An exploration of trypophobia

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To my family

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"Ngày mà con ngồi xuống và cảm thấy mệt mỏi, con đã đi được nửa chặng đường."

WORDS OF MY FATHER

SUMMARY

Images comprising clusters of objects can induce aversion and certain symptoms of anxiety, fear and disgust (so-called "trypophobia") in about 13% of the population. This thesis is an investigation of the stimulus and response characteristics of the condition. First, a symptom questionnaire (Trypophobia Questionnaire) was developed and validated based on reports of different categories of symptoms. The questionnaire demonstrated a single construct that predicted discomfort from trypophobic images, but not neutral or unpleasant images, and did not correlate with anxiety. Second, filtering images reduced the excess energy at mid-range spatial frequencies (previously associated with both trypophobic and uncomfortable images). Relative to unfiltered trypophobic images, the discomfort from filtered images experienced by observers with high TQ scores was less than that experienced with neutral images, and by observers with low TQ scores.

Clusters of concave objects (holes) did not induce significantly more discomfort than clusters of convex objects (bumps), suggesting that trypophobia (previously referred to as "fear of holes") involves clusters not of holes but of objects with particular spectral profile involving excess energy at mid-range spatial frequencies. These visual characteristics have been previously shown to induce discomfort and a strong cortical oxygenation. The same abnormal oxygenation occurred for trypophobic images, but only for individuals with high TQ scores.

Three lines of evidence suggest that trypophobia is a response of disgust rather than fear: (1) trypophobia was associated with an aversion to spiders, and not snakes; (2) trypophobic stimuli did not produce a bias in the subjective estimation of

stimulus duration but (3) increased the heart rate and its variability. Fear inducing stimuli generally give effects opposite to those listed as 2 and 3.

In conclusion, trypophobia is a reaction of disgust to clusters of objects with particular spectral profile that may resemble contamination sources (e.g., skin lesions).

CHAPTER 1. GENERAL INTRODUCTION

"I have experienced this (trypophobia) my entire life, and can give specific examples going back to when I was about 4 years old. It is definitely a phobia because it is highly irrational and can be triggered by the most mundane objects and patterns. It also sets me up with very invasive thoughts that make it hard for me to work or socialize once I've been triggered. I've been trying to describe this issue to people my whole life, and I had no idea it had a name."

J. K., personal communication, 2013

1.1. Overview

The aim of this thesis is to explore a condition called "trypophobia". Little is known about this condition, which is commonly referred to as the "fear of holes" (Cole & Wilkins, 2013; Skaggs, 2014). This description suggests that individuals experience a specific emotion (i.e., fear) towards specific objects (i.e., holes). This research attempts to provide a theoretical framework for this condition, so as to understand the nature of the inducing stimuli and the aspects of the responses that individuals display. By investigating the psychophysical properties of the images, it will be demonstrated that "holes" are not the only inducing stimuli. Rather, the condition is related to clusters of objects with certain spectral compositions that induce an abnormal cortical response. On the basis of its relationship to cognitive bias, physiological correlates and other anxiety disorders, it will also be argued that trypophobia is not necessarily a fear response, but a disgust response.

1.2. Emotions

The term "emotion" comes from the Latin word "emovere", which means "to move out" or "to stir up" (Elnicki, 2010; Hargreaves, 1998), and refers to the feelings humans experience by way of underlying motivational states (Bradley, Codispoti, Cuthbert, & Lang, 2001). Contemporary theories suggest that there are sets of "basic

emotions" that have been biologically developed and encoded in our genes (Ekman, 1992a; Fox, 2008; Niedenthal, Krauth-Gruber, & Ric, 2006). Typical lists of basic emotions reported in the literature usually include happiness, surprise, anger, sadness, disgust and fear (e.g., Ekman, 1992b; Shaver, Morgan, & Wu, 1996). These emotions have been suggested as serving important functions for our ancestors, and Fox (2008) described the following critical ecological determinants for the development of our emotions:

(a) The ability to find adequate foods, drink and shelter.

(b) The ability to get access to sexual partners.

(c) The ability to provide adequate protection and nurturing for offspring.

(d) The ability to avoid danger.

(e) The ability to escape from life-threatening events.

Fox (2008) argued that those events contributed to the shaping of our current set of core emotions, as they represent what our ancestors had to overcome in order to pass on genes to the next generation. It has therefore been suggested that emotions are neuropsychological phenomena developed to facilitate adaptation through certain physiological, cognitive or behavioural responses (Izard, 1992). More specifically, two motivational systems have been proposed as fundamental for emotions (Bradley et al., 2001). The first system is appetitive and promotes survival through behaviour related to nourishment and reproduction, and most pleasant affects (e.g., joy, happiness, etc.) are within this category. On the contrary, unpleasant affects are usually associated with the defensive system. This system ensures accurate responses to threating situations by displaying appropriate behaviour such as escape or attack,

which is known as the so-called “fight-or-flight” response (Balconi, Brambilla, & Falbo, 2009). Some of the emotions related to the defensive system will be a central point of this thesis, which is closely related to the aspects of fear, disgust and anxiety.

1.2.1. Fear

Fear has been described as the emotional state individuals experience when they become aware of stimuli that they perceive as threatening or harmful (Berger, 2010; Quinn & Fanselow, 2006). When experiencing this emotional state, individuals may display a series of behavioural responses (e.g., aggression or urge to hide) or physiological responses (e.g., muscle tension or pupil dilation) (LeDoux, 2012; Marks, 1969). Consistent with the view of other basic emotions, fear has been understood to serve a vital function for survival. In situations that are harmful or threatening, certain responses are required in order to best prepare the organism and resolve the issue(s). For example, responses such as muscle tension are associated with an increased level of adrenaline, which prepares metabolic body functions for physical action (i.e., fight) (Stevenson, Hofmann, Schoch, & Schildberger, 2000). The fear response can therefore be considered as necessary and valuable (Landis, 1964), as it is (and has been) essential to surviving the hazards of the environment (Evans, 2003).

1.2.2. Anxiety

Anxiety refers to the unsettling anticipation and appraisal of threat (American Psychiatric Association, 2013; Marks, 1969). The negative affect is usually directed towards threatening but unspecified events (Rachman, 2004), which makes anxiety pervasive and persistent rather than episodic and event-specific. The anticipation, in addition to the uncertainty and/or abstract characteristics of the actual source of the threat (Clark & Beck, 2010; Lazarus & Averill, 1972), are the aspects that distinguish

anxiety (pre-stimulus) from fear (post-stimulus) (Barlow, 2004). Anxiety can concern the physical threat to life, but also threats against psychological existence (e.g., meaninglessness) or important values in which the self is striving to be identified with (e.g., success) (Barlow, 2004). Examples of common symptoms associated with anxiety are problems concentrating, sleep deprivation, nervousness and/or restlessness, or shortness of breath (Ramsden, 2013; Spielberger & Gorsuch, 1983).

Anxiety, among other negative emotions, has also been considered desirable in some cases (Marks, 1987). Yerkes and Dodson (1908) described a model of the relationship between arousal and performance in an inverted-u (the Yerkes-Dodson law), where the optimal performance level occurs at the intermediate level of arousal (Broadhurst, 1957; Teigen, 1994), and studies have found this to apply to anxiety. For example, Keeley, Zayac, and Correia (2008) investigated the relationship between anxiety towards statistics tests and test performance among undergraduate students who undertook statistics courses. They reported that curvilinear models best predicted test performance as compared to linear models, suggesting that participants performed at an optimal level when they experienced mid-range anxiety levels.

1.2.3. Disgust

Recognised as a basic emotion (Fox, 2008; McDougall, 1936), disgust has been described as "a sensation rather more distinct in its nature, and refers to something revolting, primarily in relation to the sense of taste, as actually perceived or vividly imagined; and secondarily to anything which causes a similar feeling, through the sense of smell, touch, and even of eyesight." (Darwin, 1872, p. 250). Rozin and Fallon (1987) described three main key elements to disgust: (1) a unique facial expression, (2) a distinct physiological response (i.e., nausea) and (3) a feeling of revulsion. Consistent with its literal meaning, which is "bad taste" (dis-gust), many

theorists have considered disgust to be a mechanism related to the rejection of substances that are threatening to the self, in particular through oral incorporation (Woody & Teachman, 2000). Importantly, the inducing stimuli must be close enough (in terms of distance) in order to have a provoking effect, which makes disgust dependent on contact or proximity (Ahmed, 2013).

Tybur, Lieberman, and Griskevicius (2009) went further in separating disgust into three distinct domains. The first domain was related to avoidance of infectious organisms (i.e., pathogen disgust), the second domain motivated sexual caution that can be beneficial for long-term reproductive success (i.e., sexual disgust), and the third domain concerned the avoidance of behaviour that can violate contemporary social norms (i.e., moral disgust). Therefore, disgust has been argued to be one of the most important aspects of adaptation (Curtis & Biran, 2001), in that it promotes avoidance behaviour. Such behaviour motivates the self to keep distance to potential sources of contamination, whether pathogenic, specific sexual interactions or social relationships with norm-violating individuals (Tybur et al., 2009), and facilitates good health and survival.

1.3. Phobias

Up to this point, the negative emotions described have been considered as natural, necessary and sometimes desirable. However, fears of objects or situations can also become irrational and severe, above and beyond what one would expect to be appropriate given the actual threat (American Psychiatric Association, 2013). In addition, the individual who is experiencing an irrational fear might even be able to acknowledge the disproportion between the fear and the stimuli. However, despite the individuals' ability to think and reflect rationally about the situation, symptoms such as nausea, sweating, panic, and other negative affects can occur upon confrontation,

both in thought or action with specific stimuli or situations (Bruce & Sanderson, 1998). When someone is experiencing this exaggerated and/or unrealistic fear, the individual is said to suffer from a phobia.

In Greek mythology, Phobos was the God who could provoke fear and panic in his enemies (Errera, 1962; Kring, Johnson, Davidson, & Neale, 2012). The term "phobia" is therefore derived from the Greek word "phobos", which translates to fear, panic or terror (Athanasiadis, 1997; Marks, 1969; Morgan, 2003), and the concept of phobias (i.e., irrational fears) has been reported throughout history. As early as the times of Hippocrates (c. 460 – c. 370 BC) (Marks, 1970) have there been writings demonstrating irrational fears, which described observations similar to the actual definitions of several phobias recognised today. Thus, despite human development, changes in language and passing of time, the experience of phobias remain similar (Saul, 2001). Phobias were accepted as independent diagnostic categories by the International Classification of Diseases (ICD) and American Psychiatric Association (APA) in the mid-1900's, and are today considered as one of the most common types of anxiety disorders.

There are several diagnostic considerations for phobias, and according to the Diagnostic and Statistical Manual of Mental disorders (DSM-5) (American Psychiatric Association, 2013), individuals with phobias display a marked fear or anxiety that is immediately provoked upon confrontation with the relevant stimulus, and has persisted for at least 6 months. The fear or anxiety experienced in relation to a phobia is irrational and out of proportion relative to the actual threat that is posed. The phobic stimulus is actively avoided, or otherwise endured with intense fear or anxiety, and causes distress and impairment to everyday functioning. In addition, the disturbance cannot be accounted for by other mental disorders, such as general

anxiety. According to the DSM-5, phobias can be classified within three categories, and those are summarised below.

1.3.1. Agoraphobia

Agoraphobia has been documented throughout history, and appeared as early as 400 B. C. (approximately) in writings of Hippocrates (Asmundson, LeBouthillier, & Taylor, 2015). However, the concept was not formally coined until 1872 by Westphal as "die agorophobie". The term is derived from the Greek word "agora", which means "large and open spaces" (Boyd & Crump, 1991), and is commonly used to represent "marketplace" (Kring et al., 2012). Therefore, agoraphobia refers to the fear of open and/or crowded environments. The individuals with this anxiety disorder are frightened that they cannot reach safety (e.g., their homes) in places such as cinemas, restaurants or trains/buses (Marks, 1987). When finding themselves in such situations, they may display behaviours associated with precaution (e.g., seating near an aisle where the possibility of escape is maximised). Agoraphobia may or may not be accompanied by panic-attacks. In the cases without panic-attacks, individuals who suffer are usually concerned about the potential consequences that will occur if potential anxiety symptoms occur in certain settings (Kring et al., 2012), and epidemiological studies have suggested that over half of the cases related to agoraphobia are without panic (Wittchen et al., 2008). Such characteristics can also make agoraphobia relatively unnoticeable to the general population. In severe cases of this phobia, individuals may totally avoid open and/or crowded environments by simply not leaving their homes (Holmes, 1982), thus becoming housebound. Based on a US sample, the lifetime prevalence for agoraphobia (without panic) has been estimated to be 1.4% (Kessler et al., 2005).

1.3.2. Social phobia

Social phobia (social anxiety disorder) refers to the persistent and overwhelming fear of social interactions and situations, and extends beyond shyness (Kring et al., 2012; Stein & Stein, 2008; Turner, Beidel, & Townsley, 1990). As Hippocrates (cited in Saul, 2001, p. 18) described, an individual who suffers from social phobia is one who "…thinks every man observes him, aims at him, derides him, owes him malice." Kessler et al. (2005) estimated the lifetime prevalence of social phobia to be 12.1%. Individuals with this phobia avoid social situations that can involve the scrutiny or evaluation of others (i.e., public speaking or meeting new people) (Ruscio et al., 2008). This is due to the possibility of personal embarrassment or humiliation (Ramsden, 2013). The most common situations that are associated with this condition were described by Rachman (2004) as public speaking, attendance at parties/meetings and speaking to authority figures. Social phobia therefore leads to social timidity (Turner & Beidel, 1989), which can inhibit overall life quality as social situations are often necessary for individuals in the modern society to achieve goals that are both social (e.g., building relationships with new people) and non-social (e.g., performing in job interviews) (Kashdan & Herbert, 2001; Rapee, Craske, & Barlow, 1994). In support, it has been reported that social phobia is related to work impairment and/or unemployment (Wittchen & Beloch, 1996).

