirai et al. also manipulated the interval between the onset of the images and the arrow cue, the time course of the effect could be analysed. These data revealed that the trypophobic stimuli bias effect was already decreasing between 0 and 450 ms. In other words, trypophobic stimuli influenced a fast-acting mechanism.

A variant on the issue of processing priority is the question of whether trypophobic stimuli modulate non-conscious processing. Using a variant of the *continuous flash suppression* (CFS) paradigm, Shirai and Ogawa (2019) examined whether trypophobic images gain preferential (i.e. rapid) access to early visual processes. The CFS procedure is a masking paradigm in which two images are presented independently to the two eyes. One is a mask, the other is a target to be detected/discriminated and the former prevents the latter from being consciously seen. By gradually increasing the perceptibility of the target (e.g. increasing contrast) and reducing the perceptibility of the mask over a number of seconds, one can measure the time it takes a stimulus to reach conscious awareness. This procedure has been used to examine a number of issues. For example, Yang et al. (2007) found that faces expressing fear gain preferential access to awareness relative to happy and neutral expressions. Shirai and Ogawa (2019) presented trypophobic, fearful, hole clusters (but not necessarily trypophobic) and neutral images as targets. Participants were required to indicate which side of a fixation cross the image was located. Results showed that trypophobic images were detected more rapidly than the other stimulus types. As Shirai and Ogawa stated, this supports the notion that trypophobic stimuli induce a threat-advantage effect.

One particularly interesting aspect of both the Shirai et al. and Shirai and Ogawa data is the fact that the trypophobic images accrued greater processing priority than even fearful images. Indeed, in the former study, saccade trajectories were not influenced by fearful images at all. One possible reason for the processing advantage enjoyed by trypophobic stimuli is that they have both an emotion-inducing component as well as a visual structure advantage that is particularly salient, i.e. high contrasts. Although Cole and Wilkins (2013) showed that poisonous animals also possess high contrasts, this effect was less pronounced than it was for trypophobic stimuli. Furthermore, the fearful stimuli (as used by Shirai and colleagues) inevitably included animals that did not have this feature.

Also in a non-conscious-processing context, Can et al. (2017) examined whether participants implicitly associate trypophobic stimuli with venomous animals. The authors used a variant of the *Implicit Association Test* (IAT; Greenwald et al., 1998) in which participants arrange stimuli (i.e. words or pictures) into categories via button pressing. For example, they might indicate whether a word is pleasant or unpleasant. A number of blocks are typically presented in which the type of stimuli to be categorised and the possible categories are varied. The underlying principle of the IAT is that concepts that are more strongly associated in memory will be sorted more easily (e.g. reduced reaction time). Importantly, the paradigm is assumed to index associations that are nonconscious. Can et al. tested four-year-old children based on the rationale that such participants would have had less exposure to societal

representations of venomous animals. The authors found that although the children judged trypophobic stimuli to be relatively uncomfortable to view when explicitly asked, there was no implicit association with venomous animals.

Is everyone trypophobic?

One challenge to the poisonous animals account and the disease avoidance hypothesis (see the following section), is the fact that not all people report aversion to hole clusters. Indeed, many non-trypophobic people are surprised that these stimuli can induce such aversion. If humans have been selected for their ability to rapidly detect threats, trypophobia should be more common in the general population. It is, however, possible that everyone *is* sensitive to trypophobic stimuli. Although no studies have explicitly examined this, data from a number of published experiments support the possibility. For example, whilst undertaking a trypophobia and electroencephalography (EEG) study, Van Strien and Van der Peijl (2018) noted that the overall TQ score in their sample was low, with only two of their 24 participants reaching the threshold for being trypophobic. Despite this, there was a large overall (emotion-related) EEG effect induced by hole clusters. Van Strien and Van der Peijl had essentially shown a trypophobia response in non-trypophobic individuals. A trypophobic-related response was also observed by Pipitone et al. (2017) in individuals who again did not reach the threshold for being trypophobic, as measured with the TQ. The authors examined electrodermal activity in 37 individuals who passively viewed hole clusters. Although only six of the 37 were trypophobic, there was still an overall effect of increased electrodermal response. Furthermore, when these six participants were omitted from an analysis in which the TQ score was correlated with comfort levels when viewing a range of trypophobic stimuli, results showed that higher TQ scores were significantly associated with lower comfort levels; an effect that did not occur when control images were viewed. Again, these data support the notion that sensitivity to trypophobic stimuli is a general population-wide phenomenon.

