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THEORETICAL ARTICLE

Why are we Afraid of Holes? A Brief Review of Trypophobia Through an Adaptationist Lens

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Abstract
The aim of this paper is to provide a brief overview of trypophobia, or in other words the fear of "clusters of holes". The first peer-reviewed paper on this curious phenomenon only appeared in the scientific literature about a decade ago, i.e., Cole and Wilkins (*Psychological Science 24*(10) 1980–1985, 2013), even though it negatively affects a relatively large portion of the general population. After briefly describing the theoretical framework within which most studies of trypophobia are conducted—namely 'evolutionary psychology'—, we will characterize this phobia and then outline the two main hypotheses likely to explain the disorder: the 'dangerous animal' and the 'skin disease-avoidance' hypotheses, respectively. As trypophobia is not listed in the Diagnostic and Statistical Manual of Mental Disorders (*American Psychiatric Association,* 2013), we will discuss the issue of categorizing this phobia among other specific phobias. The aim of this brief review is therefore to describe the (rare) scientific work that has been done on this a priori innocuous and strange condition, most of which agrees with the idea that the fear of clusters of holes is related to our evolutionary history.

Keywords Trypophobia · Disgust · Fear · Animals · Pathogens · Evolutionary psychology

Introduction

In this review dedicated to trypophobia, i.e., the fear of clusters of holes, we will first describe the characteristics of this disorder and how it is identified in individuals, and then consider the various explanations that have been proposed to explain it. With regard to the hypotheses on the origin of trypophobia, we will refer primarily to the theoretical framework of evolutionary psychology and develop some central aspects of this.

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According to evolutionary psychologists, our brains have the capacity to implement mental algorithms shaped by natural selection and triggered by cues present in the physical and social environment. Thus, our behavior results from a series of adaptations, i.e., a trait or set of traits that helps an organism to survive and reproduce (Buss, 2020). Information that was relevant to our survival in the ancestral past therefore still gives rise to specific processing today. To give just a few examples, research has shown memory biases for food (Fančovičová et al., 2020; Prokop & Fančovičová, 2014), especially caloric foods (e.g., meat, almonds, olive oil) (De Vries et al., 2020; New et al., 2007) and a memory advantage for animate entities as compared to inanimate ones (Bonin et al., 2014, 2022; VanArsdall et al., 2013) as well as for objects touched by a sick person compared to those touched by a healthy person (Bonin et al., 2019; Fernandes et al., 2017, 2021; Thiebaut et al., 2022). These examples all illustrate the extent to which elements essential for survival are prioritized.

Evolutionary psychology aims not only to uncover the 'how' of behavior, but also to illuminate the 'why'. It seeks ultimate explanations (Bonin, 2022; Workman & Reader, 2014). Thanks to this dual approach, evolutionary

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psychology investigates a wide range of topics, including phobias (Coelho & Purkis, 2009). According to evolutionary psychologists, people are more likely to develop fears and phobias related to dangers that were present in their ancestral environment (e.g., predators, heights) than to dangers that emanate from our modern environment (e.g., firearms, cars, pollution). For example, fear of animals, especially snakes and spiders, is very common (Polák et al., 2020). To illustrate, arachnophobia is the most common phobia worldwide (e.g., 2.7% in the Netherlands, Oosterink et al., 2009; 9.75% in Hungary, Zsido, 2017). Davey (1994) found that 32% of women and 18% of men in England reported feeling fear, nervousness and anxiety at the sight of a spider. Similarly, the prevalence of ophidiophobia, i.e., fear of snakes, is high and estimated at 2–3% of the general population (Klorman et al., 1974). According to some researchers, fear of spiders and snakes is widespread because of the selective pressure exerted by these species in the ancestral past. Indeed, the venom secreted by the salivary glands of these animals is capable of immobilizing prey, making them particularly fearsome (Seligman, 1971). According to the World Health Organization (WHO) report of May 17, 2021 (https://www.who.int/fr/news-room/fact-sheets/detail/snakebite-envenoming): *"snakebites cause between 81,000 and 138,000 deaths a year, and around three times as many amputations and other permanent disabilities"*. Many researchers have hypothesized that we may have inherited mechanisms to protect ourselves from these creatures as a result of the selective pressure exerted by them during our long evolutionary history (Buss, 2019; Kawai, 2019; LoBue & Deloache, 2008; Rakison, 2018; Rakison & Derringer, 2008; Seligman, 1971). By way of an illustration, let us take two examples of studies that have used skin conductance responses. When adults are given electric shocks while viewing pictures of dangerous animals such as snakes, their skin conductance responses persist for longer than when presented with neutral stimuli, such as pictures of houses (Öhman et al., 1975; but see Åhs et al., 2018 and Del Guidice, 2021, for discussions of replication issues in this type of work). Moreover, Landová et al. (2020) found that viewing photographs of venomous snakes elicited stronger skin resistance responses than when non-venomous snakes were presented (and heart rate only increased with pictures of venomous snakes). It can be argued that socialization, rather than evolutionary predispositions, may play the most important role in fear conditioning. However, research on children and babies, in whom socialization has not yet reached the adult level, supports evolutionary explanations of human fear. For example, a number of studies have shown that snakes and spiders can be quickly detected from a very young age. LoBue and DeLoache (2008) gave children aged 3 to 5 years and their parents a touchscreen-based task requiring the rapid detection of targets (e.g., snake, flower, caterpillar) presented among distractors (e.g., finding a snake image in a matrix of 8 flower images, or the reverse). The results showed that children, like adults, detected snakes more quickly than other types of stimuli. Using a virtual-reality task, Yuan et al. (2018) also showed a rapid detection bias for spiders. Even more surprisingly, Rakison and Derringer (2008) reported that 5-month-old children responded more strongly to seeing a schematic image of a spider than to seeing modified versions of the schematic spider (e.g., all the features of the spider present but rearranged) that did not preserve the canonical appearance of this animal. This pattern of results has also been observed for snakes (Rakison, 2018). Another study on 6-month-old children showed that pictures of snakes and spiders induced stronger physiological arousal (as measured by pupil diameter, a component of the noradrenergic system and stress response) than pictures of flowers and fish (Hoehl et al., 2017), suggesting a biological predisposition to fear these predators due to the threat they have posed throughout our evolutionary history (Kawai, 2019; Seligman, 1971). Another commonly reported phobia is fear of heights (i.e., acrophobia).[1] This phobia can be defined as a fear of heights that is disproportionate to the actual danger and can be triggered in real or imagined situations, or also by proxy when the phobic person observes others in the phobogenic situation (Menzies & Clarke, 1995). The "evolved navigation theory" has been proposed to explain this phobia (Jackson, 2005; Jackson & Cormack, 2007). According to this theory, the costs of navigation (e.g., the energy required to move from one place to another) have shaped the way we perceive and locate ourselves in space, and in particular the perception of distance in relation to the risk of falling (Jackson, 2009). To illustrate, falls are the leading cause of injury and death in the elderly (Stevens et al., 2008) and the second greatest cause of workplace injury (Cohen et al., 2006). As a result, acrophobic individuals may overestimate the distance between surfaces. According to one study, 6.3% of men and 8.6% of women suffer from acrophobia (Fredrickson et al., 1996), and infants (aged 6 months) who are able to crawl are sensitive to heights (Bertenthal et al., 1983). Bertenthal et al. (1983) asked children to join their mothers by crossing a "visual cliff" (actually a vertical drop covered with thick glass) and found that 80% of the children avoided going over the "cliff".

While some phobias, such as the fear of dangerous animals or heights, are relatively easy to explain in terms of our evolutionary history, other less common or more bizarre phobias, such as fear of clowns, i.e., coulrophobia, see

[1] It is important to note that acrophobia should not to be confused with vertigo, which is a sensation of displacement of the body in space, caused by a dysfunction of the inner ear, nerves, or vestibular centers (Neuhauser, 2007).

Clasen (2014), or vegetables, i.e., lachanophobia, which is also associated with neophobic behavior in young children, can also be examined from an evolutionary perspective. The purpose of this article is to present published data on a curious phobia that affects a significant portion of the population: the fear of clusters of holes, also known as trypophobia. More specifically, we will provide some answers to questions such as "How do we assess trypophobia?", "What hypotheses have been put forward to explain this disorder?", "Is trypophobia due more to fear or disgust?", or "Is trypophobia a real phobia?". Using the case of trypophobia, we shall show that the evolutionary approach is an enlightening way of addressing this type of disorder.