1.3.3. Specific phobia

Specific phobia can be considered as the miscellaneous category of phobias. It comprises anything else that is not accounted for by agora- or social phobia, and has been reported to be the most common type (Berger, 2010; Ramsden, 2013). Specific phobias have a lifetime prevalence of approximately 12.5% (Kessler et al., 2005; see also Becker et al., 2007), and often co-occur with other specific phobias.

Approximately 75% of individuals with specific phobias fear more than one object or situation (on average three) (American Psychiatric Association, 2013; Kendler, Myers, Prescott, & Neale, 2001). Common types may involve animals or insects, such as snakes (i.e., ophidiophobia) or spiders (i.e., arachnophobia), but also other objects and situations such as water (i.e., aquaphobia) or enclosed spaces (i.e., claustrophobia). As with the other types of phobias, specific phobias can also reduce life quality in many ways. For example, airline transportation has become very important in the modern society, both in relation to business and for private reasons (Wilhelm & Roth, 1997). Despite being one of the safest way to travel (Sivak & Flannagan, 2003), Dean and Whitaker (1982) reported that approximately one out of six American adults are concerned about flying. A famous example of flying phobia and its implication is Dennis Bergkamp, a former professional football player at Arsenal Football Club. Travelling for away games across countries is a necessary part of being a professional athlete, however his fear of flying prevented him from playing in fixtures that involved airline transportation (Fitzpatrick, 2003).

1.3.4. Contemporary views on the aetiology of phobias

Many theoretical perspectives have been offered to account for the aetiology of phobias. First of all, in terms of classical (Pavlovian) conditioning, fear can be acquired as a result of a threatening experience (Merckelbach & Muris, 1997). One of the best known experiments to investigate this was the classic case study conducted by Watson and Rayner (1920), who demonstrated that fear of a white rat could be induced in a child if the presentation of this rat was paired with a loud noise (i.e., negative stimulus). This was despite the fact that the 11-month old subject ("Little Albert") never showed fear of rats before the experiment, as confirmed by his mother and hospital employees, in addition to his behaviour prior to the experimental

procedures. This suggested that fear of particular objects (e.g., white rat) can be learned if the presentation is sufficiently paired with negative stimuli (e.g., loud noise). Other traumatic experiences, such as direct trauma, observations or verbal/written instructions, can also lead to the development of phobias (Antony & Barlow, 2002; Kring et al., 2012). An individual who witnessed someone else reacting fearfully as a result of being bitten by a dog may develop a fear of dogs (i.e., cynophobia), whereas another individual who had an experience of being trapped in an elevator may develop fear of elevators and/or small enclosed space as a result (American Psychiatric Association, 2013; Doctor, Kahn, & Adamec, 2008).

According to conditioning theory, some phobias may therefore arise as a result of associations with negative experiences (Öst & Hugdahl, 1981). However, Seligman (1971) made the point that this cannot explain all phobias because (1) phobias tend to be induced by a rather limited set of objects and (2) not all phobias necessarily reflect the potential danger of the object or situation. For instance, Cook and Mineka (1989) stated that fears and phobias for certain animals (e.g., snakes or spiders) are common and more prevalent than fears and phobias for hammers, guns or knives, despite the latter objects being as (or even more) likely to be paired with a traumatic experience in our modern society. Fyer (1998) also noted that "height phobias are common, whereas those of matches or electrical outlets are rare" (p. 1297), suggesting that there is a non-random distribution of objects that actually are feared. In support, Davey (1994) estimated the self-reported fear of common indigenous animals in an adult UK population, and found that around half (53.3%) of the participants reported anxiety towards snakes. The high prevalence of self-reported snake aversion in the British population was evident despite snakes being relatively uncommon in the UK with only one of the three native species being venomous,

namely the adder (Warrell, 2005). A bite from this species is unlikely to be fatal, and Reid (1976) reported that only one death from snakebite was recorded in England and Wales between 1950 and 1972, whereas stings from bees and wasps accounted for 61 deaths. This suggested that fear of snakes in the UK population did not necessarily reflect the potential threat that those species might pose relative to other species, thereby questioning whether conditioning theory can sufficiently account for the development of many phobias.

To account for the non-random distribution of phobic objects, a "biological preparedness" viewpoint has been offered. According to this theory, phobias can develop as a result of ancient selection pressures associated with self-defence (McNally, 1987), whereby humans are predisposed to fear (or acquire fear) of certain objects or situations that during human evolution posed a threat to our ancestors (Seligman, 1971). Support for this view has been reported in studies of rhesus monkeys (Cook & Mineka, 1989). Monkeys who watched videotapes of peer monkeys reacting fearfully to fear-relevant stimuli (e.g., toy snakes) easily acquired fear to those stimuli. However, those who watched peers reacting fearfully to fear-irrelevant stimuli (e.g., flowers) did not acquire fear. Overall, this suggested that although phobias can be learned, the potential (evolutionary) danger of the object is important. It has therefore been proposed that some phobias are the result of a reproductive trait (Durham, 1991).

Third, some phobias only occur in certain cultural groups. This indicates that cultural factors can also influence the development of phobias, and the DSM-5 suggests that some countries, particularly in Asia or Africa, differ from the United States in terms of phobia content. One example is "taijin kyofusho", a culturally bound social anxiety disorder that appears almost exclusively in Japan (Kirmayer,

1991; Kring et al., 2012; Stein & Stein, 2008). Individuals with this phobia are often concerned about offending others by behaving inappropriately and/or having an offensive appearance (Kleinknecht, Dinnel, Kleinknecht, Hiruma, & Harada, 1997), which is different from the traditional social phobia where the fear is more related to personal embarrassment or humiliation. This can be related to the fundamental differences between cultures. In individualist cultures, hierarchical power and status differences are minimized, while equality and the possibility of personal attainment is encouraged. Members of these types of groups/societies are regarded as individuals, with unique destinies and outcomes (Triandis, 1994). It has been suggested that North American countries display prototypical individualist cultures (Niedenthal et al., 2006). In contrast, collectivist cultures are more concerned about the needs, wishes and desires within groups (e.g., casts, families, etc.), where hierarchies, status or social roles are important determinants of behaviour. Individuals within these types of cultures are discouraged to think and behave in certain manners that can be classified as individualistic, and aspects such as individual needs and desires are less prioritised compared to the needs and desires of the group as an entity (Kitayama & Markus, 1994). These types of cultures are usually found in Asian countries (Niedenthal et al., 2006), and the basis of "taijin kyofusho" has been understood to be a result of these collectivist concerns, which illustrates the cultural drive of some fears.

1.3.5. Emergence of new fears and phobias

As discussed, fears and phobias have been associated with adaptive functions, skills and traits that are beneficial for the existence and survival in the environment and/or society. It is therefore clear that alongside the development of our modern society, novel types of fear mechanisms might also co-occur as a consequence, and recent research has indeed reported many such cases. For example, our daily and

professional lives consist of the increasing use of computers and associated technology, which has changed our habits and behaviour. As a consequence of this, new disorders have appeared. For example, "nomophobia" refers to the fear of being without mobile phones or computers (King, Valença, & Nardi, 2010). Another concept, the fear of missing out (i.e., FoMO), is defined as "a pervasive apprehension that others might be having rewarding experiences from which one is absent" (Przybylski, Weinstein, Murayama, Lynch, & Ryan, 2012, p. 1841), and accounts for the increasing use of (Hughes, Rowe, Batey, & Lee, 2012) and addiction (Andreassen, Torsheim, Brunborg, & Pallesen, 2012) to the social media.

In addition to being the reason why some types of fears exist (e.g., nomophobia or FoMO), social media outlets such as Facebook have also allowed individuals from all around the world to share their experiences regarding other types of fears in a manner that was not possible before the emergence of this technology. Now, individuals have a new platform in which they can discuss and seek contact with likeminded individuals who share similar experiences, and this has contributed to the awareness of some phenomena. One such phenomenon, which will make the central point of this thesis, is a condition commonly referred to as "trypophobia", the fear of holes.

1.3.6. Trypophobia

As with some other phobias, "trypophobia" is a term that is derived from Greek (i.e., "trypos", which means 'punching, drilling and/or drilling holes'), and is often described as the fear of holes (Cole & Wilkins, 2013; Skaggs, 2014). The inducing stimuli can be any image or visual scene that presents clusters of objects in proximity to each other (see Figure 1.1), and examples of such stimuli are the patterns of a honeycomb or barnacles. Upon confrontation with such stimuli, one individual

reported that " . . . the pictures make me feel incredibly anxious and uneasy" (S. M., personal communication, 2014). Others have reported that the aversion affects their daily or professional lives. For example, a biology student wrote "… learning about cells has been absolutely horrifying" (L. H., personal communication, 2014). Another individual reported that (s)he "after investing thousands of dollars on training and equipment […] abandoned the sport of scuba diving because of the shear number of objects which had similar shapes (as trypophobic stimuli)" (L. F., personal communication, 2014), which demonstrated the implication of this condition. Symptoms such as discomfort, sweating or panic have also been reported, so it is clear that the individuals who have this condition display phobic-like experiences, both from a cognitive, physiological and behavioural perspective.

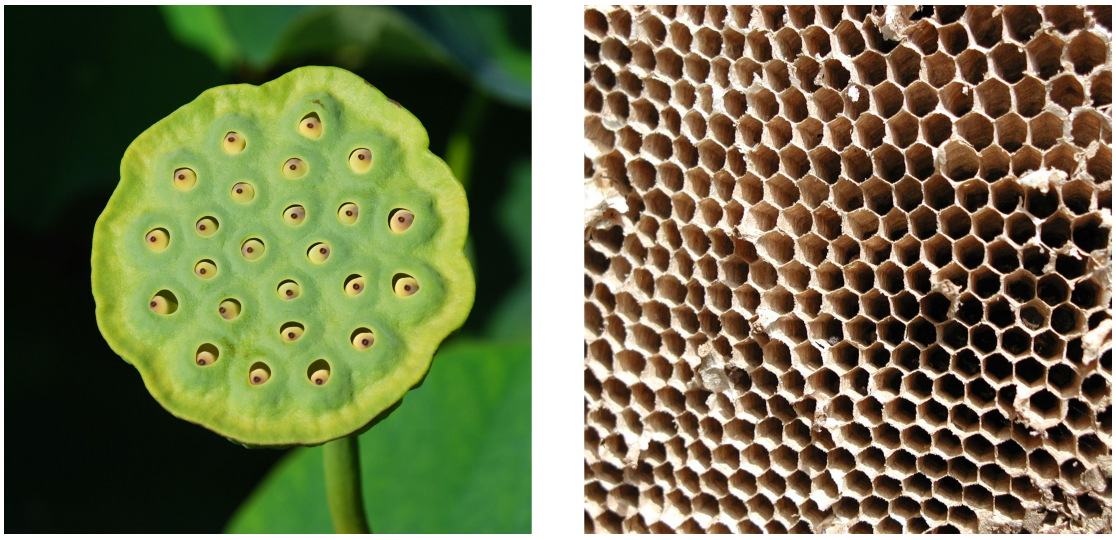


Figure 1.1. Examples of trypophobic stimuli; lotus seed head (left) and honeycomb (right).

Since the term was introduced on the Internet in the mid-2000's (Skaggs, 2014), trypophobia has received some media attention, and the topic is also discussed on various websites. For example, one of the largest groups dedicated to trypophobia (Trypophobia: Fear of Clusters of Holes, n.d.) on the social media website Facebook

contains over 11,000 members (as of June 2015), where individuals who are affected by this phobia share and discuss their experiences. In comparison, the group for social phobia and anxiety (Social Phobia/Anxiety Support, n.d.) currently has approximately 6,500 members (as of June 2015), suggesting that the interest in trypophobia is relatively high compared to other well-established conditions. With the increased interest around this topic, some researchers have sought to investigate the aspects of trypophobia that have yet to be clarified. Until 2014, only one peer-reviewed article in the scientific literature had addressed trypophobia, and the current research on this topic will now be summarised.

Cole and Wilkins (2013) were the first to introduce trypophobia to the scientific literature, with their paper entitled "Fear of holes". As the authors noted, one of the most interesting aspects about trypophobia is that the inducing stimuli are generally innocuous images that pose no threat from a semantic point of view. This makes the phenomenon hard to explain in terms both of learning and innate evolutionary principles. Indeed, the most commonly cited trypophobic stimulus is the seed head of the lotus, a harmless plant that has been used within Chinese herbal medicine (Ohkoshi et al., 2007), as a symbol in Asian religions (La-ongsri, Trisonthi, & Balslev, 2009), and even as food in some countries (Bailey, 1975). Given the heterogeneous nature of trypophobic stimuli (e.g., barnacles, bubbles, aerated chocolate, etc.), it is also difficult to derive particular features that the inducing stimuli have in common other than their configurations of objects. To investigate a potential mechanism behind this condition, Cole and Wilkins (2013) performed a spectral analysis on trypophobic images and images of dangerous organisms (e.g., the blue-ringed octopus), so as to investigate the low-level visual characteristics in those images (see section *1.5. Natural images and patterns* for detailed description). It was

reported that the two types of images shared the same high contrast energy at mid-range spatial frequencies. The authors therefore suggested that trypophobic images possess spectral features found in dangerous organisms, and that avoidance of such stimuli has survival value. The role of these visual characteristics will be further investigated in Experiment 3.3.

In order to obtain a preliminary estimation of how prevalent trypophobia is in the general population, Cole and Wilkins (2013) asked 91 male and 195 female adults whether they found the lotus seed head "uncomfortable or even repulsive to view". Eleven percent of males and 18% of females indicated that they did, suggesting that some 15% of the general population is sensitive to images associated with trypophobia. Despite this, the condition has only recently been reported in the literature, and there currently exists no formal definition. Partly as a consequence of this, "trypophobia" does not represent a phobia as defined by the DSM–5. Thus, trypophobia remains an Internet phenomenon that has received recent interest from scientists, the media and the general population. However, this does not mean that the condition did not exist prior to this recent attention. In support, individuals from different age groups have been able to recall trypophobic experiences from their past. For example, one individual described an incident where (s)he observed his/her dads hair transplant, in which the top of the head was dotted with plugs. The individual added "I gasped for breath, chills ran up and down my spine […]. I couldn't stop shuddering." (C. M., personal communication, 2014). Importantly, this happened in 1977, which was long before the Internet became a household technology, suggesting that trypophobia is not a product of the Internet. Rather, the Internet has been a facilitator for the recognition of this condition.