In sum, the poisonous animals account of trypophobia suggests that humans have evolved to rapidly detect and discriminate dangerous animals. Whereas conscious object recognition is slow, aversion based on a fast-acting "low-level" mechanism that can discriminate dangerous animals (e.g. snakes and spiders) will have been selected for. The account is supported by findings showing that trypophobic stimuli are subject to processing priority. The poisonous animals hypothesis is, however, undermined by the finding that deviation from 1/f energy is not solely a feature of trypophibia-inducing stimuli, as shown by DiMattina et al. (2024).

One final and related possibility is that the trypophobia response is modulated by aposematic patterns. Aposematism is a trait possessed by many animals in which patterns on the skin (or fur) act as a signal warning potential predators that the animal is poisonous or venomous; what evolutionary biologists refer to as "unprofitable". Although relatively widespread amongst invertebrates, it is most commonly associated with amphibians, reptiles and fishes (Santos et al., 2003). Examples of aposematism include the warning colours of bees, wasps, the *Poison Dart Frog* and the *Blue-ringed Octopus*. The patterns of these last two are often trypophobia-inducing.

The *disease avoidance* hypothesis

An alternative evolutionary account, first suggested by Imaizumi et al. (2016), posits that aversion to hole clusters is an extension of human avoidance of disease. The theory was more formally described by Kupfer and Le (2018), who provided evidence that humans have been selected for their sensitivity to parasitism and infectious disease. A common assumption is that humans have evolved an ability to avoid pathogens (see Sarabian et al., 2018), and a number of "strategies" to achieve this have been suggested, including the evolution of sexual reproduction (Hamilton et al., 1990). As discussed by Kupfer and Le (2018), many of the most deadly infectious diseases (e.g. smallpox, rubella, typhus) present as clusters of lesions that are approximately circular. Similar cluster patterns also occur when ectoparasites (e.g. tics) invade a host and when organic matter decays. The authors thus argued that being sensitive to cluster patterns would have conferred a fitness advantage on those individuals who possessed this trait. The additional mechanism of overgeneralisation, thought to explain the prevalence of many phobias (e.g. Dymond, Dunsmoor, Vervliet, Roche, & Hermans, 2015), would then extend the aversion to any stimulus that involves cluster patterns.

Hole clusters and human skin

Initial evidence for the disease avoidance account came from the common (i.e. layperson) observation

that the aversive nature of trypophobic stimuli is increased when they are digitally incorporated onto images of human skin, which is sometimes referred to as *Hasu-Colla* in Japan. Furuno et al. (2018) empirically examined this cluster-on-skin effect by presenting participants with images of adult faces, either upright or inverted, which could also include hole clusters placed on each cheek. Confirming the prediction, aversion ratings were highest when the clusters were present on upright faces. Song and Koyama (2022) extended this finding to show that when hole clusters were digitally placed over the face but, importantly, were perceived to be located in front rather than part of the face, the effect was reduced. Furthermore, the degree of aversion reported was significantly correlated with the degree to which depth was perceived between the face and cluster.

Furuno et al. (2017) additionally manipulated the specific biological context of the skin effect. The authors digitally incorporated trypophobic stimuli within the skin of a human, the fur of a dog, the fur of a lion, the surface of a plant and a stone. As predicted by the disease avoidance account, the stone condition resulted in the least aversion; presumably, such an object is less likely to transmit disease compared with the other objects. Most interesting, however, was the finding that hole clusters incorporated within dog fur elicited the most aversion. This condition was even significantly different to the aversion induced in the human skin condition. There was also a significant difference between the dog and lion conditions. Although the overall results support the disease avoidance explanation, Furuno et al. noted that it is difficult to account for these more subtle differences using the contamination/disease framework.