The Emergence of Interest in Trypophobia

Interest in trypophobia can be traced back to the 2000s, with the rise of the Internet and the sharing of online content. Many Internet users discovered that they had something strange in common: an aversion to innocuous images, for example of beehives, soap bubbles, and air holes in chocolate. Reactions to such images can range from simple revulsion to nausea and panic attacks. By way of illustration, here is a recent anecdote of trypophobic reactions on the Internet. During the *Haute Couture Week* (January 2023 in Paris), the *Schiaparelli* fashion show inspired by *Dante's Inferno* provoked strong reactions because of one of the dresses which, with no less than 30,000 hand-applied crystals, caused anxiety in a large number of Internet users. Some posted messages such as: "How did people not throw up around her? My trypophobia has been triggered" or "I've got goose bumps, but not the right ones, she's triggering my trypophobia, I'm itching".

The term “trypophobia” (from the Greek *trypa* [τρύπα] meaning holes, and *phóbos* [φόβος] meaning fear) appeared on a forum in 2005. The concept then went viral (Adam, 2020; Skaggs, 2014). Subsequently, support groups appeared on Facebook, articles were written on the topic of the fear of holes, and videos were posted on YouTube to share the difficulties of viewing "trypophobic" images. The first clinical case of trypophobia was reported in the literature by Rufo (1998). He recounted the story of a little girl in hospital who had an extreme, debilitating terror of a musical instrument with repeated patterns on its surface. Another, more recent case is that of a 12-year-old girl who exhibited a series of neurovegetative symptoms—accelerated heart rate, nausea, pallor, suffocation—when looking at *Gruyère* cheese, bread covered with seeds, or polka-dotted clothing (Martínez-Aguayo et al., 2018). As described above, before it became the subject of scientific study, trypophobia was nothing more than an "Internet phenomenon". Thus, it was only as recently as 2013 that psychology researchers began to take a specific interest in this disorder (Cole & Wilkins, 2013). In their first study in 2013, Cole and Wilkins presented an image of a lotus seed head to 286 adults between the ages of 18–55. Participants were asked to indicate whether the image was uncomfortable to look at. They found that 11% of men and 18% of women expressed visual discomfort when seeing the lotus flower. More generally, Cole and Wilkins (2013) were able to show that images containing clusters of holes caused greater visual discomfort than neutral images, even among people who did not identify as trypophobic.

How is Trypophobia Identified?

A team of researchers developed a self-administered questionnaire designed to determine the extent to which adults suffer from trypophobia (Le et al., 2015: *The trypophobia questionnaire,* referred to as the TQ). Adults are asked to look at two pictures with a "trypophobic structure", namely a lotus seed head and a beehive (see Fig. 1 in Le et al. (2015) for examples of the pictures used), and then to rate 17 statements on 5-point Likert scales.[2] Six items relate to "cognitive" and "aversive" symptoms (e.g., feeling like panicking or screaming; feeling aversion, disgust, or repulsion), four to skin symptoms (e.g., feeling itchy; having goosebumps), and seven to physiological symptoms (e.g., feeling sick or nauseous; having difficulty breathing). Two additional unrelated items were included (e.g., feeling at peace; wanting to laugh). Le et al. (2015) obtained very conclusive results regarding the quality of their questionnaire, with good item specificity that permits the diagnosis of persons with trypophobia, very high internal consistency (Cronbach's alpha = 0.96), and excellent reliability between initial completion of the questionnaire and recompletion four weeks later (Pearson's correlation = 0.85). In other words, the trypophobia questionnaire is a sensitive and appropriate tool for assessing the level of trypophobia in an adult individual. According to Le et al. (2015), if an individual scores above 31 on the questionnaire (scores can range from 17 to 85), it indicates that he or she is trypophobic. Although the scientific literature contains no data on the incidence of trypophobia, i.e., the number of individuals who suffer from trypophobia each year, published data can be found on its prevalence, i.e., the number of individuals who suffer from the disorder (old and new cases). Cole and Wilkins (2013) have found that approximately 15% of the adult population experience negative emotions—discomfort or even repulsion—when looking at clusters of holes, such as can be found in

[2] Specifically, participants rate how they feel about each proposition on a 5-point scale: 1 (not at all), 2 (slightly), 3 (moderately), 4 (considerably), and 5 (extremely).

Fig. 1 On the left, the desert taipan snake; on the right, the poison dart frog

a lotus seed head. Pipitone et al. (2017) reported that 6 out of 37 (17%) American students (mean age approximately 23 years) had scores above 31 on the TQ (Le et al., 2015) and were considered trypophobic. More recently, Pipitone and DiMattina (2020) examined another sample of young Americans and reported a lower percentage of trypophobic participants as measured by the TQ (7.4% had scores > 31). Again using the TQ, Wong et al. (2023) found a prevalence of trypophobia of 17.6% in a young population from Hong Kong (2065 young people, aged between 15 and 24, see also Alkhalifa et al. (2020) for a similar TQ score in residents [age range: 15–24] of Bahrain). Finally, in the most recent study to date, Cole et al. (2024) asked 2558 adults from the United Kingdom to take the TQ. There were six age groups, starting with the 18 to 24-year range and ending with participants aged 65 or over. The authors found that 9.7% had a TQ score above 31, meaning that they could be diagnosed as trypophobic (Le et al., 2015). There were age differences, with TQ scores decreasing with age (TQ scores = 28.2 for the 18–24 age range; 25.7 for [25–34]; 23.1 for [35–44]; 19.6 for [45–54]; 18.9 for [55–64] and 18.3 for the 65 + group). The observation of age differences in response to trypophobia-inducing stimuli may partly explain the discrepancy in the prevalence of trypophobia between studies. Interestingly, Cole et al. (2024) examined trypophobia in adults as a function of whether or not they had heard of the phenomenon in order to determine whether a social learning component might contribute to trypophobia. The possibility of such a contribution was confirmed by the finding that TQ scores were higher in participants who had heard of the disorder than in those who had not (and more specifically, they were higher in women than in men and in younger than in older participants due to former's greater use of social media). However, a significant proportion of the trypophobic participants—around a quarter—had never heard of this condition and the social learning hypothesis cannot therefore on its own account for this phenomenon.

On average, women are more likely to reach the threshold for trypophobia than men (Cole & Wilkins, 2013; Cole et al., 2024; Kupfer & Le, 2018; McAuley et al., 2019; Vlok-Barnard & Stein, 2017; Wong et al., 2023). For instance, Wong et al. (2023) found that 68% of trypophobic individuals were female. A recent study suggests that trypophobia is more prevalent in urban environments (Zhu et al., 2020), which is intriguing to say the least, but as this study is the only one to report such results and was conducted on a sample of 68 participants, further research is needed to confirm this observation. As will be discussed later, it is also possible to objectively measure physiological responses to trypophobia (e.g., heart rate variability, pupil diameter, electrodermal activity).

What are the Origins of Trypophobia?

Researchers have investigated whether trypophobic images have specific visual features, and if so, what exactly these are. Mathematical analyses of the visual structure of these images have revealed that trypophobic "triggers" correspond to high-contrast energy at mid-range spatial frequencies (Cole & Wilkins, 2013; Sasaki et al., 2017, but see Le et al., 2015, Experiment 5; Shirai & Ogawa, 2019, Experiment 2). However, other research has shown that the phase spectrum, comprising elements of an image structure, namely clusters of circular objects, plays a greater role in eliciting trypophobic responses, i.e., by affecting comfort levels, Pipitone and DiMattina (2020). Indeed, this latter observation fits well with a case study reported by Robakis (2018) of a patient with an irrational fear of circular street lights.

Two main hypotheses have been proposed to explain trypophobia, and both attribute a role to evolution: One is related to dangerous animals (Cole & Wilkins, 2013; Van Strien & Van der Peijl, 2018) and the other to the avoidance of contagious skin diseases (Imaizumi et al., 2016; Kupfer & Le, 2018). Although these two systems share similar features, i.e., risk aversion, they are functionally distinct and domain-specific (Neuberg et al., 2011).