One of the reasons why trypophobia was not recognised earlier may be due to the innocuous, and perhaps confusing, nature of the condition. Other prominent phobias (e.g., spider/phobia or height phobia) have some rational reason behind them that makes it easier to understand, and perhaps easier to accept, which may be the reason why some conditions have been thoroughly discussed, researched and established. On the contrary, many individuals with trypophobia have expressed that they do not understand why innocuous (trypophobic) images make them feel as they do, and the lack of underlying reasons may therefore have inhibited individuals from discussing their aversion. With the Internet, not only have individuals a means to (re)discover their aversion among like-minded peers, but they are also able to discuss their condition in an anonymous, yet public, manner. This can be compared to other conditions that have appeared as a consequence of attention on the web, such as "visual snow". Similarly to trypophobia, visual snow has received support groups on Facebook, such as a group called Visual Snow (n.d.), which serves to "support anyone who may have a history of knowing someone with or for people with the symptoms of Visual Snow". In addition, the Eye on Vision Foundation (2008) has been founded to raise the awareness and fundraise for research regarding the condition that has been described as perception of continuous TV-static-like patterns (Schankin et al., 2014). This shows how the Internet has been used to identify and recognise conditions that previously were relatively unknown to the public, which suggests that trypophobia is not unique in so far that it has been "discovered" on the web.

In addition to being an efficient means of communication between individuals from all around the world, the Internet is also capable of communicating different types of content, and the nature of this type of communication may also be the reason

why trypophobia was recently reported. As mentioned, trypophobia is induced by *visual* stimuli that present clusters of objects in proximity to each other. Because many types of images can induce trypophobia, it is complicated to communicate and verbally explain what causes it. In contrast, many prominent phobias are related to very specific objects or situations, such as snake/spider phobia or height phobia, in which individuals who suffer from those particular phobias can easily communicate their aversion in simple terms that most people are familiar with. While it may be hard to explain trypophobia and relevant stimuli through verbal/written communication, the Internet allows individuals to communicate their aversion through images. Prior to the Internet, visual communication was limited to printed media (e.g., newspapers or magazine) or television, and also restricted to certain people. Most individuals did not have the opportunity to explain trypophobia *visually*. Now, the Internet allows anyone to post pictures and videos on the web, which may have contributed to the recent recognition of trypophobia.

As it currently stands, there is a subset of individuals on the web who report specific symptoms towards specific images. This, however, suggests that the conceptualisation of this condition may be biased. Are the individuals who take part in these web-based groups likely to be affected by what is already reported and posted on these websites, and if so, does the relationship between the symptoms reported and images replicate in other individuals and groups? This sampling bias issue will be taken into consideration in Experiment 2.3.

1.3.7. Cognitive processes

Since phobias have been strongly associated with the awareness of certain stimuli, many researchers have studied how phobia relates to attention and information processing. For example, Mogg, Philippot, and Bradley (2004)

investigated the selective attention to facial expressions (i.e., angry, happy and neutral) in social phobia. In their experiments, participants were shown pairs of faces (e.g., angry and neutral faces) for a brief duration (e.g., 500 milliseconds), after which an arrow pointing either up or down would appear in the location of one of the faces. The participants were asked to respond by indicating the direction in which the arrow was pointing. The results showed that response times (RTs) for the experimental condition were faster if an angry face preceded the location of the arrow, relative to happy and neutral faces, although this was not found for controls. Because RTs tend to be faster for stimuli that appear in an attended area (Posner, Snyder, & Davidson, 1980), Mogg et al. (2004) suggested that there is a vigilance mechanism for angry faces, thereby demonstrating attention bias in social phobia.

Distortion of other cognitive processes has also been demonstrated. Menzies and Clarke (1995) compared individuals with and without height phobia (i.e., acrophobia) in terms of their perception of danger related to a triple extension ladder. What they found was that individuals with phobia tended to provide higher estimates for the probability of falls from the ladder, and that the subsequent injury would be more severe, compared to controls. Furthermore, individuals with acrophobia showed an increase in their estimation of the incident and severity of the injury when climbing the ladder (i.e., in the phobic situation) compared to when they were standing on the ground (i.e., out of the phobic situation). This was not evident for control participants, who showed little difference between estimates across situations, which suggested that phobias could distort cognitive processes related to judgement. In addition, this experiment also demonstrated that proximity is an important factor for phobias (see also Teghtsoonian & Frost, 1982)

1.3.8. Physiological changes

Researchers have demonstrated that phobic reactions are associated with various physiological correlates. According to Thyer and Himle (1987), some symptoms experienced as a response to stimuli related to specific (then: "simple") phobia concern cardiovascular changes such as "fast heart beat" or "skipped heart beats" (see also Ramsden, 2013; Stein & Stein, 2008). Prigatano and Johnson (1974) measured the cardiovascular reactivity in individuals with spider phobia and controls while they observed images of spiders, and the results showed that there was a significantly higher heart rate, greater heart rate variability and vasoconstriction in the clinical sample. Teghtsoonian and Frost (1982) investigated the effect of viewing distance in snake phobia by measuring heart rate and skin conductance response, and reported that there was a negative relationship between the physiological correlates and viewing distance. In addition to demonstrating that there is a physiological change related to phobic stimuli, they also supported the notion that proximity is important (as discussed).

Fredrikson et al. (1993) investigated the regional cerebral blood flow (rCBF) using position emission tomographic (PET) scans in volunteers with snake phobia during exposure to relevant phobic stimuli, and reported that the cortical rCBF was related to phobic stimulation, but not for other aversive or neutral stimuli. It was suggested that the elevation of rCBF in the secondary visual cortex reflected vigilance related to visual defence (see also Wik et al., 1993). In an electroencephalogram (EEG) study, Merckelbach, Muris, Pool, and de Jong (1998) investigated the resting EEG asymmetries and their relation to phobic symptoms. What they reported was that the level of self-reported symptoms (pre-treatment) was related to an over-activation of the right parietal hemisphere. This links particularly

well with the suggestion that the right parietal areas are involved in self-reported fear and arousal (Heller, Nitschke, & Lindsay, 1997), in addition to the notion that negative emotions (i.e., disgust or fear) is related to a stronger right-hemisphere activation (relative to the left-hemisphere) (Davidson, 1992; Fox, 1991).

In the current thesis, the cardiovascular reactivity associated with trypophobia will be investigated by using photoplethysmography (PPG). PPG is an electro-optic technique that can be used to detect cardiovascular pulse waves (i.e., blood volume pulse) (Barreto, Aguilar, & Jakubzick, 1997) by monitoring the changes in blood volume in vessels (Allen, 2007). This technique is based on the assumption that blood pumps through vessels as a result of every heart beat, which is particularly pronounced in peripheral vessels such as those in fingers or earlobes (Healey, 2014). PPG devices can monitor the relative changes in blood volume in the peripheral vessels by emitting infrared light through the tissue near these areas and measuring the absorption of light by the blood flowing through these vessels. A peak in the PPG signal therefore indicates a peak in blood flow, and can be used to provide important information about the cardiac activity (Allen, 2007). It has been suggested that PPG signals can be a good alternative to the traditional use of electrocardiography (ECG) as a way to understand the autonomic nervous system (ANS) through information about heart rate and its variability (Elgendi, Jonkman, & DeBoer, 2011).

1.3.9. Behavioural aspects of phobias

Phobic experiences often involve specific behaviours, some of which are reflected in the criteria for phobias (American Psychiatric Association, 2013). For example, Thyer and Himle (1987) reported that “Feel like running” was ranked as the third most common symptom experienced as a function of specific (then: “simple”) phobia, and encountering phobic stimuli will often result in panic-like reactions

(Antony & Barlow, 2002). Some types of phobias are also associated with a higher risk of substance abuse. For example, Turner, Beidel, Dancu, and Keys (1986) reported that approximately half of their social phobia sample consumed alcohol (see also Mullaney & Trippett, 1979) and anxiolytic drugs to control their social stress, in addition to a case of illegal drugs (i.e., marijuana).

1.3.10. Treatment for phobias

Phobias vary in terms of how severe they are, and in some severe cases they can become significant sources of disability that may lead to reduced life quality. For example, needle phobia has been reported to affect approximately 10% of the general population (Sokolowski, Giovannitti, & Boynes, 2010), and similar conditions such as blood-injection-injury (BII) phobias may interfere with attitudes towards vaccination or help-seeking behaviour in acute situations (American Psychiatric Association, 2013). Other phobias such as fear of driving (Ehlers et al., 2007) or flying (Rothbaum, Hodges, Watson, Kessler, & Opdyke, 1996) can also cause problems in our modern society (as discussed). It is therefore evident that in some cases, help is required in order for individuals to cope with their phobias and function in society.

Many techniques that have been used to treat phobias involve exposure to the phobic stimuli (Kring et al., 2012), for example systematic desensitization (Wolpe, 1958). This technique usually involves identifying a range of phobic and avoided situations, which are ranged in terms of difficulty or severity (i.e., a fear hierarchy), and exposure therapies have been used as a method to treat phobias (Garcia-Palacios, Botella, Hoffman, & Fabregat, 2007). Once such a list has been identified, the patient will be exposed to the phobic stimuli, starting from the lowest level of discomfort and gradually towards the highest level. For example, an individual with fear of spiders

may first be asked to read about spiders, followed by looking at pictures and ultimately facing a real spider. Importantly, patients who undergo systematic desensitization will be taught relaxation techniques, such as progressive muscle relaxation (Hazlett-Stevens & Borkovec, 2001) or autogenic training (Fanielle, Bobon-Schrod, & Mirel, 1977). The aim is to control muscular tension, or achieve a deep relaxation state and reduce stress, while being exposed to the feared situations in order to reduce the fear responses.

While systematic desensitization aims to reduce the fear response among individuals with phobias by pairing the phobic stimuli with relaxation techniques (i.e., counterconditioning) (Davison, 1968), Marks, Lovell, Noshirvani, Livanou, and Thrasher (1998) reported that exposure therapy can be effective for treating post-traumatic stress disorders even if the relaxation component was absent. In vivo (i.e., real-life) exposure involves confrontation of the actual phobic stimulus (DuPont, 1982), such as a live snake (Choy, Fyer, & Lipsitz, 2007). Similarly to systematic desensitization, in vivo exposure may involve a fear hierarchy where the patient works from the least anxiety-provoking stimuli upwards, and this type of treatment has been reported to yield positive outcomes. For example, Gilroy, Kirkby, Daniels, Menzies, and Montgomery (2000) treated individuals with spider phobia by using therapist-delivered live exposure, and compared that type of treatment to relaxation placebo (i.e., control condition). What they found was that live exposure therapy significantly reduced symptoms, as assessed by measurements such as the Spider Questionnaire or a Behavioural Assessment Test (BAT), and that the therapy was more effective than relaxation placebo. There has also been support for the use of in vivo exposure techniques in treating disorders such as claustrophobia (Booth & Rachman, 1992), agoraphobia (Emmelkamp et al., 2002; Emmelkamp & Wessels,

1975) or obsessive compulsive disorder (OCD) (Van Oppen et al., 1995). Others (e.g., Bandura, Blanchard, & Ritter, 1969) have also expressed preference for in vivo exposure treatment, which is closely related to habituation.

In some cases, general practitioners (GP's) may also prescribe medication to reduce symptoms of phobias, such as antidepressant and anxiolytic drugs. Stein et al. (1998) compared the effect of paroxetine (i.e., an antidepressant) and placebo in a randomized controlled trial study of social anxiety disorder, and the results suggested that the antidepressant was more effective than placebo in reducing the short-term (11 weeks) symptoms and disability. However, the use of medication has been suggested to be a short-term solution associated with a higher risk of relapse (Feltham & Horton, 2012), because the occurrence of negative side-effects may result in patients wishing to discontinue the medication. Once the medication stops, the treatment effects may no longer be sustained (Kring et al., 2012). In addition, is has been suggested that psychological treatments should be preferred over medication. For example, Thom, Sartory, and Jöhren (2000) compared the effect of psychological treatments (i.e., stress management training and imaginal exposure), anxiolytic drugs (i.e., benzodiazepine) and a control condition (i.e., no treatment). They reported that although both types of treatment were better than no treatment, only the participants in the psychological treatment condition would have a sustained effect, whereas individuals in the drug condition relapsed.

Despite the fact that specific phobias are usually well understood, relatively prevalent in the general population, and despite the availability of various treatments, individuals with this type of anxiety disorder rarely seek help (Antony & Barlow, 2002). Furthermore, Wang, Demler, and Kessler (2002) investigated the prevalence and adequacy of treatment of mental illnesses in a US sample, and reported that less

than one out of six individuals with public health problems received treatment that was considered as "minimally adequate". In a cross-sectional study, Oliver, Pearson, Coe, and Gunnell (2005) investigated the help-seeking behaviour and attitudes in men and women with common mental health problems. First of all, it was found that men, particularly young men, were less likely than women to report that they would seek help, and if they were to seek help, the preferred source was from friends or family. Fourteen percent reported that they would not seek help from GPs. Furthermore, among those who had scores on the upper end of the General Health Anxiety questionnaire, only 28% had sought GP help. One possible reason for the lack of help-seeking behaviour, especially professional, could be the stigma associated with mental health problems (Corrigan, 2004; Crisp, Gelder, Rix, Meltzer, & Rowlands, 2000; Wahl, 1999), concerns regarding the GP's competence (Paykel, Hart, & Priest, 1998) or other complications associated with a mental health disorder history such as future job prospects (Oliver et al., 2005). Overall, the literature on the use of treatment for phobias in the general population suggests that the current situation is far from optimal, and that alternative treatments methods should be developed and offered to those who have the issues with professional help as described above.