Defence against disease may also be expected to manifest in terms of general aversion to skin pathologies. In this context, Shirai and Ogawa (2021) employed a priming paradigm to examine whether skin-problem-related words would increase aversion to images of hole clusters. Participants undertook a lexical decision task in which they indicated whether a stimulus was a word or not. They then evaluated trypophobic, negative and neutral images for aversion level. Results showed that the skin-problem-related words increased aversion to trypophobic images relative to control words that were negative but not associated with skin problems. As discussed by Shirai and Ogawa, because the priming words referred to completely different physical objects than trypophobic images, the results cannot be explained in terms of visual priming. In another skin pathology-related study, Yamada and Sasaki (2017) asked 856 participants to rate trypophobic images for aversion and report any previous or current skin-related medical problems. The authors found that participants with a history of skin complaints, compared to those without, rated the images more uncomfortable to view.

The skin pathology aspect of the disease avoidance hypothesis is also supported by the findings that it is not only holes that induce trypophobia. As noted, many infectious diseases manifest as clusters of skin lesions. These clusters, however, are not typically holes; instead they are convex blisters and bumps. Although not assessing the (not yet published) disease avoidance hypothesis, Le et al. (2015) examined whether trypophobia also occurs in response to clusters of bumps. By manipulating the direction of a light source and hence shadows, the authors generated either clusters of holes or bumps. Aversion ratings revealed that discomfort was no different for holes, bumps, or images that included both. Chaya et al. (2016) have also shown that trypophobia can be induced by disc-like clusters (i.e. eyes).

Comparing the disease avoidance and poisonous animals accounts

Pipitone et al. (2022) directly compared the poisonous animals and disease avoidance accounts in a single experiment. Two hundred and four participants were presented with images of inanimate objects (e.g. sofa), dangerous animals (e.g. spider), non-dangerous animals (e.g. ladybird/ladybug) and human skin (e.g. palm of hand) and asked to rate each for comfort level. Importantly, the images either had a hole cluster digitally incorporated into the object depicted or were left unaltered. As one would expect, all images were judged to be less comfortable to view when containing hole clusters. The important analysis, however, examined the degree of comfort level reduction (in the cluster conditions) for the human skin and dangerous animal categories. The result found this reduction to be significantly greater for the former. Furthermore, this effect was itself more pronounced in participants who had relatively high TQ scores. Since the incorporation of trypophobic stimuli had a greater effect on human skin compared with dangerous animals, Pipitone et al. argued that these data support the disease avoidance hypothesis.

Which response best reflects trypophobia?

A central aspect of the disease avoidance hypothesis has been the attempt to determine which response best characterises trypophobia. As noted, trypophobia had already been given a name (in 2005) before any peer-reviewed article appeared. The phobia label thus suggests that *fear* is the predominant response. This, however, is not supported by a number of studies. For example, in developing the TQ, Le et al. (2015) reduced the most common symptoms described by sufferers to 17 items. These could be further reduced to cognitive-related symptoms (e.g. feeling "uneasy"), skin-related symptoms (e.g. "itchiness" or "skin crawl") and physiological symptoms (e.g. "nausea" or "trouble breathing"). None of these descriptions suggest that fear is the major response.

Imaizumi et al. (2016) suggested that the disease avoidance hypothesis predicts that the predominant response should be *disgust* rather than fear, the latter being more typically associated with phobia. Imaizumi et al. administered the TQ, the *Disgust Scale Revised* (DS-R; Olatunji et al., 2009) and a number of other scales (e.g. empathetic concern) to 126 Japanese adults. The *DS-R* has 25 items and three subscales comprising core disgust, animal-reminder disgust and contamination disgust. Imaizumi et al. found that amongst all the measures taken, the first of these three was the best predictor of trypophobia sensitivity. The authors thus concluded that trypophobic stimuli cue an observer, or act as a "reminder", that disease is present.