The Dangerous Animal Hypothesis

The first hypothesis about the origin of trypophobia that we describe is the "dangerous animal" hypothesis. This hypothesis is so named because a "trypophobic spectral pattern" has been found in several dangerous animal species. Many species are venomous and their bites or stings can have harmful or even fatal consequences (e.g., anaphylactic shock caused by the sting of certain Hymenoptera (e.g., hornet, wasp, fire ant), Casale & Burks, 2014; envenomation from black widow spider bites, Garb & Hayashi, 2013; Vetter & Isbister, 2008). Cole and Wilkins (2013) studied the spectral composition of images of ten animals considered to be the most venomous. These included the Brazilian wandering spider (*Phoneutria nigriventer*), the deathstalker scorpion (*Leiurus quinquestriatus)*, the king cobra snake (*Ophiophagus hannah*), the inland taipan snake (*Oxyuranus microlepidotus*), the marbled cone snail (*Conus marmoreus*), the poison dart frog (*Ranitomeya amazonica*), the blue-ringed octopus (*Hapalochlaena maculosa*), the box jellyfish (*Cubozoa*), the pufferfish (*Tetraodontidae*), and the stonefish (*Synanceia verrucosa*) (see Fig. 1 for examples of some of these animals). An analysis of the spectral compositions of images of these animals revealed that they are very similar to those of trypophobic images such as the lotus seed head. Complementary analyses of 20 images of spiders and 20 images of snakes reproduced the spectrum obtained for images of the 10 most venomous animals on the planet. Thus, the aversion to trypophobic images could be explained by a fear of dangerous animals, a fear that our hunter-gatherer ancestors experienced on a daily basis, as dangerous animals were common in the ancestral environment (Natterson-Horowitz & Bowers, 2023). In line with this interpretation, researchers have found that trypophobic images and images of snakes provoke an increase in evoked potentials of early posterior negativity in occipital and parieto-occipital cortical areas (Van Strien & Van der Peijl, 2018; but see Wabnegger et al., 2019 for a study showing an enhanced late negativity), thus reflecting automatic processing of evolutionarily relevant visual information. Previous studies had also shown greater early posterior negativity for pictures of snakes than for pictures of other species such as worms, beetles, and even spiders (Grassini et al., 2016; Van Strien et al., 2014, 2016). Thus, data from evoked potentials measured in response to trypophobic pictures and pictures of dangerous animals (e.g., snakes) suggest that the aversion elicited by trypophobic pictures may be related to ancestral threats (Van Strien & Van der Peijl, 2018). To investigate potential associations between venomous animals and trypophobic stimuli, Can et al. (2017) tested implicit associations in 4-year-old Chinese children. The children were first presented with pairs of images (e.g., trypophobic versus non-trypophobic photograph, photograph of a venomous versus non-venomous animal, drawing of a venomous versus non-venomous animal) and had to decide which of the two they preferred. The results showed that the children avoided choosing the trypophobic images and the photographs of dangerous animals. However, there was no preference when the animals were presented as drawings, suggesting that young children are sensitive to trypophobic content and that the visual characteristics of these images affect visual comfort. Can et al. (2017) then used an implicit association test to examine the extent to which trypophobic images were associated with venomous animals (versus non-venomous animals). The three image categories—trypophobic image, venomous animal, non-venomous animal—were assigned to two response buttons. For example, a blue button was associated with trypophobic images and venomous animals, and a green button was associated with non-venomous animals. The children were then asked to press the button corresponding to the presented picture as quickly as possible. The reasoning was as follows: If there is an implicit association between trypophobic pictures and venomous animals, then response times should be faster when these two types of pictures are associated with the same response button. The results showed that there was no significant difference in reaction times, suggesting that the avoidance of trypophobic images is not related to learned associations with poisonous animals. The researchers considered that if such an association does exist, it would emerge later in life. More data are needed on the ontogeny of trypophobia, as certain cognitive, social, and emotional mechanisms may develop and evolve over time in humans (Tooby & Cosmides, 1990).

The Skin Disease-Avoidance Hypothesis

A second hypothesis on the origin of trypophobia is related to diseases, and especially infectious skin diseases (Imaizumi et al., 2016; Kupfer & Le, 2018; Yamada & Sasaki, 2017). This hypothesis has been more extensively studied than the one we presented above, probably because researchers believe that disease avoidance is more likely to explain the origin of trypophobia than fear of animals. Among the many selective pressures faced by our hunter-gatherer ancestors, the problem of pathogens (e.g., bacteria, viruses, worms) was undoubtedly the most important. Indeed, pathogens are capable of inflicting severe damage on their hosts (Ewald, 1993; Van Blerkom, 1993) and are responsible for the greatest number of deaths in our entire evolutionary history, more than all other causes (e.g., accidents, wars, natural disasters) combined (Inhorn & Brown, 1990). For example, smallpox alone was the cause of 10% of all deaths in the last millennium (Thèves et al., 2014). Many of the most virulent and deadly diseases, such as leprosy, rubella, typhus, plague and scarlet fever, produce circular stigmata and/or clusters of pustules on the skin surface. In addition to pathogenic micro-organisms, certain ectoparasites such as ticks and fleas can also affect our health and leave stigmata in the form of clusters of holes on the skin (Heukelbach & Feldmeier, 2004; Kupfer & Fessler, 2018). When this "physical

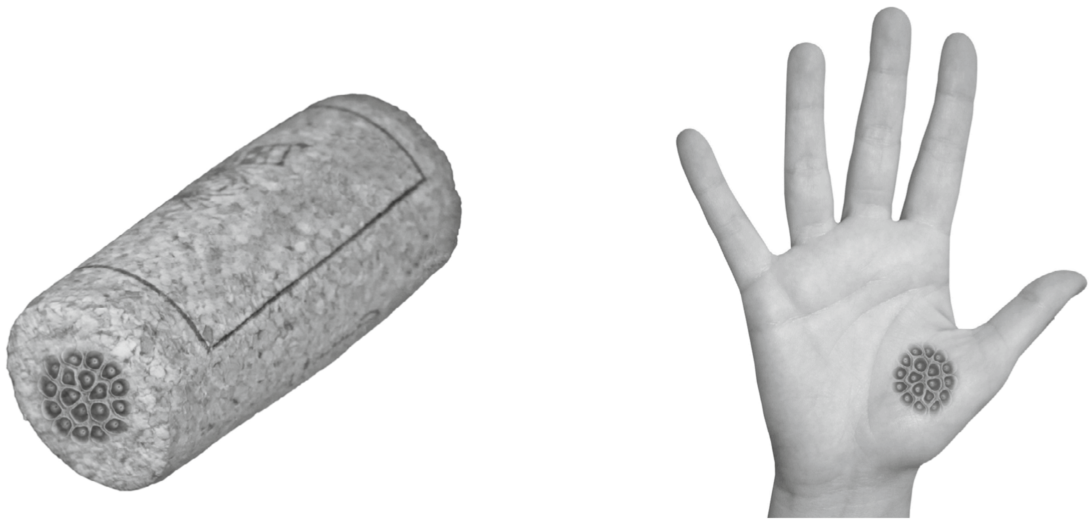

Fig. 2 Examples of images using the Hasu-colla principle. Original pictures were taken from the Bank of Standardized Stimuli (Brodeur et al., 2014)

signature" is observed on organic matter (e.g., clusters of worms on meat), it often indicates the presence of pathogens associated with putrefaction and rotting, informing the observer would therefore be dangerous to consume the matter in question (Amendt et al., 2004). One hypothesis is that we have inherited mechanisms that enable us to detect and keep at bay various sources of contamination and some researchers consider that these mechanisms constitute the behavioral immune system (BIS: Murray & Schaller, 2016; Schaller, 2016; Schaller & Duncan, 2007; Schaller & Park, 2011; Thiebaut et al., 2021 for reviews). The emotion of disgust is central to the BIS and is an adaptive behavioral response that ensures the expulsion of spoiled food if it has been ingested (e.g., a moldy apple) or causes us to keep our distance from persons in poor health (e.g., someone with the flu) (Oaten et al., 2009). These mechanisms ultimately reduce the transmission of infectious diseases. Researchers have hypothesized that the aversion elicited by trypophobic images is directly related to these inherited mechanisms involved in pathogen avoidance or, in other words, that trypophobia is due to activation of the BIS. With this in mind, Kupfer and Le (2018) showed trypophobic (versus non-trypophobic) participants disease-related pictures with or without clusters of holes (e.g., smallpox scars on the hand versus the torso of a lesion-free man) as well as non-disease-related pictures with or without holes (e.g., a lotus seed head versus a plant with a smooth surface). The participants were asked to indicate on a 9-point Likert scale how pleasant they found each picture to look at (1 = extremely pleasant, 9 = extremely unpleasant). The results showed that disease-related pictures with holes bothered both groups of participants, but that only the trypophobic group expressed a high level of discomfort at the sight of pictures with non-disease related holes. Interestingly, the participants most sensitive to pathogenic disgust[3] expressed more negative reactions to all types of trypophobic pictures. McAuley et al. (2019) explored possible links between the trypophobia questionnaire (Le et al., 2015) and a disgust questionnaire measuring moral, sexual and pathogenic disgust (Tybur et al., 2009). They found that the best predictor of trypophobia scores was pathogenic disgust, i.e., disgust related to disease and contamination. These results therefore support the hypothesis that trypophobia is due to the activation of anti-pathogenic mechanisms, i.e., the BIS. A similar study also reported that trypophobia could be predicted by disease-related disgust as well as by personal distress, i.e., the empathy trait of self-directed emotional distress, and visual discomfort (Imaizumi et al., 2016). Yamada and Sasaki (2017) had previously shown that infected people find trypophobic images more unsettling. However, it is clear that more studies of this type, which have the advantage of being more 'ecological', will be needed in the future.