1.4. Psychological assessments and psychometric properties

In assessment procedures, self-report questionnaires are commonly used as a means of discriminating between individuals with and without phobias (e.g., Radomsky, Rachman, Thordarson, McIsaac, & Teachman, 2001; Szymanski & O'Donohue, 1995). Some scales (e.g., Ehlers et al., 2007) have been constructed by asking individuals who suffer from a phobia about the symptoms they experience, with the purpose of creating questionnaire items. One of the purposes of this thesis is to develop a diagnostic instrument whereby trypophobia can be recognised and

quantified. When psychological tests and measurements are proposed and developed, certain qualities of the test should be investigated and demonstrated (Cronbach & Meehl, 1955; Wright, 2011). These qualities are often referred to as psychometric properties, and are outlined as measures of *reliability* and *validity* (Aiken, 1997; Anastasi, 1968; Domino & Domino, 2006). This will be discussed below.

1.4.1. Reliability

A test used in the assessment of personal behaviour is considered to be reliable if the test score obtained is consistent over time and situations (Wright, 2011). For example, the trait version of the State-Trait Anxiety Inventory (Spielberger & Gorsuch, 1983) should be expected to yield the same results regardless of conditions and external factors, because such a personal trait is expected to remain stable. Furthermore, any significant changes or differences in test results should only be accounted for by growth, learning, disease or injury (Aiken, 1997). For example, a change in the Beck Depression Inventory (Beck, Steer, & Carbin, 1988) would be expected, or even desired, as a result of treatment for depression.

One way to demonstrate reliability is to investigate the *test-retest* coefficient, which is obtained by correlating the scores for the same group of individuals over two time periods (Domino & Domino, 2006). A reliable test should demonstrate a good correlation between the initial observation (i.e., test) and follow-up observation (i.e., re-rest). Such findings would demonstrate that the test outcome remains constant and stable, something that is expected from many traits (Coaley, 2014), especially over short intervals (e.g., days), but also longer intervals (e.g., months or years) in some cases (Aiken, 1997).

Some tests are completed by the investigator/examiner (e.g., a clinician) and not the subject or patient, for example the Millon® Clinical Multiaxial Inventory-III

(Millon, Millon, Davis, & Grossman, 1994). For these types of tests, the results produced should not be dependent on the person administering it, meaning that the different examiners should be able to use the instrument in an unambiguous manner. *Inter-rater reliability* (Wright, 2011) takes into consideration how consistent a test is across multiple examiners, and measurements such as Cohen's kappa (Cohen, 1968) or concordance correlation coefficients (Lawrence, 1989) have been offered as methods of reporting this psychometric aspect.

Another aspect of reliability is related to *internal consistency*, which is usually measured in terms of Cronbach's Alpha (α). Internal consistency refers to how well the items within a test correlate with each other (Cronbach, 1951). A scale with good internal consistency consists of items that produce similar scores, providing it is proposed that they measure the same construct. Similarly, *split-half reliability* investigates the relationships between items that are supposed to assess a single construct by comparing one half of the items in a single test with the other half (Domino & Domino, 2006; Wright, 2011), in which a strong relationship is expected. However, for tests that attempt to measure several constructs, such as a personality questionnaire measuring different aspects (e.g., agreeableness and neuroticism), this type of reliability can not be assumed.

1.4.2. Validity

Although a test might be able to demonstrate high levels of reliability, it is only valid if it actually measures what it is intended to measure (Wright, 2011). As a psychometric property, *validity* therefore refers to degree to which a test serves its purpose from a theoretical perspective.

Construct validity refers to the degree to which a test (e.g., questionnaire) is able to identify or measure the trait or construct (e.g., neuroticism) it claims to

measure. Evidence for this type of validity can be achieved by using multivariate statistics (e.g., factor analysis). Such analyses allow researchers to "summarize the interrelationships among the variables (within a test) in a concise but accurate manner as an aid in conceptualization" (Gorsuch, 1983, p. 2). They reveal factors that later can be interpreted and understood as constructs (e.g., personality traits). These methods can therefore provide a way to examine the internal structure of the test and how the items within a test correspond to the hypothesised or proposed construct(s), and have been applied when investigating the underlying construct(s) within tests (e.g., Bryant, Moulds, & Guthrie, 2000; Emmons, 1984).

The Standards for Educational and Psychological Testing (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999) outlines two subcategories of construct validity that allow further investigation of this psychometric property, namely *convergent* and *discriminant (divergent) validity*. Convergent evidence is demonstrated when a strong relationship between the test and other types measures that assess the same construct is obtained. Thus, convergent validity investigates the association between the test and theoretically *related* measures. In contrast, discriminant (divergent) validity focuses on the independence of the newly constructed test, and aims to demonstrate dissociation between the test and theoretically *unrelated* measures.

Criterion-related validity refers to how a new test compares to other established measures of the same construct that previously have been validated (Wright, 2011). The first way to investigate this is to administer both the established test and the new test at the same time, and to compare how similar they are (i.e., *concurrent validity*). For instance, if one proposes a new measurement for anxiety,

evidence for concurrent validity can be obtained if the new measurement shows a strong relationship to tests such as the State-Trait Anxiety Inventory (Spielberger & Gorsuch, 1983). The other way to demonstrate criterion-related validity is to investigate how well the new test predicts some sort of "gold standard" or valid measure in the future (i.e., *predictive validity*). For example, the Scholastic Assessment Test (SAT) is widely used in the United States as a standardised test of cognitive abilities, in which the score is often used as an important component in applications for admission into higher education. It is therefore fair to expect that such an important test actually predicts academic performance in the future, and this has been demonstrated for the SAT (e.g., Kobrin, Patterson, Shaw, Mattern, & Barbuti, 2008).

Content validity refers to the extent to which a test sufficiently measures and describes the aspects of the concept it is designed to measure (Kaplan & Saccuzzo, 2013), and focuses on how representative the test is (Haynes, Richard, & Kubany, 1995). A test with sufficient content validity should therefore cover all the dimensions or aspects related to the particular construct, which is usually evaluated by independent experts in the field (Wright, 2011).

1.4.3. Sensitivity and specificity

Tests are often used to detect or diagnose certain traits that the examiners are interested in, and sensitivity and specificity refers to a diagnostic tests' ability to detect individuals with and without conditions (Akobeng, 2007). Lalkhen and McCluskey (2008; see also Altman & Bland, 1994) described the former as the proportion of true positives correctly identified (i.e., the probability of correctly diagnosing patients with the condition), and the latter as the proportion of false

negatives correctly identified (i.e., the probability of correctly rejecting patients without the disease). The two measures are therefore binary classification tests.

1.5. Natural images and patterns

Trypophobia is unusual in involving images with specific spatial properties. The human visual system will therefore be briefly reviewed from the perspective of pattern recognition.

Our evolution has been highly influenced by the natural environment, and the development of the visual system is no different. Based on the principle of redundancy reduction (Barlow, 1961), it is assumed that the visual system has adapted to conform to and encode particular visual statistics and regularities found in the natural environment. More specially, the relationship between adjacent units of information (e.g., pixels) in an image involves a certain degree of predictability. For example, when looking at an image of the sky, one would expect a blue pixel to be next to another blue pixel, which would result in relatively smooth contrast variations. Eventually, the contrast variation may break, where a blue pixel may be next to a yellow pixel (e.g., the edge of the sun). Because the edges provide the useful information (Marr & Hildreth, 1980), sparse coding can be achieved by taking advantage of the predictability of natural images in which the processing cost of the images may be reduced. On the contrary, if an image includes random units of information, there is no redundancy to exploit.

Field (1987) stated that "images from the natural environment should not be presumed to be random patterns" (p. 2379), and it has been suggested that natural scenes possess specific scale-invariant visual properties within a narrow range of possible image statistics (Simoncelli & Olshausen, 2001). One such property is the amplitude spectrum, which is a component of Fourier Transform. The latter is a

mathematical technique that can be used to decompose the statistical properties of images and express them as spatial frequency content, where spatial frequency is the variation of contrast over space. In a simple one-dimensional grating, the spatial frequency is the number of stripes (black and white) across a given amount of space. Thus, gratings with rapid changes in luminance over space (i.e., narrow stripes) would have high spatial frequency, whereas gratings with fewer changes in luminance over space (i.e., wider stripes) would have low spatial frequency. The Fourier amplitude spectrum is therefore a summary of the level of contrast amplitude across spatial frequency bands.

In natural images, Field (1987) found that the relationship between spatial frequency and Fourier amplitude showed a slope of roughly f^{-1} (or a slope of -1 for log amplitude versus log spatial frequency). Thus, these types of images tend to have low contrasts at high spatial frequencies (and vice versa), which are properties that have been suggested to be optimal for the mammalian visual system to process (Field, 1994). More specifically, Olshausen and Field (1997) suggested that images with 1/f structures were associated with a sparse cortical response, in which only a small proportion of the neurons are active (i.e., fire) at one time, whereas the majority remain inactive. This is particularly important because neural computation of information is associated with a high metabolic demand, in which only a small portion (two percent in the visual cortex) (Lennie, 2003) of cortical neurons can be active at the same time. Efficiency in encoding visual information is therefore important (Hibbard & O'Hare, 2015), which is achieved with sparse coding.

1.5.1. Predicting discomfort of patterns

Wilkins (1995) wrote that "[s]ome things are unpleasant to look at by virtue of what they represent, and others because of their intrinsic physical properties" (p. 1),

and the association between discomfort and certain geometric patterns, such as stripes (Harle, Shepherd, & Evans, 2006), has been established. For example, because successive lines of text in their basic form are patterns of stripes, reading has been reported to induce symptoms (Wilkins & Nimmo-Smith, 1984). The distortions from text and similar geometric patterns have been described as visual illusions of colour, shape and motion (e.g., flicker, blurring, shimmering, etc.), and these symptoms have been associated with the concept of *visual stress* (Wilkins, 1995).

The common feature among these uncomfortable stimuli is that they have unnatural Fourier amplitudes relative to natural scenes (O'Hare & Hibbard, 2011). For example, Juricevic, Land, Wilkins, and Webster (2010) created images of "noise", and varied the amplitude spectrum slope, colour axis, mean colour, and luminance and chromatic contrast. Images with visual properties that did not correspond to natural characteristics were found to be the most uncomfortable to view among a student sample. More specifically, Fernandez and Wilkins (2008) demonstrated that complex images (i.e., painted art) with a curvilinear Fourier amplitude spectra with excess energy at mid-range spatial frequencies were rated as most uncomfortable, the same spatial frequency bands that the human visual system is most sensitive to (Campbell & Robson, 1968). By using a computational model of V1, Hibbard and O'Hare (2015) investigated how sparsely the visual system responds to the unnatural image characteristics described above. They reported that images with unnatural statistical structures produced excessively large neural response in the primary visual cortex (i.e., reduced sparseness), which suggests that there may be a high metabolic demand associated with those particular images.

While individuals who suffer from conditions such as migraine (Marcus & Soso, 1989; Shepherd, 2001) or epilepsy (Wilkins, Andermann, & Ives, 1975) have

been reported to be particularly susceptible to visual characteristics that deviate from those found in natural scenes, it has also been demonstrated that certain visual stimuli can induce perceptual distortions among the general population as well (Borsting, Chase, & Ridder, 2007; Fernandez & Wilkins, 2008; Wilkins & Nimmo-Smith, 1987). Evidently, the general population also show sensitivity to certain visual patterns; hence it can be argued that sensitivity to these unnatural, yet commonly found, visual characteristics is on a continuum, and that susceptibility is a matter of degree. Because trypophobic images have been reported to possess similar visual characteristics (Cole & Wilkins, 2013), it was suggested that some of the discomfort induced by those images were due to the visual composition of the images, as opposed to what the images represent. Later in this thesis, the excess energy at mid-range spatial frequencies in trypophobic images will be removed through filtering, so as to investigate the role of the visual characteristics in trypophobia. If the amplitude spectrum is an important factor for the discomfort induced by those images, then it may be suggested that individuals who experience trypophobia are oversensitive to unnatural visual characteristics, similarly to those with conditions such as migraine or epilepsy.

1.5.2. Hypermetabolism

It appears that observing images that depart from natural visual characteristics (as described above) is associated with less sparse coding in the visual cortex. Furthermore, Hibbard and O'Hare (2015) suggested that the failure to create a sparse response to those images places an excessive metabolic demand in the visual cortical areas. Near-infrared spectroscopy (NIRS) and functional magnetic resonance (fMRI) have been used to demonstrate an excessive metabolic demand as a result of particular visual characteristics. Because processing visual stimuli requires

oxygenated blood to reach the visual cortex, the cortical haemodynamic response is a reflection of the neural activity in response to presented images. First of all, Haigh et al. (2013) measured the amplitude of the haemodynamic response to coloured grating bars (i.e., stripes) using NIRS. Across five experiments, it was reported that a greater contrast between the bars (i.e., large distance between chromaticities) was associated with an increased haemodynamic response. Second, in an fMRI study, Huang, Cooper, Satana, Kaufman, and Cao (2003) investigated the relationship between hyperneuronal activity of the visual cortex and square-wave gratings at different spatial frequencies among individuals with migraine and non-headache controls. They reported that the peak fMRI Blood-Oxygen-Level dependent (BOLD) response was associated with square-wave gratings having a spatial frequency of 1.2 cycles per degree, which also was the type of stimulus that "irritated" the patients most. Furthermore, this peak BOLD response was particularly prominent for individuals with migraine (compared to non-headache controls).

The research outlined above demonstrated that particular individuals might experience a hyperneuronal activity in the visual cortex when confronted with the stimuli that they find uncomfortable. It can therefore be suggested that visual discomfort arises as a homeostatic signal. Wilkins and Hibbard (2014) proposed that discomfort is a protective mechanism that contributes to the reduction of metabolic load on the visual cortex that is induced by certain visual stimuli. This is important given that the brain, despite comprising about 2% of the total body mass (in normal males), consumes a substantial ≈20% of the total basal oxygen consumption (Sokoloff, 2007). In order to investigate whether trypophobic images are associated with this cortical hypermetabolism, the haemodynamic response induced by trypophobic images will be measured by using near infrared spectroscopy (NIRS).