Using the *Questionnaire for the Assessment of Disgust Proneness* (Schienle et al., 2003) and structured clinical interviews, Wabnegger et al. (2019) also found that the trypophobic response is best characterised as disgust rather than fear. Similarly, Vlok-Barnard and Stein (2017) found that 60.5% of individuals (n = 195) who used the Facebook trypophobia support group reported that disgust was the predominant experience, with 11.8% stating that disgust was the *only* experience. In contrast, only 5.1% reported mostly fear, with 1% experiencing only fear. The predominance of a disgust response was also found by Hain and Stevenson (2025), Thiebaut et al. (2025), and Suzuki et al. (2023). The latter of these two occurred in all three groups of children assessed (4–5 years, 6–7 years, 8–9 years) as well as adults.

Kupfer and Le (2018) made a secondary and more subtle prediction with respect to the specific disgust response and hence potential cause. The authors argued that if trypophobia is concerned with general pathogen avoidance, the typical disgust-related response should be feelings of nausea and an urge to vomit. However, if trypophobic stimuli additionally cue the presence of ectoparasites or skin-transmitted pathogens, then the typical response should also concern touch and skin sensations such as skin crawling and itching. Kupfer and Le further added that ectoparasites (i.e. stimuli that threaten the skin barrier) induce different feelings than those induced by ingestible pathogens such as spoiled food (Blake et al., 2017). The authors asked 255 trypophobic and 182 non-trypophobic individuals to rate, for comfort, disease-relevant and disease-irrelevant cluster images as well as disease-relevant and disease-irrelevant non-cluster images. The authors additionally asked participants to consider the degree to which they experienced fear and disgust when viewing trypophobic stimuli. An open-ended question was also presented to the trypophobic group, in which they were asked to "describe your main feelings(s) when looking at images like these". In terms of comfort ratings, results showed that both groups indicated higher levels of aversion towards disease-relevant, as opposed to disease-irrelevant, clusters. Thus supporting the general disease avoidance hypothesis. Furthermore, only the trypophobic group indicated higher levels of aversion to disease-irrelevant hole clusters. However, data from the open-ended question also supported the more subtle secondary prediction that Kupfer and Le made. Although participants often described general disgust feelings such as nausea, a greater proportion used terms relating to skin, such as skin itching or skin crawling.

Given that a disgust response is central to the disease avoidance hypothesis, a number of authors have suggested that trypophobic stimuli should predominantly activate the parasympathetic nervous system, rather than the sympathetic nervous system (Song & Koyama, 2022; Thiebaut et al., 2025). As a response to danger, fear is known to activate the sympathetic nervous system with responses including increased heart rate, blood pressure and pupil dilation (Gray, 1987; Kreibig, 2010). A corollary to these responses is a decrease in processes associated with the digestive system (Cannon, 1914; Stam et al., 1995). In contrast, the parasympathetic system aids digestion and has an opposite effect on heart rate, blood pressure and pupil size (e.g. Gilchrist et al., 2016). Although not as clear cut as is often presumed

(see Kreibig, 2010), this system has also been found to modulate the disgust response (Calder et al., 2001; de Jong et al., 2011; Murphy et al., 2003). Ayzenberg et al. (2018) employed pupilometry to examine how trypophobic stimuli modulate pupil size. Participants were presented with trypophobic, fear-inducing (e.g. snakes), neutral and luminance gratings as control images. The results showed that trypophobic stimuli elicited the greatest change in pupil size. More significant was the observation that these stimuli led to relatively large constriction, an effect consistent with activation of the parasympathetic system, the system that modulates the disgust response.