Trypophobia is a topic that has been studied extensively by researchers in Asia and a Japanese team used a process called *Hasu-colla* to study the disorder (*Hasu* means lotus in

[3] To assess disgust sensitivity, it is possible to use self-administered questionnaires such as the "three domain disgust scale" (Tybur et al., 2009). Using a 6-point Likert scale, this scale measures moral disgust (e.g., stealing from a neighbor), sexual disgust (e.g., watching a pornographic video), and pathogenic disgust (e.g., accidentally touching someone's open wound).

Japanese and *Colla* is an abbreviation for collage) (Furuno et al., 2017). This process consists in using image editing software to apply the perforated area of the lotus seed head (without the petals, stamens, and pistil) to photographs (see Fig. 2 for two examples). Artists also use this process to create interesting effects (e.g., Furuno et al., 2018). In Furuno et al.'s (2017) study, *Hasu-colla* were either applied to photographs of men, women or harmless animals (such as horses or cats), or the "holey" patterns were presented in isolation on a gray background. Participants rated how pleasant/unpleasant each visual montage was to look at. Aversion scores were higher when the pattern was applied to a human or animal than when it was presented in isolation. No difference was observed between animal and human pictures. Pipitone et al. (2022) attempted to test predictions of the two evolutionary hypotheses of trypophobia in participants from two countries (United States and Croatia). To do so, they applied the *Hasu-colla* procedure to objects (e.g., an armchair), body parts (e.g., the palm of the hand), dangerous animals (e.g., a spider), and non-dangerous animals (e.g., a ladybug). In an alternative condition, the different objects were presented without holes. Participants rated their level of visual comfort in response to each type of stimulus using Likert scales (-5 = extremely uncomfortable to 5 = extremely comfortable). Greater differences in visual comfort between "trypophobic" and "non-trypophobic" patterns were observed for body parts than for venomous animals, and these differences were even greater for participants more prone to trypophobia. For Pipitone and colleagues (2022), this pattern of results is more consistent with the skin disease hypothesis given that the greatest changes in visual comfort were observed in response to trypophobic patterns lying on the human skin. The skin disease hypothesis has received further support from research using the semantic priming technique, which found that adults primed with words related to skin diseases produced lower comfort scores for trypophobic pictures, but not for negative pictures (e.g., a barking dog) (Shirai & Ogawa, 2021). Recently, DiMattina et al. (2024) compared the level of visual comfort evoked by natural textures, trypophobic pictures, and skin-disease pictures among trypophobic (TQ > 31) and non-trypophobic participants. Their findings revealed that only trypophobic individuals experienced trypophobic pictures as being equally uncomfortable as those of skin disease. It is interesting to note that the natural textures that resemble trypophobic stimuli were rated as the most uncomfortable to look at. Further support for the skin disease hypothesis comes from the fact that individuals with a history of skin disease have been found to be more trypophobic than those without such problems (Yamada & Sasaki, 2017). In summary, the (scarce) data available in the literature on trypophobia seem to be more consistent with the hypothesis that trypophobia is due to the activation of pathogen avoidance mechanisms, particularly those relating to skin disease.

The Physiological Impact of Trypophobia

To assess trypophobia, it is also possible to use techniques that provide objective measures, in this case physiological measures. These objective measures (e.g., heart rate, skin conductance, pupil diameter) have been widely used in the past to measure the emotion of disgust. For example, research by Kreibig (2010) distinguished two types of disgust based on objective measures: disgust associated with mutilation and disgust associated with contamination. A decrease in heart rate (with no change in heart rate variability) was observed for the first type of disgust, while both heart rate and heart rate variability increased for the second. Thus, a number of studies have attempted to identify physiological markers of trypophobia, which are often related to the emotion of disgust. We shall present these below.

In one study, Le et al. (2020) compared the heart rate, heart rate variability[4] and cortical hemodynamic responses,[5] i.e., markers of visual discomfort and stress, of trypophobic versus non-phobic individuals. Participants viewed images containing clusters of holes and neutral images. While there was no difference between the two groups of participants for the neutral images, the images with clusters of holes had an effect on the individuals with high TQ scores (TQ > 31): Their heart rate (and heart rate variability) increased, an observation which is consistent with the findings for contamination-related disgust (Kreibig, 2010), as did the amplitude of their hemodynamic responses in higher cortical areas. Trypophobia may therefore be related to visual stress (Wilkins, 1995) and reflect cortical hyperexcitability (with hemodynamic responses occurring mainly in posterior cortical areas, Le et al., 2020). Consequently, symptoms of trypophobia (e.g., discomfort) would be one of the homeostatic mechanisms that help reduce both the metabolic load of the visual cortex (Wilkins & Hibbard, 2014) and visual stress (Hibbard & O'Hare, 2015). By encouraging avoidance, these symptoms would be adaptive.

Pupil diameter was measured in another study, in which participants viewed trypophobic, frightening or neutral images (Ayzenberg et al., 2018). Greater pupil constriction was observed in response to images containing holes,

[4] Heart rate corresponds to the number of heartbeats per minute and heart rate variability consists of changes in the time intervals between adjacent heartbeats (Shaffer & Ginsberg, 2017).

[5] Cortical hemodynamic responses are changes in the oxygenation of the blood reaching the visual cortex in response to visual stimuli, and people who are most sensitive to visual discomfort are those with the greatest hemodynamic responses (Wilkins, 2016).

suggesting activation of the parasympathetic nervous system involved in disgust, while greater pupil dilation was observed for frightening images. These results are comparable to those reported by studies that have investigated physiological differences in fear and disgust. Indeed, disgusting images cause pupil contraction, while fearful images cause pupil dilation (Al-Omar et al., 2013). Finally, Pipitone et al. (2017) found that trypophobic images increased electrodermal activity compared to neutral images (but this time, without any effect on heart rate). This pattern has also been observed for disgusting pictures, which increase skin conductance (Stark et al., 2005) and are responsible for a general activation of the parasympathetic nervous system (De Jong et al., 2011; Levenson, 1992). Similarly, a recent study conducted in Japan found that children aged between 4 and 9 expressed more feelings of itchiness, disgust and fear when evaluating trypophobic compared to neutral images (Suzuki et al., 2023). This result indirectly supports the idea that trypophobia evolved from the need to avoid dermatological diseases. Taken together, studies on the physiological effects of trypophobia seem to indicate a very strong link with disgust, an emotion that is central to the avoidance of sources of contamination (Oaten et al., 2009; Thiebaut et al., 2021; Tybur et al., 2009). Given that trypophobia seems to be more closely related to disgust than to fear, the question arises as to whether trypophobia is a true phobia (Can et al., 2017).

Is Trypophobia a Real Phobia?

The criteria that define a specific phobia include intense fear and anxiety about an object or situation, as well as avoidance and clinically significant distress that interferes with daily life (*American Psychiatric Association (APA)*, 2013). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM)-5, a distinction must be made between phobias specific to an object or situation (e.g., animals, heights, blood) and social phobia, which is defined as the fear of acting in public (*APA*, 2013). In the DSM-5, there are seven criteria that must be considered in order to diagnose a specific phobia. These are the following: (1) a fear or intense anxiety about a specific object or situation; (2) the phobogenic object or situation almost always causes immediate fear or anxiety; (3) the phobogenic object or situation is actively avoided; (4) the fear or anxiety is disproportionate to the actual danger; (5) the fear, anxiety, or avoidance is persistent, usually lasting six months or more; (6) the fear, anxiety, or avoidance causes clinically significant distress or impairment of occupational or social functioning, and (7) the disorder is not best explained by symptoms of another mental disorder.

The question of whether trypophobia meets the criteria for a clinical phobia is a matter of debate. Currently, trypophobia is not included in the DSM-5.[6] Some researchers have expressed reservations about classifying trypophobia as a "true phobia". One of these is Pipitone, who asserts that “For most people, even though they may find trypophobic images repulsive to look at, they can still go about their daily routine.” (August 28, 2023, The Washington Post). Indeed, according to the DSM-5, in phobias, “fear, anxiety or avoidance cause clinically significant suffering or impaired occupational or social functioning” (criterion No. 6 above). Furthermore, Mayor et al. (2021) have claimed that trypophobia can “(…) at best be classified under the unspecific category-specific phobia, Other Type.” (p. 2). Finally, according to Can et al. (2017): “(…) it is questionable whether it is justified to legitimize trypophobia.”