NIRS is a non-invasive technique that can be used to determine the oxygenation in biological tissue (Soul & du Plessis, 1999; Van Beekvelt, Colier, Wevers, & Van Engelen, 1985). The technique relies upon two principles: (a) biological tissue has been demonstrated to be relatively transparent to light in the near infrared region (700-1300 nm) (Jobsis, 1977) and (b) the concentration of some compounds present in the biological tissue depends on the level of oxygenation (Elwell, 1995). The absorption of light transmitted from an external source depends on the concentration of the compounds, making it possible to obtain continuous measurements of the changes in oxyhaemoglobin (HbO_2) and deoxyhaemoglobin (HHb) by monitoring the light absorbed over time. Due to its portable nature and relatively low cost, NIRS has been implemented in research areas such as neurology, surgery or physiology with the purpose of investigating the cerebral haemodynamic response (Soul & du Plessis, 1999).

CHAPTER 2. ASSESSMENT OF TRYPOPHOBIA

"I gasped for breath, chills ran up and down my spine, and I wanted to jump out of my skin! I couldn't stop shuddering."

C. M., personal communication, 2014

Self-report scales are central to the assessment of anxiety disorders, such as arachnophobia (Szymanski & O'Donohue, 1995), ophidiophobia (Klorman, Weerts, Hastings, Melamed, & Lang, 1974; Salkovskis, Rimes, Warwick, & Clark, 2002) and claustrophobia (Radomsky et al., 2001), and the literature reports numerous scale developments and refinements to serve this purpose (e.g., Beidel, Turner, & Morris, 1995; Cutshall & Watson, 2004; Salkovskis et al., 2002). The condition described as "trypophobia", literally the fear of holes (Cole & Wilkins, 2013), has not been recognised as a disorder in the DSM-5, and there are currently no reported methods to assess or measure the condition. In order to provide a means of assessment, the second chapter of this thesis describes the development and psychometric evaluation of a self-report questionnaire for trypophobia.

Experiment 2.1. Construction of a scale and its psychometric properties

The initial step of a scale development is to generate an item pool, and Glass and Arnkoff (1997) described three ways to do so: (a) by consulting the theoretical and empirical literature, including prior measures, diagnostic criteria or items from clinical experience (e.g., Turner, Johnson, Beidel, Heiser, & Lydiard, 2003); (b) by conducting structural interviews with patients (e.g., Ehlers et al., 2007); and (c) by empirically investigating the client's thoughts through methods of cognitive assessment (e.g., thought listings or thinking aloud). As trypophobia has not been recognised as a disorder in the DSM-5, there were no methods of selecting

individuals with trypophobia other than by their participation on a website support group (i.e., self-report). In order to generate an item pool for a questionnaire for trypophobia, the most common symptoms induced by trypophobic images were obtained from testimonials provided and published online by individuals in this group.

Psychometric properties of the scale were investigated by assessing the construct validity of the scale (i.e., factor structure) (Costello & Osborne, 2005; Furr, 2011; Meyers, Gamst, & Guarino, 2012) and the reliability of the scale (i.e., internal consistency, split-half reliability and test-retest reliability) (Meyers et al., 2012; Radomsky et al., 2001; Rust & Golombok, 1999; Wright, 2011). In order to find a criterion to best distinguish between individuals who report trypophobia and a more general sample, a sensitivity and specificity analysis was conducted.

2.1.1. Methods

Participants. Two samples were recruited. One sample included 155 volunteers (28 males, 127 females) who used the Trypophobia: Fear of Clusters of Holes (n.d.) Facebook page (i.e., the "web-based" trypophobic cohort), aged from 18 to 73 years (M = 30.1, SD = 11.3). To corroborate the "web-based" trypophobic cohort, a second sample included 117 individuals (33 males, 84 females) recruited from a panel of University of Essex student and staff volunteers (the "university" group), aged from 18 to 50 years (M = 23.1, SD = 5.81). The University of Essex ethics committee granted ethical approval for the current experiment.

Materials. Symptoms were derived from testimonials provided by individuals who used the internet-based supporting group for trypophobia (Trypophobia: Fear of Clusters of Holes, n.d.). Comments from 200 individuals were collected, dated from 19th September 2012 to 15th April 2013, in which symptoms induced by viewing

trypophobic images were reported. For example, comments such as “I was so uneasy and itchy and disturbed…” were coded as “uneasy”, “itchy” and “disturbed”. Comments that did not involve any descriptions of symptoms were disregarded.

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

1. Cognitive-related symptoms, such as “Uneasy” or “Aversion”. Six items were included for this category.
2. Skin-related symptoms, such as “Itchiness” or “Skin crawl”. Four items were included for this category.
3. Physiological symptoms, such as “Nausea” or “Have trouble breathing”. Seven items were included for this category.

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

2.1.2. Procedure

A web-based software survey tool, Qualtrics (Qualtrics Labs Inc, 2013), was used to present the questionnaire. Participants were presented with a welcome screen informing them about the procedure. They were informed that the illustrative images included might be found aversive. Consent was obtained by choosing either “Agree” or “Disagree”, the former indicating that the information had been read, that participation was voluntarily and that the participant was 18 years or older. The next section involved viewing images that appeared on a trypophobia website (www.trypophobia.com). Two images were presented at the outset of the questionnaire, illustrating a lotus seed head and a honeycomb. The version distributed to the “web-based” trypophobic cohort included an option to skip the images if necessary. It was expected that the individuals who were members of a trypophobia group and report the condition were familiar with such images.

Each symptom in the scale (see Table 2.1) was rated according to the extent that the reaction to which it referred occurred when observing trypophobic images, using a 5-point Likert scale: 1 (Not at all), 2 (Slightly), 3 (Moderately), 4 (Considerably) and 5 (Extremely).

2.1.3. Results

Construct validity. The data for the two samples of participants were initially combined in order to reach a sample size described as “good” (i.e., 300 participants) by Comrey (1988). The 17 preliminary items and two foil items were subjected to a principal axis factoring with promax rotation (Furr, 2011). Three factors were

identified with eigenvalues greater than 1, but the scree plot (see Figure 2.1) indicated a single-factor model as the two factors fell under the "elbow" (Floyd & Widaman, 1995). The foil item "Feel at peace" had the weakest (negative) loading at -.460, whereas the foil item "Want to laugh" did not load above .3 with the factor. As expected, both the foil items showed little or no relationship to the unitary structure.

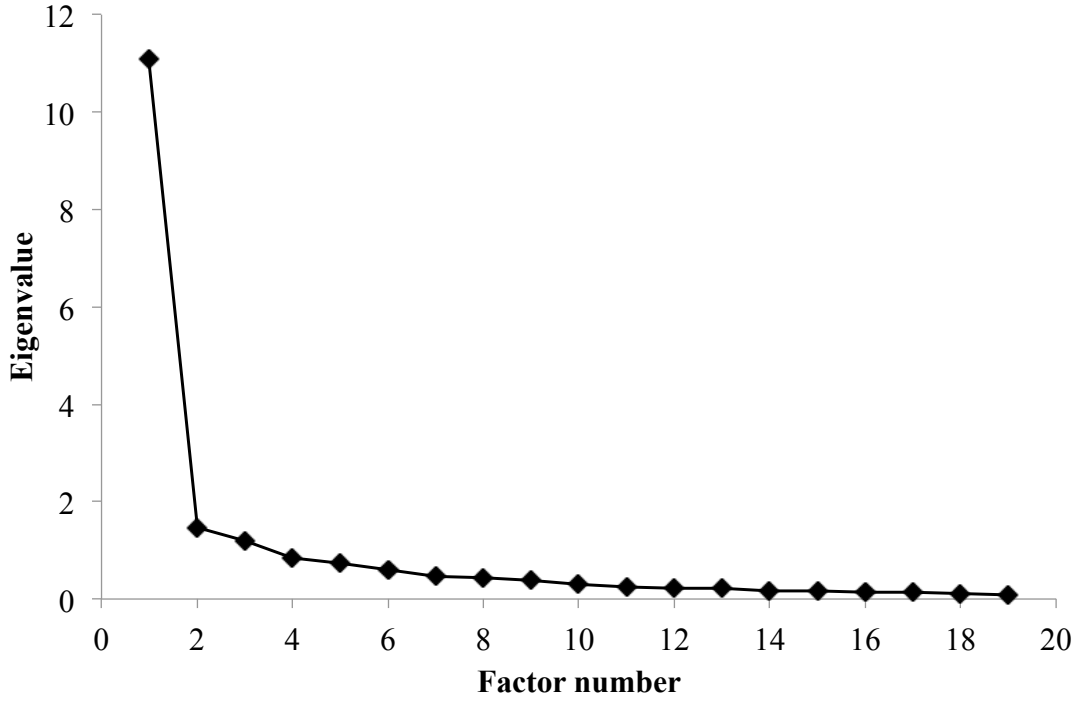


Figure 2.1. A scree-plot of the initial solution for the seventeen preliminary items and two foil items.

When the foil items were removed, the remaining items were again subjected to a principal axis factoring with promax rotation, and a single-factor solution was again obtained. The factor yielded an eigenvalue of 10.8 and explained 63.3% of the total variance. Table 2.1 summarises the items within the factor and their respective loadings. Separate factor analyses for the "web-based" trypophobic cohort and "university" group yielded broadly similar findings: There remained a single factor with overall good factor loadings, as shown in the final columns of Table 2.1.

Although one item ("Have an urge to destroy the holes") had a weaker loading with the factor of the "web-based" trypophobia group, Costello and Osborne (2005) argued that sample sizes could significantly affect how items are classified, which suggests that the strengths of the factor loadings for low sample sizes should be interpreted with caution.

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

Table 2.1. Factor loadings for items in the Trypophobia Questionnaire (TQ).

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

Note. a = all participants, b = "trypophobic" cohort, c = "university" group

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

Split-half reliability. A split-half reliability analysis was conducted to investigate whether all items of the scale contributed equally to what is being measured, where the average scores of one half of the scale was compared and correlated to the other half. Since the scale contains an odd number of items, the groups were split into nine and eight items, and all possible combinations (N = 24,310) were taken into consideration. For the "web-based" trypophobic cohort, the average Pearson's correlation coefficient was r = .83. The "weakest" correlation obtained was positive, moderate-to-strong (r = .54) and highly significant ($p < .001$), thereby demonstrating good split-half reliability within the scale. Similar findings were found for the "university" group.

Test-retest reliability. Fifty-three individuals (10 males, 43 females) from the "web-based" trypophobic cohort, aged from 18 – 61 (M = 32.4, SD = 10.3), agreed to be contacted at a later stage, and after four weeks they were sent the TQ by e-mail to complete a second time. A paired-samples t-test indicated that the TQ score did not significantly differ over the 4-week interval, initial test (M = 52.5, SD = 13.2) and re-test (M = 51.2, SD = 13.2), $t(52) = 1.31$, $p = .195$, $d = 0.1$. The Pearson's correlation was $r(51) = .85$, $p < .001$, demonstrating a good test-retest reliability.

Sensitivity and specificity. Prior to the sensitivity and specificity analysis, a criterion for outliers (in terms of TQ score) was defined in order to make the results more representative. Tukey's method (Tukey, 1977) uses the lower quartile (Q1; 25th percentile) and the upper quartile (Q3; 75th percentile) of the data, in addition to the inter-quartile range, which is defined as the interval between Q1 and Q3. Outliers are described as values outside a range, which is defined as Q1-(r*IQR) and Q3+(r*IQR).

Common r factors have been reported as 1.5 or 2.2 (e.g., Hoaglin, Iglewicz, & Tukey, 1986; Marques de Sá, 2007; Tukey, 1977). In order to remain conservative, the r factor of 1.5 was used in the current study. The method revealed 14 outliers in the "university" group (TQ scores above 34), which were excluded from subsequent analyses (Experiment 2.1 and Experiment 2.2). No outliers were detected for the "web-based" trypophobic cohort.

All the outliers were high scores (above 34), indicating a positive skew, and suggesting that the "university" group included a few individuals with trypophobia, as might be expected. These individuals were excluded from subsequent analyses, although analyses were performed in which the outliers were included, and those occasions in which their inclusion changed the results were reported. An independent-samples t-test revealed that the average TQ score was significantly higher for the "web-based" trypophobic cohort ($M = 52.9$, $SD = 14.4$) than the "university" group ($M = 20.3$, $SD = 4.08$), $t(256) = 22.3$, $p < .001$, $d = 3.5$. To find the optimal score that separated those who reported trypophobia and a general sample, the (a) sensitivity, (b) specificity and (c) the average of a and b was calculated for various cut-points in the TQ score (see Table 2.2).

Table 2.2. Summary of the sensitivity, specificity, and the average sensitivity and specificity at different TQ scores.

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

The Receiver Operating Characteristics (ROC) curve showed that the area under curve (AUC) was 0.947, illustrated in Figure 2.2. This AUC value exceeds the 0.80 criterion suggested by Meyers et al. (2012), indicating that the TQ provides an excellent basis for identifying trypophobia, on the basis of self-report of symptoms.