Another approach to assessing the predominant response to trypophobic stimuli has been the examination of event-related potentials (ERPs) when participants view trypophobic, fear-related and disgust-related stimuli. It is well established that early posterior negativity (EPN) is a marker of automatic processing of emotionally and evolutionary significant visual information, including fear-inducing (e.g. snakes; Van Strien et al., 2014) and disgust-inducing objects (Wheaton et al., 2013). Furthermore, Van Strien and Van der Peijl found a significant correlation between the degree to which participants are averse to trypophobic stimuli (as measured with the TQ) and EPN amplitudes in response to hole clusters. Moreover, fear-related and disgust-related stimuli induce differing levels of EPN within the same experiment (Van Strien et al., 2014). Thus, EPN is a sensitive measure of differing responses to emotional stimuli. Wabnegger et al. (2019) used this fact to examine degrees of EPN when participants viewed holes, fear-related, disgust-related and neutral images. Although the authors found differences between fear-related and disgust-related images with respect to other electroencephalographic markers (e.g. late positive potentials), there was no difference in EPN for disgust and fear-related stimuli.

In sum, the disease avoidance theory is supported by the observation that the aversion experienced is significantly increased when hole clusters are incorporated within (images of) human skin. Furthermore, although an elevated level of fear is commonly reported in trypophobia studies (e.g. Hain & Stevenson, 2025), the most frequent response is disgust, as the account predicts. Furthermore, many disgust effects in trypophobia studies are modulated by whether participants have trypophobia or not. For example, DiMattina et al. (2024) found that individuals with relatively high TQ scores are more disgusted by images of skin disease than individuals with relatively low TQ scores. Involvement of the parasympathetic nervous system, associated with digestion, in response to viewing trypophobic images also supports the disease avoidance hypothesis. Finally, individuals with a history of skin problems tend to find hole clusters particularly uncomfortable to view (Yamada & Sasaki, 2017).

The *social learning* account

Many psychological conditions do, of course, have a social learning component (Muris et al., 1997). Indeed, many aspects of human behaviour are usually said to be either due to genetic inheritance, social influence or, more likely, a combination of the two. The learning theory account, particularly specific to trypophobic, is what might also be called the *internet-meme* hypothesis (Oelze, 2018). This account states that trypophobia is nothing more than a successful meme in which individuals have "caught" the condition via social media and news websites. In other words, a trypophobic individual had never previously considered the potential aversive effects of hole clusters, even when they happened to see examples. Such thoughts only occurred when they were exposed to images via internet discussion. They had, in effect, been persuaded by others that there was something to be concerned about, or, as Oelze (2018) stated, "a fear made worse by the internet".

The strictest form of the internet-meme hypothesis is easily refuted. Many people recall being averse to hole clusters before trypophobia became a relatively well-known phenomenon around 2013–2014. Furthermore, people aged 40 and older often remember having the condition as a child (e.g. Robakis, 2018), before the internet existed. The more subtle, however, and theoretically interesting, aspect of the internet-meme theory is the possibility that social media, whilst not solely causing trypophobia, has *contributed* to the prevalence of the phenomenon.

Cole et al. (2024) examined the internet-meme hypothesis by measuring trypophobia levels in relatively younger and older individuals (total $N = 2539$), the former of which are known to use the internet more (Perrin, 2015). Results showed that younger people are more trypophobic as predicted by the internet-meme account. This finding alone, however, can only be seen as providing necessary but not sufficient support for the meme hypothesis. For

example, it is known that the prevalence of many phobias is less in older people (Fredrikson et al., 1996). Cole et al. therefore, undertook a second experiment testing the hypothesis that the prevalence of trypophobia and sensitivity to trypophobic stimuli should be related to awareness of the phenomenon. The authors measured the degree of trypophobia in people who have heard of the phenomenon compared with people who were unaware of its existence. Three related predictions were made. The most stringent stated that there should not exist a single person who has trypophobia but has also never heard of the phenomenon. A second, less stringent hypothesis is that the proportion of trypophobic individuals (as opposed to non-trypophobic) should be larger in a sample of people who are familiar with the condition compared with the proportion in a sample that has never heard of it. A third prediction was that the *degree* of trypophobia should be greater in people who have heard of it compared with those who have not. To put this all another way, the internet-meme theory argues that a person is more likely to be trypophobic and have a greater degree of trypophobia if they have heard of the condition.