It should be noted, however, that the fact that trypophobia is not included in the DSM-5 should not be taken too readily as evidence that it is not a specific phobia. In fact, the DSM-5 does not provide an exhaustive list of phobias, and as pointed out by Cole (2024), aversion to cats is not reported or illustrated in the DSM-5, even though it would be difficult to deny the existence of ailurophobia. According to Cole (2024), trypophobia meets all (seven) criteria of the DSM-5 and can therefore be defined as a specific phobia. This position has also already been adopted by Vlok-Barnard and Stein (2017), according to whom the evidence suggests that trypophobia should be classified as a specific phobia. In their view, a revised version of the DSM could therefore declare it to be a "true" phobia, along with snake phobia, spider phobia, or height phobia. Vlok-Barnard and Stein (2017) conducted a study intended to determine what the main clinical characteristics of trypophobia are. The participants (83.6% women) involved in this research, all of whom were drawn from a 12,000-member Facebook trypophobia support group, completed a series of questionnaires assessing psychological distress, history of the disorder, anxiety, depression, severity, physiological sensation, and feelings of fear and disgust. It was found that 78.5% of the participants reported that they had not had any painful experiences in the past that might have predisposed them to develop trypophobia. The main symptoms experienced were itching (67.2%), goose bumps (67.2%), and nausea (53.8%). The most common comorbidities were major depressive disorder (for 19% of diagnosed participants) and generalized anxiety disorder (for 17.4% of diagnosed participants). 60.5% of participants reported experiencing more disgust than fear when confronted with clusters of holes, while 11.8%

[6] It should be noted that trypophobia is also not listed in the International Classification of Diseases (ICD-11, *World Health Organization*, 2021), but as outlined by Cole (2024), the fear of holes satisfies essential criteria necessary in order to be described as a specific phobia.

reported experiencing only disgust. For the emotion of fear, 5.1% reported feeling more fear than disgust and 1% felt only fear. Finally, 21% of the sample felt both disgust and fear. The study also found that the majority of participants reported that they had never sought treatment (for the issue of the treatment of trypophobia, see Part 7 below), but that Internet support groups were of great help to them. Finally, a significant number of participants met more DSM-5 criteria for a specific phobia than for obsessive–compulsive disorder (OCD). Although disgust is mainly associated with OCD, it has also been described in specific phobias such as arachnophobia (Sawchuk et al., 2002) or ophidiophobia (Rádlová et al., 2020).

The role of anxiety in trypophobia is still a subject of debate. According to the DSM-5, anxiety is one of the basic criteria that must be satisfied for a phobia to be classified as a specific phobia. In trypophobia, however, the role of anxiety is not as straightforward as in other phobias. Some studies have found an association between trypophobia and anxiety (Mayor et al., 2021; Vlok-Barnard & Stein, 2017; Wong et al., 2023) or social anxiety (Chaya et al., 2016), while others have found no or only weak associations (Le et al., 2015; Pipitone & DiMattina, 2020; Pipitone et al., 2017, 2022).

Can Trypophobia Be Treated?

In Martinez-Aguayo et al.'s (2018) study of a young girl who complained of nausea and abdominal pain when exposed to trypophobic textures, the researchers reported on the solutions offered to her to provide relief. What were they? As with other phobias, medication, i.e., sertraline (a serotonin reuptake inhibitor often used as an antidepressant), was used in conjunction with cognitive-behavioral therapy (CBT) (see Walkup et al., 2008 for research showing the benefits of an approach combining medication and CBT in children). After five weeks of treatment, the patient's condition improved by 20% compared to the first visit. When confronted with stimuli likely to provoke trypophobic reactions, the girl showed fear, but the neurovegetative symptoms had disappeared. In addition, the severity of the generalized anxiety disorder also decreased during this period. Nine weeks after the start of treatment, the intensity of the phobia had been halved. As mentioned earlier, Robakis (2018) reports the case of a 67-year-old woman who was unable to drive her car because of traffic lights and their circular appearance. Other stimuli, such as lotus flowers or holes in pitted olives, also bothered her. The patient recognized the irrational nature of such reactions. Her trypophobia all but disappeared after several months of drug treatment with duloxetine, i.e., another serotonin and noradrenaline reuptake inhibiting antidepressant, and gabapentin, i.e., an antiepileptic drug. Thus, as in the case of specific phobias, the combination of exposure therapy (Foa & Kozak, 1986) and medication can be of significant help to people with trypophobia. This research gives hope to all those who suffer from trypophobia, but at present we can only regret that too few studies have been conducted on the treatment of trypophobic patients.

Conclusions

According to evolutionary psychology, humans are more likely to develop phobias, even today in our modern environment, to stimuli that threatened the survival of our ancestors in the distant past, such as spiders, snakes or heights. However, phobias have also been reported for unusual stimuli that have no a priori connection with our evolutionary history, such as the fear of clowns or the fear of clusters of holes, i.e., the topic of this review. Trypophobia has a negative impact on a relatively large portion of the general population (Cole & Wilkins, 2013) and may ultimately be classified as a specific phobia (Cole, 2024). Much research is needed to better understand this disorder, and in particular its origins, its relationship to anxiety, and the emotions it arouses. In addition, although some cross-cultural research has already been carried out to better understand cross-cultural trypophobic responses (e.g., Pipitone et al., 2022, compared US and Croatian participants), more research of this kind is needed. Further research into the management of this type of disorder is also needed, as there is currently very little available. Such studies will be useful for health professionals and, more importantly, for people who suffer from trypophobia. Evolutionary psychology is a recent discipline in the field of cognitive science and it is giving rise to a growing number of studies (Bonin & Méot, 2019; Elimari & Lafargue, 2023). Among the many research topics investigated by this discipline, phobias are approached from a functional perspective, that is to say by asking "why" they exist. In this review, we have examined why certain individuals experience negative emotions when confronted with images of clusters of holes. Evolutionary psychologists consider that trypophobia, like many other phobias, is the result of selective pressures faced by our hunter-gatherer ancestors in the remote past. So the next time your eyes fall on a lotus seed head or a beehive, we hope we have helped the "Cro-Magnon in you" (Bonin, 2022) better understand the reasons for the discomfort you feel or that others experience if you are lucky enough not to feel anything yourself!

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References

Adam, D. (2020). The hole truth. *New Scientist, 245*(3625), 38–41. https://doi.org/10.1016/S0262-4079(20)30127-5

Åhs, F., Rosén, J., Kastrati, G., Fredrikson, M., Agren, T., & Lundström, J. N. (2018). Biological preparedness and resistance to extinction of skin conductance responses conditioned to fear relevant animal pictures: A systematic review. *Neuroscience & Biobehavioral Reviews, 95*, 430–437. https://doi.org/10.1016/j.neubiorev.2018.10.017

Alkhalifa, F., Wilkins, A., Almurbati, N., & Pinelo, J. (2020). Examining the visual effect of trypophobic repetitive pattern in contemporary urban environments: Bahrain as a case for middle east countries. *Journal of Architecture and Urbanism, 44*(1), 44–51. https://doi.org/10.3846/jau.2020.11142

Al-Omar, D., Al-Wabil, A., & Fawzi, M. (2013). Using pupil size variation during visual emotional stimulation in measuring affective states of non communicative individuals. Lecture Notes in Computer Science In C. Stephanidis & M. Antona (Eds.), *Universal access in human-computer interaction. User and context diversity* (Vol. 8010, pp. 253–258). Berlin: Springer. https://doi.org/10.1007/978-3-642-39191-0_28

Amendt, J., Krettek, R., & Zehner, R. (2004). Forensic entomology. *Naturwissenschaften, 91*, 51–65. https://doi.org/10.1007/s00114-003-0493-5

American Psychiatric Association, DSM-5 Task Force. (2013). *Diagnostic and statistical manual of mental disorders. DSM-5™* (5th ed.). American Psychiatric Publishing, Inc. https://doi.org/10.1176/appi.books.9780890425596

Ayzenberg, V., Hickey, M. R., & Lourenco, S. F. (2018). Pupillometry reveals the physiological underpinnings of the aversion to holes. *PeerJ, 6*, e4185. https://doi.org/10.7717/peerj.4185

Bertenthal, B. I., Campos, J. J., & Caplovitz, K. S. (1983). Self-produced locomotion: An organizer of emotional, cognitive, and social development in infancy. In R. N. Emde & R. Harmon (Eds.), *Continuities and discontinuities in development.* New York: Plenum.

Bonin, P. (2022). *Ce Cro-Magnon qui est en moi!* Paris: Edilivre.