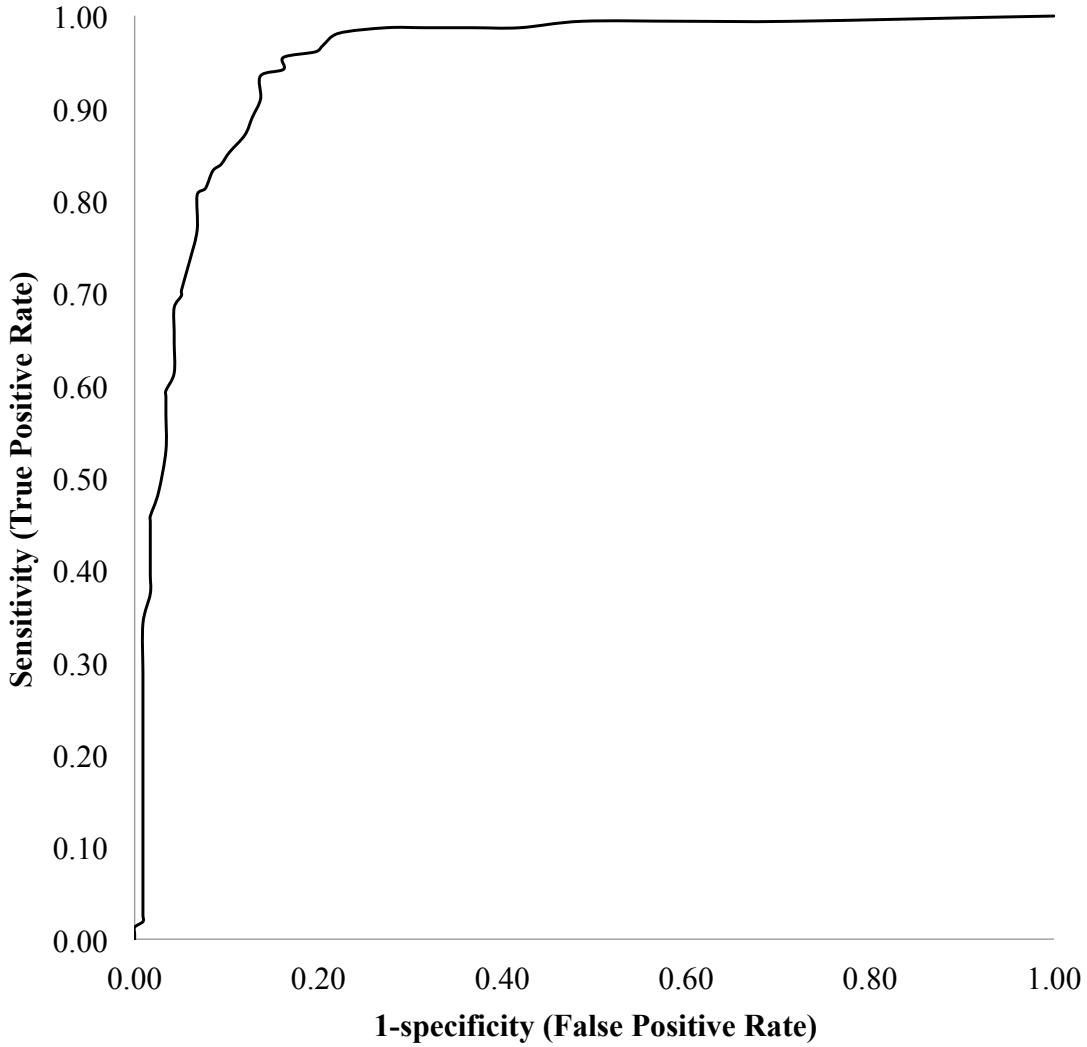


Figure 2.2. ROC-curve for the TQ.

2.1.4. Interim discussion

A factor analysis revealed that the seventeen symptoms most commonly reported by individuals self-reported with trypophobia demonstrated factor analytic validation by yielding a single construct, despite the heterogenic nature of the

questionnaire items. These findings were obtained regardless of the group from which the data were sampled, whether a group of individuals who use a trypophobia support group on the web or university students and staff, which addresses the concern raised in the literature regarding the use of considerably homogeneous convenience samples in factor analyses (e.g., Fabrigar, Wegener, MacCallum, & Strahan, 1999). All the items satisfied the criterion for acceptable loadings suggested by Kline (1994). The scale also had a strong internal consistency, and acceptable item-total correlations above .4, as suggested by Kline (1986). The TQ showed good test-retest reliability after four weeks, notwithstanding the fact that in this sample all the respondents reported symptoms and in consequence the number of symptoms had a relatively small range. Overall, the scale demonstrated good initial psychometric properties. The sensitivity and specificity analysis suggested that a TQ total score above 31 is likely to be drawn from the cohort of individuals who report trypophobia, and can be used as an initial screening method for trypophobia. Note that the TQ identifies trypophobia on the basis of symptoms, and with only exemplary images.

The decision to use Principal Axis Factoring (PAF) over Principal Components Analysis (PCA) was due to the assumptions of a single underlying latent construct within the item pool. Whereas PCA has been suggested to be a method of data reduction, the aim for PAF is to reveal any latent variables that cause the items in the questionnaire to covary. Fabrigar et al. (1999) reported that PCA should not be used "[w]hen the goal of the analysis is to identify latent construct" (p. 276), which indeed was the goal of the current experiment. Furthermore, Costello and Osborne (2005) reported that oblique rotations should yield more accurate and more reproducible solutions, as it allows factors to correlate, something one will expect in certain disciplines such as social sciences (see also Fabrigar et al., 1999; Furr, 2011).

There are two aspects regarding the current experiment that will be further discussed. The first aspect is the sample size. Researchers have not been able to agree what constitutes as an acceptable ratio between number of participants and items when performing a factor analysis. Floyd and Widaman (1995) suggested 5-10 participants per variable as a guideline, while Comrey (1988) reported that "[a] sample size of 200 is reasonably good for ordinary factor-analytic work with 40 or fever variables" (p. 759). Costello and Osborne (2005) examined the role of the sample size in factor analysis, and suggested a more conservative criterion. By comparing samples with participant-item ratios of 2:1, 5:1, 10:1 and 20:1, they concluded that a larger sample size was associated with a higher likelihood to produce more accurate solutions. More specifically, while only 10% of the samples with 2:1 ratios were reported to produce expected (so-called "correct") solutions, the samples with a 10:1 ratio showed a 60% success rate. In the cases where the most conservative ratio (20:1) was used, 70% of the samples were successful, and the 20:1 ratio has later been supported by Meyers et al. (2012). In the literature, "modest" ratios have been reported in studies with factor analyses, such as Ehlers et al. (2007), Öst (2007), Radomsky et al. (2001) and Cho, Smits, and Telch (2004) with approximately 2:1, 4:1, 7:1 and 11:1 ratios, respectively. Having a participant-item ratio of approximately 14:1, the current experiment therefore includes a high number of participants relative to similar investigations.

Another aspect that will be discussed is the gender distribution of the samples, which were predominantly females. Regarding this concern, it is important to note the differences between males and females when it comes to anxiety disorders and the literature reporting it. First, the DSM-5 states that "females are more frequent affected (by phobias) than males, at a rate of approximately 2:1" (American

Psychiatric Association, 2013, p. 199), which is consistent with the estimations in Fredrikson, Annas, Fischer, and Wik (1996) or Magee, Eaton, Wittchen, McGonagle, and Kessler (1996). Second, Oliver et al. (2005) reported that males, especially young males, were least likely to seek help for mental health problems (see also Matheson et al., 2014). Third, Cole and Wilkins (2013) estimated that a higher proportion of females (18%) reported trypophobia compared to males (11%). The higher prevalence of phobias (and trypophobia) reported in females, and the differences between genders in help-seeking attitudes, may explain why the majority of individuals who seek help on the trypophobia support Facebook page were females, which is reflected in the sample obtained.

To further support the samples used in the current experiment, the phobia literature reports many instances where there are higher proportions of females in the sample. Ehlers et al. (2007) reported the development and preliminary psychometric properties for a driving cognition questionnaire, and reported a driving phobia sample of "35 women and 7 men" (p. 494). In a psychometric evaluation of the Claustrophobic scale, Öst (2007) used a sample of "78 females (90%) and 9 males" (p. 1054), and others also report a larger proportion of females in their sample, for example Klorman et al. (1974), Szymanski and O'Donohue (1995) or Henningsen and Meinck (2003). It can therefore be suggested that the samples obtained in the current experiment conform to other similar scale constructions, both in terms of sample sizes and gender distribution.

Experiment 2.2. Convergent and discriminant validity

Further psychometric properties of the scale developed in Experiment 2.1 were investigated by asking the participants to rate images that have been reported to induce trypophobia, in addition to neutral (non-trypophobic) images of holes and

images of unpleasant objects (i.e., convergent validity) (Glass & Arnkoff, 1997; Mellenbergh, 2011; Radomsky et al., 2006; Salkovskis et al., 2002; Turner et al., 2003; Van Diest, Smits, Decremer, Maes, & Claes, 2010).

Furthermore, the relationship between the TQ and general trait anxiety will be investigated, using the trait version of the Spielberger State-Trait Anxiety Inventory (STAI) (Spielberger & Gorsuch, 1983). One of the requirements for specific phobias outlined by the DSM-5 is that "the disturbance is not better explained by the symptoms of another mental disorder, including fear, anxiety…" Rachman (2004) described anxiety as "one of the most prominent and pervasive emotions, and a large number (of individuals) are distressed by inappropriate and excessive anxiety" (p. 1). It is also a recurring theme among the testimonials provided by individuals who report trypophobia. It is therefore necessary to examine whether trypophobia, as measured by the TQ, is an independent condition that is not accounted for by other conditions such as anxiety (discriminant validity) (Mellenbergh, 2011; Öst, 2007; Papageorgiou & Wells, 2002; Radomsky et al., 2001).

The STAI is an instrument for measuring transient and enduring levels of anxiety. The 40-item instrument is based on a 4-point Likert scale and divided into two subscales, a state anxiety scale and a trait anxiety scale. Kaneda and Fujii (2000) investigated the differences between individuals who met the DSM-4 diagnostic criteria for anxiety disorders and control individuals in terms of STAI scores. The results from their study indicated that individuals identified with anxiety disorders showed a significantly higher mean total score for both state-anxiety and trait-anxiety compared to so-called "normal" participants, which supported the STAI as a screening method for anxiety.

2.2.1. Methods

Participants. After completing the symptom questionnaire in Experiment 2.1, the participants were invited to rate images from three categories in terms of unpleasantness. All individuals from the "web-based" trypophobic cohort had the choice to opt out of the image rating, and the number of participants decreased by seventeen. The participants from this group therefore included 138 individuals (23 males, 115 females) aged from 18 to 73 years (M = 30.9, SD = 11.6). All individuals from the "university" group were included.

Materials. Twenty images from three categories were obtained:

a) Trypophobic images: These images were taken from www.trypophobia.com and an internet-based supporting group (Trypophobia: Fear of Clusters of Holes, n.d.). All the images were of different objects and none were artificially manipulated. Google was used to find the high-resolution versions of the images.

b) Non-trypophobic images (neutral images): A Google search for "objects with holes" provided a list of objects such as guitar case, trumpet, etc., and the images illustrating those objects were obtained from a Google image search. These images were not present on the trypophobia websites, and comprised the neutral images. It was desirable to include neutral images that involved circular object(s) given the nature of the trypophobic images, hence other standardized image sets were not found suitable.

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

Using MATLAB©, the images were cropped to obtain the largest central square image and resized to 512 x 512 pixels (using the nearest neighbour algorithm). Figure 2.3 shows a montage of examples of the images.

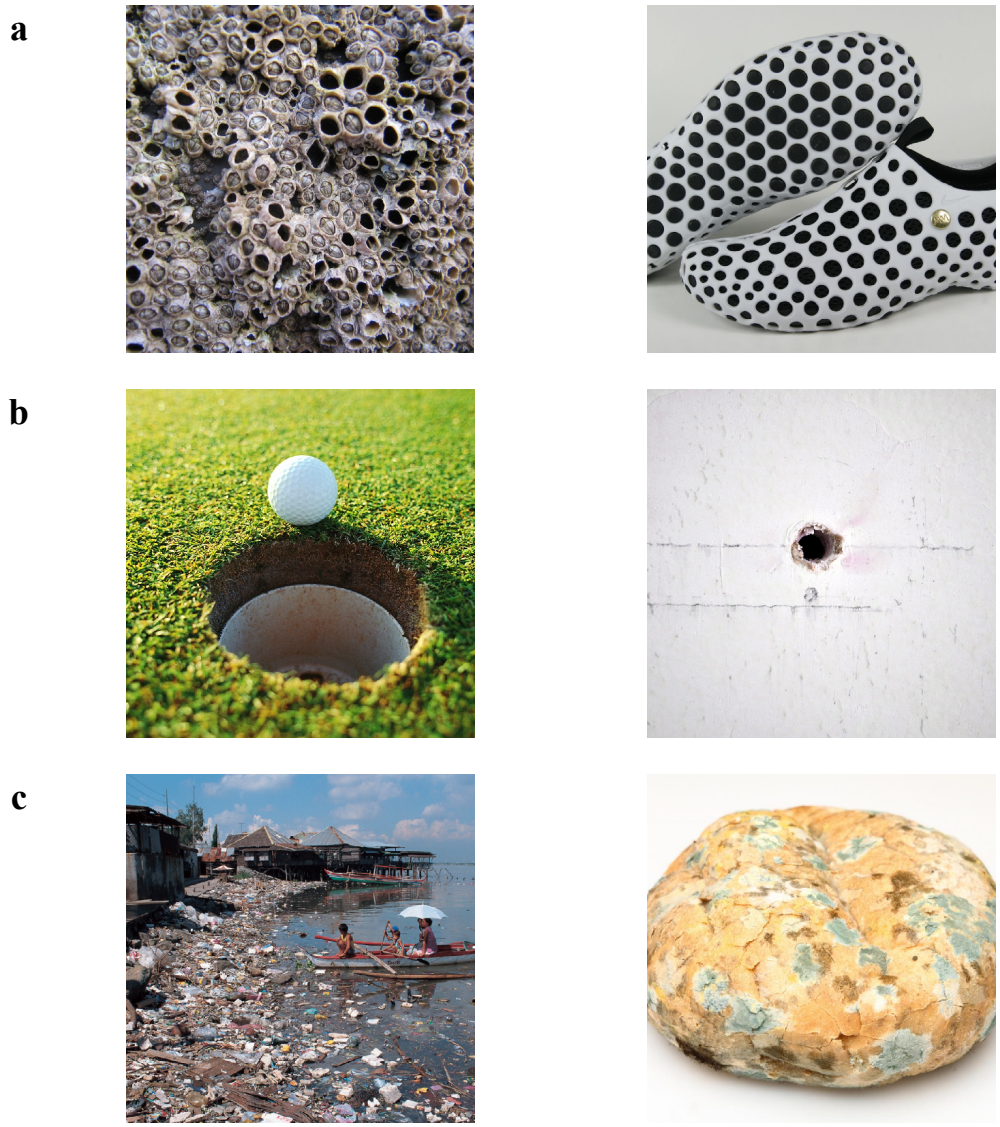


Figure 2.3. Montage of examples of the images: (a) trypophobic, (b) neutral, and (c) unpleasant images.