In this second experiment, 283 participants completed the TQ that also included one additional question. This asked whether they had ever heard of the phenomenon. The results showed that 24% of people with trypophobia had never heard of the condition. This, therefore, does not support the internet-meme theory. Cole et al. did, however, find that the proportion of trypophobic individuals was greater in people who had heard of the phenomenon compared with those who had not. Furthermore, the degree to which a person was trypophobic was larger in people who had heard of the condition. Overall, these data suggest that social learning has contributed to the prevalence of trypophobia but cannot solely account for its existence. We will add that even if its large internet presence is indeed primarily responsible for trypophobia, this would be no different to how many other aversions and phobias are argued to be passed on. That is, a condition acquired by a person becoming aware of an aversion experienced by a model (e.g. family member or friend; e.g. Blair et al., 2016; King et al., 1998; Rachman, 1978). There is also the knowledge gained from society and media that views certain objects extremely negatively (e.g. snakes, cockroaches; Schindler et al., 2016). Evidence showing that young children are also averse to hole clusters additionally suggests that the internet-induced explanation of the phenomenon is not likely to be correct. As noted in a previous section, both Can et al. (2017) and Suzuki et al. (2023) have shown hole cluster aversion in children aged four and four-five, respectively (see also Imura et al., 2024). These participants are, of course, unlikely to use social media and access news websites.

Finally, one has to consider the most general form of learning, i.e. classical conditioning. This, however, is unlikely to explain the acquisition of trypophobia. As described, contrasts at different spatial frequencies are known to contribute to the phenomenon. This necessarily means that viewing distance is important for the degree of aversion experienced. It is therefore improbable that a stimulus can induce an aversion when viewed at, for instance, ten metres but not do so when viewed at, for instance, one metre. There is also the fact that 10–18% of the population (i.e. the prevalence of trypophobia) cannot have had an extremely negative interaction with images of holes, an interaction which then induces a general aversion. This is supported by Vlok-Barnard and Stein (2017), who found that 78.5% of the 195 trypophobic individuals questioned reported that they had not had a distressing experience involving holes or clusters of holes that might have predisposed them to the condition.

Future directions

There are a number of outstanding issues related to the cause that future researchers may want to pursue.

Given the mixed results noted above (e.g. Pipitone & DiMattina, 2020; Sasaki et al., 2017), the degree to which image statistics contribute to trypophobia is yet to be determined. The issue, however, need not be solely concerned with *luminance* contrasts (at different spatial scales). *Chromatic* contrasts that vary from those typically present in natural scenes are also known to increase visual discomfort (Haigh et al., 2013; Penacchio et al., 2021). As with virtually all objects and scenes, hole clusters, such as those in the lotus seed flower, typically include contrasting colours. Such contrasts may contribute more to the aversion than luminance contrasts. Indeed, contrasting salient colours is often the critical feature in the aposematic warning patterns of many animals (Rojas et al., 2015).

One specific question that needs to be addressed is whether hole clusters digitally incorporated within skin are particularly aversive compared with other

types of clusters. Recall that the skin disease account is supported by evidence showing that hole clusters placed on skin are more aversive than off skin (Furuno et al., 2018; Pipitone et al., 2022; Yu et al., 2024). However, it is possible that *any type of cluster* placed on the skin is particularly aversive. For example, one can imagine a cluster of thin, long slashes or cuts placed within skin also being aversive. Indeed, a variety of skin injuries are uncomfortable to view (Kupfer, 2018), and trypophobia is, of course, an aversion to clusters of *holes* (or disc-like stimuli). The disease avoidance theory thus makes the clear prediction that the increase in aversion that occurs when clusters are placed within skin should be greater when they resemble skin diseases, i.e. clusters of holes/discs.