Bonin, P., Gelin, M., & Bugaiska, A. (2014). Animates are better remembered than inanimates: Further evidence from word and picture stimuli. *Memory & Cognition, 42*, 370–382. https://doi.org/10.3758/s13421-013-0368-8

Bonin, P., & Méot, A. (2019). Pourquoi avons-nous encore peur des serpents ? Apport de la psychologie évolutionniste à la compréhension de certains biais comportementaux [Why are we still afraid of snakes? Evolutionary psychology's contribution to understanding certain behavioral biases]. *L'année Psychologique, 119*, 363–396. https://doi.org/10.3917/anpsy1.193.0363

Bonin, P., Thiebaut, G., Witt, A., & Méot, A. (2019). Contamination is "good" for your memory! Further evidence for the adaptive view of memory. *Evolutionary Psychological Science, 5*(3), 300–316. https://doi.org/10.1007/s40806-019-00188-y

Bonin, P., Thiebaut, G., Bugaiska, A., & Méot, A. (2022). Mixed evidence for a richness-of-encoding account of animacy effects in memory from the generation-of-ideas paradigm. *Current Psychology, 41*, 1653–1662. https://doi.org/10.1007/s12144-021-02666-8

Brodeur, M. B., Guérard, K., & Bouras, M. (2014). Bank of standardized stimuli (BOSS) phase II: 930 new normative photos. *PLoS ONE, 9*(9), e106953. https://doi.org/10.1371/journal.pone.0106953

Buss, D. M. (2019). *Evolutionary psychology: The new science of the mind* (6th ed.). New York, London: Routledge.

Buss, D. M. (2020). Evolutionary psychology is a scientific revolution. *Evolutionary Behavioral Sciences, 14*(4), 316–323. https://doi.org/10.1037/ebs0000210

Can, W., Zhuoran, Z., & Zheng, J. (2017). Is trypophobia a phobia? *Psychological Reports, 120*(2), 206–218. https://doi.org/10.1177/0033294116687298

Casale, T. B., & Burks, A. W. (2014). Hymenoptera-Sting Hypersensitivity. *New England Journal of Medicine, 370*, 1432–1439. https://doi.org/10.1056/NEJMcp1302681

Chaya, K., Xue, Y., Uto, Y., Yao, Q., & Yamada, Y. (2016). Fear of eyes: Triadic relation among social anxiety, trypophobia, and discomfort for eye cluster. *PeerJ, 4*, e1942. https://doi.org/10.7717/peerj.1942

Clasen, M. (2014). Evil monsters in horror fiction: An evolutionary perspective on form and function. In S. Packer & J. Pennington (Eds.), *A history of evil in popular culture: What Hannibal Lecter, Stephen King and vampires reveal about America* (Vol. 2, pp. 39–47). Praeger/ABC-CLIO.

Coelho, C. M., & Purkis, H. (2009). The origins of specific phobias: Influential theories and current perspectives. *Review of General Psychology, 13*(4), 335–348. https://doi.org/10.1037/a0017759

Cohen, M. A., Clark, R. E., Silverstein, B., Sjostrom, T., & Spielholz, P. (2006). Work-related deaths in Washington State, 1998–2002. *Journal of Safety Research, 37*(3), 307–319. https://doi.org/10.1016/j.jsr.2006.02.007

Cole, G. G. (2024). Is trypophobia real? *Bjpsych Open, 10*(2), e48. https://doi.org/10.1192/bjo.2023.621

Cole, G. G., Millett, A., & Juanchich, M. (2024). The social learning account of trypophobia. *Quarterly Journal of Experimental Psychology*. https://doi.org/10.1177/17470218241232665

Cole, G. G., & Wilkins, A. J. (2013). Fear of holes. *Psychological Science, 24*(10), 1980–1985. https://doi.org/10.1177/0956797613484937

Davey, G. C. L. (1994). The "disgusting" spider: The role of disease and illness in the perpetuation of fear of spiders. *Society & Animals, 2*(1), 17–25. https://doi.org/10.1163/156853094X00045

De Jong, P. J., van Overveld, M., & Peters, M. L. (2011). Sympathetic and parasympathetic responses to a core disgust video clip as a function of disgust propensity and disgust sensitivity. *Biological Psychology, 88*(2–3), 174–179. https://doi.org/10.1016/j.biopsycho.2011.07.009

De Vries, R., Morquecho-Campos, P., de Vet, E., de Rijk, M., Postma, E., de Graaf, K., Engel, B., & Boesveldt, S. (2020). Human spatial memory implicitly prioritizes high-calorie foods. *Scientific Reports, 10*(1), 1–6. https://doi.org/10.1038/s41598-020-72570-x

Del Giudice, M. (2021). Åhs et al'.s (2018) systematic review on biological preparedness and resistance to extinction: A commentary and reanalysis. *Neuroscience and Biobehavioral Reviews, 120*, 13–15. https://doi.org/10.1016/j.neubiorev.2020.11.009

DiMattina, C., Pipitone, R. N., Renteria, M. R., & Ryan, K. J. (2024). Trypophobia, skin disease, and the visual discomfort of natural textures. *Scientific Reports, 14*, 5050. https://doi.org/10.1038/s41598-024-55149-8

Elimari, N., & Lafargue, G. (2023). Qu'est-ce que la psychologie évolutive : Cognition et comportements à la lumière de l'évolution [What is evolutionary psychology: Cognition and behavior in the light of evolution]. *L'année Psychologique, 123*, 173–214. https://doi.org/10.3917/anpsy1.231.0173

Ewald, P. W. (1993). The evolution of virulence. *Scientific American, 268*(4), 86–93. https://doi.org/10.1038/scientificamerican0493-86

Fančovičová, J., Szikhart, M., & Prokop, P. (2020). Learning about mushrooms is influenced by survival processing. *The American Biology Teacher, 82*, 529–534. https://doi.org/10.1525/abt.2020.82.8.529

Fernandes, N. L., Pandeirada, J. N., & Nairne, J. S. (2021). The mnemonic tuning for contamination: A replication and extension study using more ecologically valid stimuli. *Evolutionary Psychology, 19*(1), 1474704920946234. https://doi.org/10.1177/1474704920946234

Fernandes, N. L., Pandeirada, J. N., Soares, S. C., & Nairne, J. S. (2017). Adaptive memory: The mnemonic value of contamination. *Evolution and Human Behavior, 38*(4), 451–460. https://doi.org/10.1016/j.evolhumbehav.2017.04.003

Foa, E. B., & Kozak, M. J. (1986). Emotional processing of fear: Exposure to corrective information. *Psychological Bulletin, 99*(1), 20–35. https://doi.org/10.1037/0033-2909.99.1.20

Fredrikson, M., Annas, P., Fischer, H., & Wik, G. (1996). Gender and age differences in the prevalence of specific fears and phobias. *Behaviour Research and Therapy, 34*(1), 33–39. https://doi.org/10.1016/0005-7967(95)00048-3

Furuno, M., Sakurai, Y., Imaizumi, S., & Koyama, S. (2018). Face-inversion effect on disgust evoked by a cluster of dots. *i-Perception, 9*(3), 1–9. https://doi.org/10.1177/2041669518784960

Furuno, M., Imaizumi, S., Maeda, K., Hibino, H., & Koyama, S. (2017). The influence of background objects on unpleasantness evoked by lotus-seed-pods-on-the-living-body images ("hasucolla"). *International Journal of Affective Engineering, 16*(3), 221–230. https://doi.org/10.5057/ijae.IJAE-D-16-00045

Garb, J. E., & Hayashi, C. Y. (2013). Molecular evolution of α-Latrotoxin, the exceptionally potent vertebrate neurotoxin in Black Widow spider venom. *Molecular Biology and Evolution, 30*, 999–1014. https://doi.org/10.1093/molbev/mst011

Grassini, S., Holm, S. K., Railo, H., & Koivisto, M. (2016). Who is afraid of the invisible snake? Subjective visual awareness modulates posterior brain activity for evolutionarily threatening stimuli. *Biological Psychology, 121*, 53–61. https://doi.org/10.1016/j.biopsycho.2016.10.007

Heukelbach, J., & Feldmeier, H. (2004). Ectoparasites—The underestimated realm. *The Lancet, 363*(9412), 889–891. https://doi.org/10.1016/S0140-6736(04)15738-3

Hibbard, P. B., & O'Hare, L. (2015). Uncomfortable images produce non-sparse responses in a model of primary visual cortex. *Royal Society Open Science, 2*, 140535. https://doi.org/10.1098/rsos.140535

Hoehl, S., Hellmer, K., Johansson, M., & Gredebäck, G. (2017). Itsy bitsy spider…: Infants react with increased arousal to spiders and snakes. *Frontiers in Psychology, 8*, 1710. https://doi.org/10.3389/fpsyg.2017.01710

Imaizumi, S., Furuno, M., Hibino, H., & Koyama, S. (2016). Trypophobia is predicted by disgust sensitivity, empathic traits, and visual discomfort. *Springerplus, 5*(1449), 1–5. https://doi.org/10.1186/s40064-016-3149-6

Inhorn, M. C., & Brown, P. J. (1990). The anthropology of infectious disease. *Annual Review of Anthropology, 19*(1), 89–117. https://doi.org/10.1146/annurev.an.19.100190.000513

Jackson, R. E. (2005). Falling towards a theory of the vertical—horizontal illusion. In H. Heft & K. L. Marsh (Eds.), *Studies in perception and action VIII* (pp. 241–244). Erlbaum.