Procedure. The images were presented in a random order. Beneath each image, a 9-point scale was provided which ranged from "extremely repulsive" through "repulsive", "very unpleasant", "unpleasant", "neither unpleasant or

pleasant", "pleasant," "very pleasant", "attractive" to "extremely attractive", and the participants were asked to rate the images in terms of the scale. In the last part of the survey, the participants were asked to complete the STAI. All the participants were asked to do this, including those who opted out from the image-rating task.

2.2.2. Results

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

Figure 2.4 shows, for each participant, the average unpleasantness rating of images and the TQ score. In Figure 2.4a, a relationship between the unpleasantness rating of trypophobic images and TQ score was evident. Pearson's correlation coefficients were $r(136) = -.53$, $p < .001$ and $r(101) = -.54$, $p < .001$ for the "web-based" trypophobic cohort (diamonds) and the "university" group (squares), respectively. In Figure 2.4b (neutral images) and Figure 2.4c (unpleasant images), little relationship was found: Pearson's correlation coefficient for neutral images was $r(136) = -.011$, $p = .894$ ("web-based" trypophobic cohort) and $r(101) = -.14$, $p = .175$ ("university" group). For the unpleasant images, Pearson's $r(136) = -.14$, $p = .093$ ("web-based" trypophobic cohort) and $r(101) = -.02$, $p = .862$ ("university" group). Including the outliers did not change the results, except for the correlation between TQ score and rating of unpleasant images for the "university" group, which was significant ($r(115) = .21$, $p < .05$).

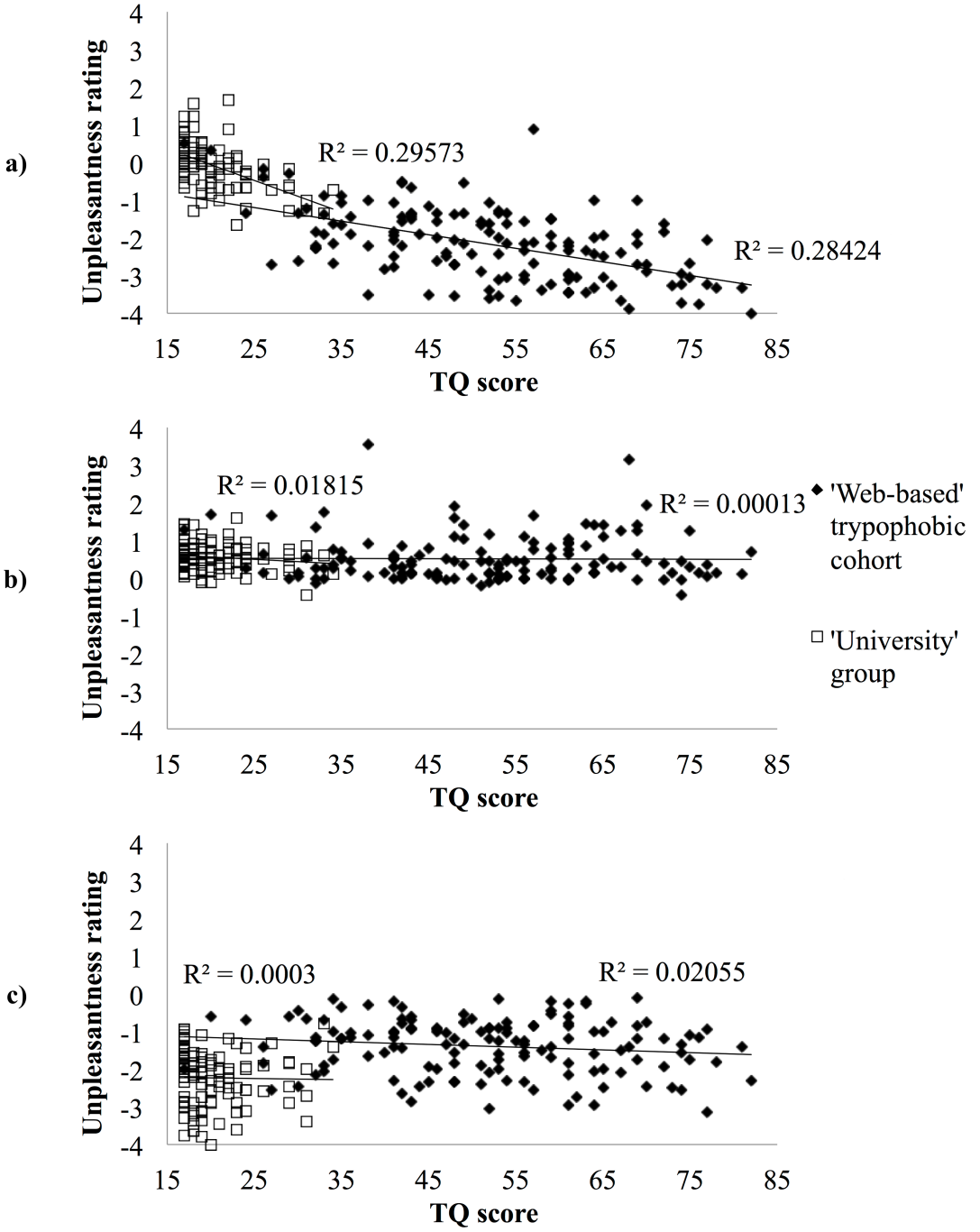


Figure 2.4. Scatterplot showing the average image rating of each participant as a function of their TQ score: (a) trypophobic images, (b) neutral images and (c) unpleasant images.

Discriminant validity. There were no significant differences between the "web-based" trypophobic cohort (M = 45.1, SD = 12.9) and the "university" group (M = 45.1, SD = 11.3), $t(256) = 0.02$, $p = .982$, $d < .01$, in terms of STAI score. For the former and the latter groups, the relationship between TQ score and STAI showed

Pearson's correlation coefficients of $r(153) = .216$, $p < .05$ and $r(101) = .018$, $p = .853$, respectively. This demonstrated that there was little correlation between the TQ and STAI. Similar results were obtained when the outliers were included in the analysis.

2.2.3. Interim discussion

In order to investigate the convergent validity of the instrument, the TQ score was correlated with the unpleasantness ratings of the trypophobic, neutral and unpleasant images. For both the "web-based" trypophobic cohort and the "university" group, and for trypophobic images only, the TQ score was found to significantly predict the unpleasantness ratings. Given the prevalence of trypophobia, the "university" group inevitably included a small proportion of individuals who experienced trypophobia. Evidently, the symptoms experienced by individuals when viewing trypophobic images were specifically related to the unpleasantness induced by those images and not other images. The weak relationship between the TQ and STAI demonstrated that the TQ has discriminant validity. Although the correlation was significant for the "web-based" trypophobic cohort, it was small. Taylor (1990) argued that even small correlation coefficients ($r = .20$) could reach significance, given a sufficiently large sample size ($N > 100$), but provide little practical importance. Based on this, there was little evidence to suggest that general anxiety accounted for trypophobia.

Experiment 2.3. Replication using a student sample

Kraut et al. (2004) raised some concerns regarding research based on Internet sites. For example, due to anonymity, individuals can participate with unknown intentions. Factors that can undermine the integrity of the research, such as multiple submissions from a single individual, may not be controlled for when using on-line

methods. Hence, the purpose of the present experiment was to replicate the convergent and discriminant validity reported in Experiment 2.2 by using a non-internet-based sample.

2.3.1. Method

Participants. Eight male and 34 female psychology undergraduate students, aged from 18 to 36 years (M = 20.5, SD = 4.1) from the University of Essex took part for course credit. None of these individuals participated in Experiment 2.1 and 2.2.

Materials and procedure. The TQ, STAI and images from Experiment 2.2 were included. The participants were presented the TQ, the rating task of images (using the same scale as Experiment 2.2), followed by the STAI. Prior to the experimental procedures, the participants were asked to read and sign a consent form that informed them about the experiments and the potentially aversive images included.

2.3.2. Results

As in Experiment 2.2, Tukey's method (Tukey, 1977) was used to detect outliers in the sample in terms of TQ score, again using an r factor of 1.5. One outlier was revealed (TQ score above 48) and excluded from further analysis, however similar results were obtained when the outlier was included.

Convergent validity. The relationship between the unpleasantness rating of trypophobic images and TQ score showed a moderate Pearson's correlation coefficient of $r(39) = -.52$, $p < .01$. No relationship was found between the unpleasantness rating of neutral/unpleasant images and TQ score: Pearson's correlation coefficient for neutral images was $r(39) = -.15$, $p = .482$. For the unpleasant images, Pearson's $r(39) = -.13$, $p = .404$. This suggested that, as

previously, the TQ score significantly predicted the unpleasantness ratings only for trypophobic images.

Discriminant validity. The relationship between TQ score and STAI showed a weak Pearson's correlation coefficient of $r(39) = .24$, $p = .140$, suggesting that there was little relationship between the two measurements.

2.4. Summary of chapter

When a condition is first reported, it is necessary to be able to identify individuals from the population. The current chapter described the development and initial psychometric evaluation of the Trypophobia Questionnaire (TQ). The items within the questionnaire were derived from the symptoms most commonly reported by individuals who take advantage of a trypophobia discussion group on a social media website (Facebook). The symptoms fall into three broad categories (affective changes, skin reactions and bodily changes). Despite the heterogeneous nature of the symptoms, a factor analysis suggested that the 17-item scale has a single-factor structure with a high internal consistency and high reliability. Further qualities of the scale were investigated in terms of convergent and discriminant validity, which demonstrated that the TQ is a scale with good psychometric properties that may be used as a measurement in both clinical practice and research. Importantly, the relationship between the symptoms in the TQ and the behaviour towards trypophobic images was also evident in a student sample. This demonstrated that although the symptoms and images were derived from the web, the relationship between individuals' trypophobic experiences and their ratings of trypophobic images extended to other groups of individuals, thereby addressing the sampling bias issue raised in the introduction.

2.5. Limitations and shortcomings

In a study of phobia treatment, Bandura et al. (1969) recruited phobic (snake) individuals "through an advertisement placed in community newspapers" (p. 177), which was a sample based on self-report. To refine the participant pool, the authors administered a Behavioural Avoidance Test (BAT). The BAT consisted of 29 performance tasks that involved interactions with a snake. Tasks were classified in terms of the level of threat, where a high score indicates an ability to perform more crucial tasks. Participants who were able to perform the task with highest level of threat (i.e., lifting the snake inside the cage using gloves for five seconds) were eliminated from the experiment. Despite originally defining themselves as sufferers of ophidiophobia, more than one third (i.e., 38%) of the participants showed fearless behaviour and were able to perform the task associated with the highest level of threat. These findings suggested that there are certain limitations with these methods of sampling, as self-report and behaviour do not necessarily conform to each other. One of the shortcomings in the current chapter is therefore that the "web-based" trypophobic cohort includes individuals who are members of a trypophobia support group, and report trypophobia, which has been taken as indication of condition. No further examination was done so as to investigate whether these individuals are "true" phobics, and future work should put more emphasis on this aspect. Ideally, interactions between patients who seek treatment for trypophobia and trained clinicians should be incorporated in a screening procedure, so as to ascertain that the individuals indeed experience a phobic level of distress and validate their symptoms (Turner et al., 2003).

Given the resources and substantial time required to perform a procedure proposed above, it is unlikely that such a design could provide enough data to yield

meaningful analyses (e.g., factor analysis) in the current investigation. The novel state of the condition means that many are not familiar with trypophobia, for example a young boy (age 12) who was described by his mother as "excited to learn that there are others out there with the same aversion (trypophobia) and that it is an actual phobia with a name." (M. A. H., personal communication, 2014). The current chapter therefore aimed to provide an initial measurement, with the purpose to make it possible for further research to have an easily manageable tool to measure trypophobia, thereby raising the awareness of the condition.

CHAPTER 3. REFINING THE STIMULUS CHARACTERISTICS

"Quite a few other mundane patterns in nature are bothersome ... The holes that woodpeckers peck in trees to hide their acorns is one example. Foods that have little bubbles are also bothersome, such as cooking pancakes and crumpets."

J. K., personal communication, 2014

Because most phobias are generally associated with very specific objects or situations, such as snakes (i.e., ophidiophobia) or enclosed spaces (i.e., claustrophobia), a distinct feature regarding trypophobia is the large range of objects that potentially are responsible for the condition. Inducing stimuli have been reported[1] in natural scenes (e.g., honeycomb or barnacles), urban environments (e.g., fashion collections or architecture), or other man-made objects (e.g., aerated chocolate or football boots). This demonstrates the heterogeneous nature of the stimuli. The only common feature of the stimuli is that they comprise objects in close proximity, which suggests that trypophobia is induced by specific patterns, and not the object(s) that the phobic stimuli represent.

Experiment 3.1. The role of holes versus clusters

Although trypophobia has been regarded as the fear of *holes* (Cole & Wilkins, 2013; Skaggs, 2014), testimonials from individuals indicate that it is not just holes that induce the symptoms. For example, one individual reported symptoms upon observing "…clusters of bumps, holes, or patterns" (J. L. M., personal communication, 2014), suggesting that fear of *holes* might not be the most appropriate description. In support of this, images of skin lesions (i.e., clusters of

[1] Based on testimonials from websites (e.g., www.trypophobia.com) and groups on social media websites (e.g., Trypophobia triggers, n.d).

spots) also appear on the trypophobia website (www.trypophobia.com), suggesting that clusters of objects other than holes can also induce symptoms.