One particular challenge to the disease avoidance explanation, or any account based on Darwinian principles, is the fact that trypophobia is not particularly prevalent. Indeed, many people are surprised that others find holes difficult to view. As noted in the present review, it is, however, possible that sensitivity, if not phobia, to hole clusters is a population-wide phenomenon. For example, two studies (Pipitone et al., 2017; Van Strien & Van der Peijl, 2018) reported trypophobia-like responses when the majority of the participants did not reach the TQ threshold for having the condition (based on maximum sensitivity and specificity of the scale; Le et al., 2015). One method for directly assessing the issue would be to examine whether participants *who score the lowest TQ value* still rate hole clusters to be more aversive than control images. Individuals who generate 17 (i.e. the lowest score) on the TQ have essentially indicated that they find whole cluster images to be unaversive. For example, when asked whether the two images on the scale induce "disgust or repulsion", make their "skin crawl" or make them "feel uncomfortable or uneasy", all responded "not at all". If such individuals still rate hole clusters to be more aversive than control images, this would suggest that sensitivity to holes is population-wide.

In terms of the typical response, it is well-established that disgust is the predominant reaction when hole clusters are viewed (Imaizumi et al., 2016; Vlok-Barnard & Stein, 2017; Wabnegger et al., 2019). However, there are a number of different disgust emotions (Simpson et al., 2006) and hole clusters may induce one type more than another. Identifying the most common specific response will provide a further clue to its cause. Recall that Kupfer and Le (2018) suggested that if trypophobic stimuli cue the presence of ectoparasites or skin-transmitted pathogens, the typical reaction should concern skin sensations (e.g. skin crawling and itching). In contrast, if trypophobia is due to pathogen avoidance, the typical reaction should be nausea and an urge to vomit. The specific trypophobic response is, however, yet to be determined. Furthermore, as suggested by Kupfer and Fessler (2018), it would be interesting to know if the condition is associated with other disgust-related anxiety disorders, such as Obsessive-Compulsive Disorder. Indeed, the co-morbidities of trypophobia (see Mayor et al., 2021) are not well established. For example, it is not yet clear whether anxiety is more prevalent in trypophobic individuals. Although the most comprehensive assessment suggests that it is (Wong et al., 2023), two other studies showed a weak or absent association (Le et al., 2015; Pipitone et al., 2017).

Conclusions

Trypophobia, an aversion to clusters of circular shapes, predominantly holes, occurs to various degrees in the broad population but is particularly acute in around 10–18% who may be referred to as being trypophobic. Despite over a decade's worth of research, there is currently no clear consensus as to why trypophobia occurs. Four principal theories have so far been put forward. That the aversion is due to the statistical properties of the inducing images, which, in turn, generate cortical hyperexcitability, an evolutionary disposition to avoid disease, an evolutionary disposition to avoid poisonous animals, a social learning process in which affected individuals have effectively caught the condition via its wide social media presence.

When taking all the evidence into account, we suggest that the poisonous animals explanation is the weakest. The degree of fear induced by images of such animals is clearly nothing like the degree of disgust and repulsion induced by, for instance, images of skin pathologies or maggot-infested meat. Indeed, unlike clusters of circles on skin, dangerous animals do not seem to commonly induce trypophobia. The most stringent version of the social learning account is also weak; trypophobia was experienced by many people before the internet arose. Evidence for the role of contrasts at different spatial frequencies is mixed, with the most comprehensive assessment showing that filtering trypophobic images does not

significantly reduce aversion. Instead, we suggest that trypophobia is most likely explained by the disease avoidance hypothesis in which humans have been selected for their ability to avoid potentially dangerous pathogens; pathogens that often manifest as clusters of circular shapes on the skin. Furthermore, trypophobia can also be partly explained by a less stringent version of the social learning account in which wide media presence has facilitated its prevalence.

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