Jackson, R. E. (2009). Individual differences in distance perception. *Proceedings of the Royal Society B: Biological Sciences, 276*(1662), 1665–1669. https://doi.org/10.1098/rspb.2009.0004

Jackson, R. E., & Cormack, L. K. (2007). Evolved navigation theory and the descent illusion. *Perception & Psychophysics, 69*, 353–362. https://doi.org/10.3758/BF03193756

Kawai, N. (2019). *The fear of snakes: Evolutionary and psychobiological perspectives on our innate fear*. Springer.

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. https://doi.org/10.1016/S0005-7894(74)80008-0

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology, 84*(3), 394–421. https://doi.org/10.1016/j.biopsycho.2010.03.010

Kupfer, T. R., & Fessler, D. M. (2018). Ectoparasite defence in humans: Relationships to pathogen avoidance and clinical implications. *Philosophical Transactions of the Royal Society B: Biological Sciences, 373*(1751), 20170207. https://doi.org/10.1098/rstb.2017.0207

Kupfer, T. R., & Le, A. T. (2018). Disgusting clusters: Trypophobia as an overgeneralised disease avoidance response. *Cognition and Emotion, 32*(4), 729–741. https://doi.org/10.1080/02699931.2017.1345721

Landová, E., Peléšková, Š, Sedláčkova, K., Janovcová, M., Polák, J., Rádlová, S., Vobrubová, B., & Frynta, D. (2020). Venomous snakes elicit stronger fear than nonvenomous ones: Psychophysiological response to snake images. *PLoS ONE, 15*(8), e0236999. https://doi.org/10.1371/journal.pone.0236999

Le, A. T., Cole, G. G., & Wilkins, A. J. (2015). Assessment of trypophobia and an analysis of its visual precipitation. *Quarterly Journal of Experimental Psychology, 68*(11), 2304–2322. https://doi.org/10.1080/17470218.2015.1013970

Le, A., Cole, G., & Wilkins, A. (2020). Trypophobia: Heart rate, heart rate variability and cortical haemodynamic response. *Journal of Affective Disorders, 274*, 1147–1151. https://doi.org/10.1016/j.jad.2020.06.002

Levenson, R. W. (1992). Autonomic nervous system differences among emotions. *Psychological Science, 3*(1), 23–27. https://doi.org/10.1111/j.1467-9280.1992.tb00251.x

LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science, 19*(3), 284–289. https://doi.org/10.1111/j.1467-9280.2008.02081.x

Martínez-Aguayo, J. C., Lanfranco, R. C., Arancibia, M., Sepúlveda, E., & Madrid, E. (2018). Trypophobia: What do we know so far? A case report and comprehensive review of the literature. *Frontiers in Psychiatry, 9*, 15. https://doi.org/10.3389/fpsyt.2018.00015

Mayor, E., Meyer, A., Miani, A., & Lieb, R. (2021). An exploration of the nomological network of trypophobia. *PLoS ONE, 16*(9), 1–15. https://doi.org/10.1371/journal.pone.0257409

McAuley, L., Shiramizu, V. M., O'Shea, K. J., Stevenson, J. L., Jones, B. C., & Dawydiak, E. J. (2019). Individual differences in pathogen disgust predict responses to trypophobic images. Retrieved from osf.io/yrdv7, https://doi.org/10.31234/osf.io/9vzt7

Menzies, R. G., & Clarke, J. C. (1995). Danger expectancies and insight in acrophobia. *Behaviour Research and Therapy, 33*(2), 215–221. https://doi.org/10.1016/0005-7967(94)P4443-X

Murray, D. R., & Schaller, M. (2016). The behavioral immune system: Implications for social cognition, social interaction, and social influence. *Advances in Experimental Social Psychology, 53*, 75–129. https://doi.org/10.1016/bs.aesp.2015.09.002

Natterson-Horowitz, B., & Bowers, K. (2023). *L'âge sauvage: L'adolescence chez les humains et les animaux [The wild age: Human and animal adolescence]*. Genève: Editions Markus Haller.

Neuberg, S. L., Schaller, M., & Park, J. H. (2011). Human threat management systems: Self-protection and disease avoidance. *Neuroscience & Biobehavioral Reviews, 35*(4), 1042–1051. https://doi.org/10.1016/j.neubiorev.2010.08.011

Neuhauser, H. K. (2007). Epidemiology of vertigo. *Current Opinion in Neurology, 20*(1), 40–46. https://doi.org/10.1097/WCO.0b013e328013f432

New, J., Krasnow, M. M., Truxaw, D., & Gaulin, S. J. (2007). Spatial adaptations for plant foraging: Women excel and calories count. *Proceedings of the Royal Society B: Biological Sciences, 274*(1626), 2679–2684. https://doi.org/10.1098/rspb.2007.0826

Oaten, M., Stevenson, R. J., & Case, T. I. (2009). Disgust as a disease-avoidance mechanism. *Psychological Bulletin, 135*(2), 303–321. https://doi.org/10.1037/a0014823

Öhman, A., Eriksson, A., & Olofsson, C. (1975). One-trial learning and superior resistance to extinction of autonomic responses conditioned to potentially phobic stimuli. *Journal of Comparative and Physiological Psychology, 88*(2), 619–627. https://doi.org/10.1037/h0078388

Oosterink, F. M. D., de Jongh, A., & Hoogstraten, J. (2009). Prevalence of dental fear and phobia relative to other fear and phobia subtypes. *European Journal of Oral Sciences, 117*(2), 135–143. https://doi.org/10.1111/j.1600-0722.2008.00602.x

Pipitone, R. N., & DiMattina, C. (2020). Object clusters or spectral energy? Assessing the relative contributions of image phase and amplitude spectra to trypophobia. *Frontiers in Psychology: Perception Science, 11*, 1847. https://doi.org/10.3389/fpsyg.2020.01847

Pipitone, R. N., DiMattina, C., Martin, E. R., Pavela Banai, I., Bellmore, K., & De Angelis, M. (2022). Evaluating the 'skin disease-avoidance'and 'dangerous animal' frameworks for understanding trypophobia. *Cognition and Emotion, 36*(5), 943–956. https://doi.org/10.1080/02699931.2022.2071236

Pipitone, R. N., Gallegos, B., & Walters, D. (2017). Physiological responses to trypophobic images and further scale validity of the trypophobia questionnaire. *Personality and Individual Differences, 108*, 66–68. https://doi.org/10.1016/j.paid.2016.11.068

Polák, J., Rádlová, S., Janovcová, M., Flegr, J., Landová, E., & Frynta, D. (2020). Scary and nasty beasts: Self-reported fear and disgust of common phobic animals. *British Journal of Psychology, 111*(2), 297–321. https://doi.org/10.1111/bjop.12409

Prokop, P., & Fančovičová, J. (2014). Seeing coloured fruits: Utilisation of the theory of adaptive memory in teaching botany. *Journal of Biological Education, 48*(3), 127–132. https://doi.org/10.1080/00219266.2013.837407

Rádlová, S., Polák, J., Janovcová, M., Sedláčková, K., Peléšková, Š, Landová, E., & Frynta, D. (2020). Emotional reaction to fear- and disgust-evoking snakes: Sensitivity and propensity in snake-fearful respondents. *Frontiers in Psychology, 11*, 31. https://doi.org/10.3389/fpsyg.2020.00031

Rakison, D. H. (2018). Do 5-month-old infants possess an evolved detection mechanism for snakes, sharks, and rodents? *Journal of Cognition and Development, 19*(4), 456–476. https://doi.org/10.1080/15248372.2018.1488717

Rakison, D. H., & Derringer, J. (2008). Do infants possess an evolved spider-detection mechanism? *Cognition, 107*(1), 381–393. https://doi.org/10.1016/j.cognition.2007.07.022

Robakis, T. K. (2018). Trypophobia associated with gabapentin: A case report. *Journal of Clinical Psychopharmacology, 38*(2), 162–163. https://doi.org/10.1097/JCP.0000000000000842

Rufo, M. (1998). La petite fille qui avait peur des trous [The little girl who was afraid of holes]. *Soins, Pédiatrie, Puériculture, 182*, 3–3.

Sasaki, K., Yamada, Y., Kuroki, D., & Miura, K. (2017). Trypophobic discomfort is spatial-frequency dependent. *Advances in Cognitive Psychology, 13*(3), 224–231. https://doi.org/10.5709/acp-0222-2

Sawchuk, C. N., Meunier, S. A., Lohr, J. M., & Westendorf, D. H. (2002). Fear, disgust, and information processing in specific phobia: The application of signal detection theory. *Journal of Anxiety Disorders, 16*(5), 495–510. https://doi.org/10.1016/S0887-6185(02)00168-8

Schaller, M. (2016). The behavioral immune system. In D. M. Buss (Ed.), *The handbook of evolutionary psychology* (2nd ed., Vol. 1, pp. 206–224). Wiley.

Schaller, M., & Duncan, L. A. (2007). The behavioral immune system: Its evolution and social psychological implications. In J. P. Forgas, M. G. Haselton, & W. von Hippel (Eds.), *Evolution and the social mind: Evolutionary psychology and social cognitions* (pp. 293–307). Psychology Press.

Schaller, M., & Park, J. H. (2011). The behavioral immune system (and why it matters). *Current Directions in Psychological Science, 20*(2), 99–103. https://doi.org/10.1177/0963721411402596

Seligman, M. E. P. (1971). Phobias and preparedness. *Behavior Therapy, 2*, 307–320. https://doi.org/10.1016/S0005-7894(71)80064-3

Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Frontiers in Public Health, 5*, 258. https://doi.org/10.3389/fpubh.2017.00258

Shirai, R., & Ogawa, H. (2019). Trypophobic images gain preferential access to early visual processes. *Consciousness and Cognition, 67*, 56–68. https://doi.org/10.1016/j.concog.2018.11.009

Shirai, R., & Ogawa, H. (2021). Priming with skin-problems increases fear of clusters. *Scientific Reports, 11*, 10362. https://doi.org/10.1038/s41598-021-89917-7

Skaggs, W. (2014). Fear of holes. *Scientific American. Mind, 25*(2), 12. https://doi.org/10.1038/scientificamericanmind0314-12b

Stark, R., Walter, B., Schienle, A., & Vaitl, D. (2005). Psychophysiological correlates of disgust and disgust sensitivity. *Journal of Psychophysiology, 19*(1), 50–60. https://doi.org/10.1027/0269-8803.19.1.50

Stevens, J. A., Mack, K. A., Paulozzi, L. J., & Ballesteros, M. F. (2008). Self-reported falls and fall-related injuries among persons Aged ≥ 65 years–United States, 2006. *Journal of Safety Research, 39*(3), 345–349. https://doi.org/10.1016/j.jsr.2008.05.002

Suzuki, C., Shirai, N., Sasaki, K., Yamada, Y., & Imura, T. (2023). Preschool children aged 4 to 5 years show discomfort with trypophobic images. *Scientific Reports, 13*, 2768. https://doi.org/10.1038/s41598-023-29808-1

Thèves, C., Biagini, P., & Crubézy, E. (2014). The rediscovery of smallpox. *Clinical Microbiology and Infection, 20*(3), 210–218. https://doi.org/10.1111/1469-0691.12536

Thiebaut, G., Méot, A., Witt, A., Prokop, P., & Bonin, P. (2021). The behavioral immune system: How does it contribute to our understanding of human behavior. In A. M. Columbus (Ed.), *Advances in Psychology Research.* (Vol. 144). Nova Science.

Thiebaut, G., Méot, A., Witt, A., Prokop, P., & Bonin, P. (2022). COVID-19 and memory: A novel contamination effect in memory. *Evolutionary Psychology, 20*(2), 14747049221108928. https://doi.org/10.1177/14747049221108929

Tooby, J., & Cosmides, L. (1990). The past explains the present: Emotional adaptations and the structure of ancestral environments. *Ethology and Sociobiology, 11*(4–5), 375–424. https://doi.org/10.1016/0162-3095(90)90017-Z

Tybur, J. M., Lieberman, D., & Griskevicius, V. (2009). Microbes, mating, and morality: Individual differences in three functional domains of disgust. *Journal of Personality and Social Psychology, 97*(1), 103–122. https://doi.org/10.1037/a0015474

Van Blerkom, J. (1993). Development of human embryos to the hatched blastocyst stage in the presence or absence of a monolayer of Vero cells. *Human Reproduction, 8*(9), 1525–1539. https://doi.org/10.1093/oxfordjournals.humrep.a138293

Van Strien, J. W., Christiaans, G., Franken, I. H., & Huijding, J. (2016). Curvilinear shapes and the snake detection hypothesis: An ERP study. *Psychophysiology, 53*(2), 252–257. https://doi.org/10.1111/psyp.12564

Van Strien, J. W., Franken, I. H., & Huijding, J. (2014). Testing the snake-detection hypothesis: Larger early posterior negativity in humans to pictures of snakes than to pictures of other reptiles, spiders and slugs. *Frontiers in Human Neuroscience, 8*, 691. https://doi.org/10.3389/fnhum.2014.00691

Van Strien, J. W., & Van der Peijl, M. K. (2018). Enhanced early visual processing in response to snake and trypophobic stimuli. *BMC Psychology, 6*(1), 21. https://doi.org/10.1186/s40359-018-0235-2

VanArsdall, J. E., Nairne, J. S., Pandeirada, J. N. S., & Blunt, J. R. (2013). Adaptive memory: Animacy processing produces mnemonic advantages. *Experimental Psychology, 60*, 172–178. https://doi.org/10.1027/1618-3169/a000186

Vetter, R. S., & Isbister, G. K. (2008). Medical aspects of spider bites. *Annual Review of Entomology, 53*, 409–429. https://doi.org/10.1146/annurev.ento.53.103106.093503

Vlok-Barnard, M., & Stein, D. J. (2017). Trypophobia: An investigation of clinical features. *Revista Brasileira De Psiquiatria, 39*(4), 337–341. https://doi.org/10.1590/1516-4446-2016-2079

Wabnegger, A., Schwab, D., & Schienle, A. (2019). The hole story: An event-related potential study with trypophobic stimuli. *Motivation and Emotion, 43*, 985–992. https://doi.org/10.1007/s11031-019-09784-8

Walkup, J. T., Albano, A. M., Piacentini, J., Birmaher, B., Compton, S. N., Sherrill, J. T., Ginsburg, G. S., Rynn, M. A., McCracken, J., Waslick, B., Iyengar, S., March, J. S., & Kendall, P. C. (2008). Cognitive behavioral therapy, sertraline, or a combination in childhood anxiety. *New England Journal of Medicine, 359*(26), 2753–2766. https://doi.org/10.1056/NEJMoa080463

Wilkins, A. J., & Hibbard, P. B. (2014). "Discomfort and hypermetabolism," in *Proceedings of the 50th Anniversary Convention of the AISB*, 1st-4th April 2014. Goldsmiths: University of London, 11–13.

Wilkins, A. J. (1995). *Visual Stress*. Oxford University Press.

Wilkins, A. J. (2016). A physiological basis for visual discomfort: Application in lighting design. *Lighting Research & Technology, 48*(1), 44–54. https://doi.org/10.1177/1477153515612526

Wong, S. M. Y., Tang, E. Y. H., Hui, C. L. M., Suen, Y. N., Chan, S. K. W., Lee, E. H. M., Chan, K. T., Wong, M. T. H., Wilkins, A. J., & Chen, E. Y. H. (2023). Excessive fear of clusters of holes, its interaction with stressful life events and the association with anxiety and depressive symptoms: Large epidemiological study of young people in Hong Kong. *The British Journal of Psychiatry, 9*, e151. https://doi.org/10.1192/bjo.2023.540

Workman, L., & Reader, W. (2014). *Evolutionary Psychology. An introduction* (3rd ed.). Cambridge University Press.

World Health Organization (WHO). (2021). International Statistical Classification of Diseases and Related Health Problems 11th ed., ICD-11. WHO, 2021.

Yamada, Y., & Sasaki, K. (2017). Involuntary protection against dermatosis: A preliminary observation on trypophobia. *BMC Research Notes, 10*(658), 1–5. https://doi.org/10.1186/s13104-017-2953-6

Yuan, X., Cui, X., Cao, Z., Kan, H., Wang, X., & Wang, Y. (2018). Attentional bias towards threatening visual stimuli in a virtual reality-based visual search task. *Acta Psychologica Sinica, 50*(6), 622–636. https://doi.org/10.3724/SP.J.1041.2018.00622

Zhu, S., Sasaki, K., Jiang, Y., Qian, K., & Yamada, Y. (2020). Trypophobia as an urbanized emotion: Comparative research in ethnic minority regions of China. *PeerJ, 8*, e8837. https://doi.org/10.7717/peerj.8837

Zsido, A. N. (2017). The spider and the snake – A psychometric study of two phobias and insights from the Hungarian validation. *Psychiatry Research, 257*, 61–66. https://doi.org/10.1016/j.psychres.2017.07.024

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