Human perception is based on two-dimensional retinal images. Despite this two-dimensional structure, the brain is able to use information to yield a three-dimensional perception of depth (Kleffner & Ramachandran, 1992), because the human visual system takes into account prior knowledge or assumptions about the world when presented ambiguous stimuli (Adams, Graf, & Ernst, 2004). An example is the "light-from-above" principle, a robust effect that is based on Bayesian framework of prior knowledge about where light comes from and the shadows or shading that the light produces (e.g., Kleffner & Ramachandran, 1992; Stone, Kerrigan, & Porrill, 2009; Thomas, Nardini, & Mareschal, 2010).

Based on these principles, it follows that an object generated by a dent/hole or "dimple" (i.e., concave) should catch light in its lower part, while the upper part is relatively dark (i.e., in shadow). The opposite applies if an object is a bump or "pimple" (i.e., convex) (Berbaum, Bever, & Chung, 1984; Ramachandran, 1988). By applying these concepts to circular objects, it was possible to manipulate objects so that they were either perceived as holes or bumps by rotating them 180 degrees. In order to investigate whether it is only holes that contribute to trypophobia, the current experiment created clusters of objects that were either perceived as holes or bumps, depending on their orientation. If it is in fact clusters of *holes* that affect individuals with trypophobia, then such images should yield a pronounced level of discomfort among individuals with this condition, relative to images of clusters of bumps.

3.1.1. Methods

Participants. One hundred and two (20 males and 82 females) naïve psychology students from the University of Essex participated for course credit. In

addition, 19 student and staff volunteers (three males and 16 females) were invited on the basis of their TQ score (M = 46.4, SD = 15.7, range = 32, 76) obtained from an external survey, and those participated for reimbursement. Participants were aged from 18 to 49 years (M = 21.6, SD = 6.9). None of the participants had previously participated in the earlier experiments of this thesis. The University of Essex ethics committee granted ethical approval for the current experiment.

Apparatus. The screen used to present the experiment was a 27" Apple iMac with a screen resolution of 2560 x 1440 pixels (full brightness). A chin rest was used to ensure the distance (0.4 m) between participants and the screen.

Materials. (1) Small clusters: Stimuli were created using 128 x 128 pixel grey squares with a circular object (i.e., a sphere in which the depth cue is defined by shading; see Figure 3.1a). The images of holes comprised 4 x 4 of the squares, resulting in 512 x 512 images with 16 objects. The object was randomly offset from the centre of the square it occupied without touching the edge so as to create asymmetrical clusters, while preventing overlap of the objects. Figure 3.1b illustrates an example of images of holes. Subsequently, all objects within the images of holes were rotated 180 degrees, so as to create images of bumps (Figure 3.1c). Patterns were also created in which the orientations of the objects were randomly determined, comprising the images of mixed objects (Figure 3.1d). For each category (holes, bumps and mixed objects), four versions were created.

(2) Medium clusters: Each image from the small cluster category was reduced in size by 50%, and reproduced four times in a contiguous two by two matrix to create a new image (see Figure 3.1e). The images in this category therefore contained 64 objects each.

(3) Large clusters: The above procedure was undertaken with the medium clusters category, increasing the number of objects to 256 (see Figure 3.1f).

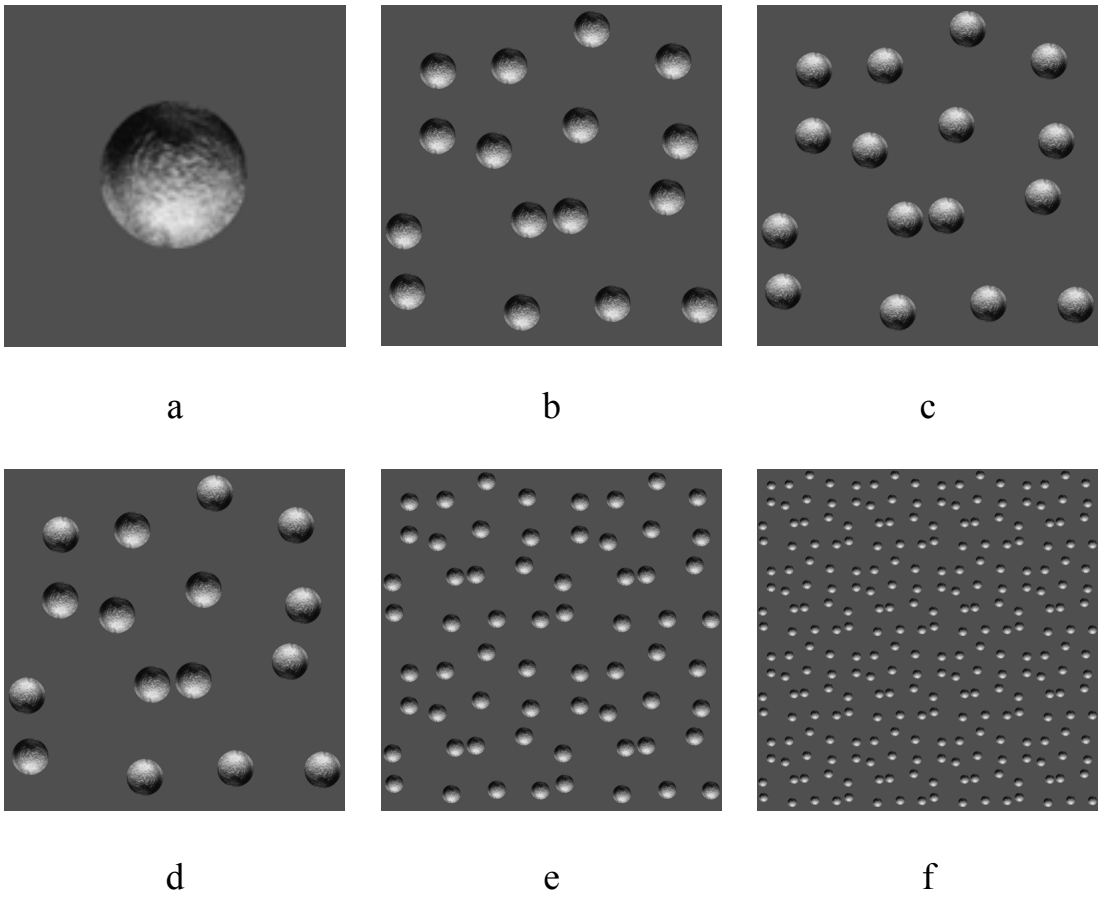


Figure 3.1. The 128 x 128 grey square with a (a) circular object was used to create 512 x 512 (pixels) images of clusters of (b) holes, (c) bumps and (d) mixed objects. To increase the number of objects, clusters with (e) medium and (f) large number of objects were subsequently created.

Procedure. Qualtrics (Qualtrics Labs Inc, 2013) was used to present the experiment. Before proceeding to the task, the participants were informed that the images in the experiment might be found uncomfortable to observe, and consent was obtained. The participants who had not yet completed the TQ in the external survey were asked to do so. Subsequently, all the participants were presented the images of object clusters in random orders, and below each image was a rating scale, from 1-10

(1 = “Not at all uncomfortable”, 10 = “Extremely uncomfortable”). Participants were asked to rate the images by clicking on the appropriate level of discomfort they experience from the corresponding image.

3.1.2. Results

Overall, 81 individuals did not meet the criterion for trypophobia (TQ score < 32) and composed the control group, whereas 40 individuals did so, and composed the trypophobic group. The first analysis was conducted to investigate whether the images created induce more discomfort among individuals who met the criterion for trypophobia compared to the control group, so as to demonstrate that the images resemble other trypophobic images. For each individual, the average rating of all the images was obtained. An independent samples t-test revealed that the trypophobic group (M = 4.03, SD = 1.84) rated the images as significantly more uncomfortable compared the control group (M = 2.96, SD = 2.01), $t(119) = 2.82$, $p < .01$, $d = 0.6$. This suggests that the images created were trypophobic in nature.

The subsequent analyses were conducted to investigate the differences between object category and cluster sizes, and only included the individuals from the trypophobic group. The means and standard deviations for the ratings for all object categories and cluster sizes are presented in Table 3.1. An ANOVA with the object category (hole, bumps and mixed objects) and cluster size (small, medium and large) as within-subjects factors revealed a significant main effect of object category, $F(2, 78) = 3.63$, $p < .05$, $\eta^2 = .005$, and a significant main effect of cluster size, $F(1.24, 48.50) = 6.84$, $p < .01$, $\eta^2 = .129$. There was no significant interaction, $F(3.03, 118.28) = 0.76$, $p = .518$, $\eta^2 = .001$.

Table 3.1. Mean (SD) rating of the images.

Cluster size	Holes	Bumps	Mixed objects
Small	3.45 (2.23)	3.31 (2.26)	3.59 (2.23)
Medium	3.73 (2.06)	3.88 (2.24)	4.03 (2.07)
Large	4.65 (2.49)	4.66 (2.55)	4.96 (2.58)

Two *a priori* pairwise comparisons were conducted to investigate the main effect of object category. The aim was to examine whether images of holes were reported to be more uncomfortable to observe compared to images of bumps or images of mixed objects. Three composite scores were created for each object category by averaging across the score for the images of small, medium and large clusters. It was found that the average rating of images of holes ($M = 3.94$, $SD = 1.78$) was not significantly different from the average rating of images of bumps ($M = 3.95$, $SD = 1.96$), $t(39) = 0.06$, $p = .954$, $d < 0.1$. The average rating of images of holes[2] was significantly lower than the average rating of images of mixed objects ($M = 4.19$, $SD = 1.92$), $t(39) = 2.50$, $p < .05$, $d = 0.1$.

Three pairwise comparisons with Bonferroni correction were conducted to investigate the main effect of cluster size. As in the previous analysis, three composite scores were created for each cluster size (i.e., small, medium and large) by averaging across the score for the images with holes, bumps and mixed objects. The results indicated that the average rating of images of large clusters ($M = 4.75$, $SD = 2.47$) was significantly higher than the average rating of images of medium clusters ($M = 3.87$, $SD = 2.04$), $t(39) = 2.16$, $p < .01$, $d = 0.4$, and images of small clusters ($M = 3.45$, $SD = 2.26$), $t(39) = 2.73$, $p < .01$, $d = 0.4$. The average ratings for images of

[2] Similar results were found when images of bumps were compared with images of mixed objects, $t(30) = 2.20$, $p < .05$, $d = 0.1$.

medium clusters and small clusters were not significantly different, $t(39) = 1.71$, $p = .096$, $d = 0.2$. Overall, the ratings of discomfort increased with the size of the cluster.

3.1.3. Interim discussion

Given the large number of images associated with trypophobia, some of which do not contain clusters of holes but clusters of other objects, these results suggested that holes alone are unlikely to be the only cause for this condition. Based on the current findings, it can be suggested that the fear of *holes* does not accurately reflect the condition. Individuals who met the criterion for trypophobia rated clusters of holes, bumps and mixed objects (i.e., both holes and bumps) similarly in terms of discomfort, which demonstrated that images of clusters of holes did not induce a greater level of discomfort than images of clusters of bumps. Furthermore, it was found that images of clusters of mixed objects were relatively more uncomfortable to observe than images of clusters of holes. There was therefore nothing to suggest that images of holes were worse than images of bumps or images of mixed objects. Importantly, clusters of both concave and convex (mixed) objects were reported to induce significantly more discomfort compared to clusters of identical objects (concave or convex), suggesting that increasing the three-dimensional perception by adding another depth factor would increased the discomfort. It can therefore be suggested that although clusters of holes comprise the majority of the images associated with trypophobia, the clustering nature of objects plays an important role in the discomfort induced by these images, while the nature of the object itself is trivial.

Experiment 3.2. Fourier analysis of trypophobic images

Cole and Wilkins (2013) noted that it is the visual structure of the inducing stimuli that is aversive and contrasted this with phobias (e.g., ailurophobia) where the

mere presence of the object is often enough to cause distress, regardless of whether it is visible. Indeed, the visual aspect of trypophobia may provide a clue as to a cause. Images from nature tend to have consistent spatial properties that the human visual system processes efficiently, and little discomfort is induced by such stimuli (Fernandez & Wilkins, 2008). Furthermore, Field (1987) demonstrated that natural images show a characteristic feature concerning the relationship between spatial frequency and Fourier amplitude. Specifically, a slope of roughly 1/f is found (or a slope of -1 for log amplitude versus log spatial frequency). Some images that induce discomfort do not share this 1/f characteristic (e.g., Fernandez & Wilkins, 2008; Juricevic et al., 2010).

Prompted by this, Cole and Wilkins (2013) performed a spectral analysis of the images obtained from a trypophobia website (www.trypophobia.com), and found that they too contained greater energy at mid-range spatial frequencies when compared with a set of control images of holes. The power function (linear on log-log axes) relating the Fourier power and spatial frequency (both log-transformed) was found to account for significantly more variance of the average spectra for the control images (97.7%) compared to trypophobic images (95.7%). This shows that trypophobic images possess a particular low-level visual characteristic that is known to be associated with discomfort among both clinical groups (e.g., Marcus & Soso, 1989; Shepherd, 2001; Wilkins et al., 1975) and the general population (e.g., Borsting et al., 2007; Fernandez & Wilkins, 2008; O'Hare & Hibbard, 2011). The aim of the current experiment was to replicate these findings by analysing the images used in this thesis.

3.2.1. Spectral analysis of abstract images

The images from Experiment 3.1 were used in the following analysis. The 512 x 512 images were already in grey-level, and the mean pixel grey level was set to 128 (SD = 50). The Fourier spectra (averaged over orientation and expressed on log-log axes) of each image were fit by a power function[3] and the percentage of variance explained by the fit was subjected to a 3 (object category) x 3 (cluster size) ANOVA. There was a significant main effect of cluster size, $F(2, 27) = 1211.99$, $p < .001$, $\eta^2 = .064$, no main effect of object category, $F(2, 27) = 1.895$, $p = .170$, $\eta^2 < .001$, and no significant interaction, $F(4, 27) = .927$, $p = .463$, $\eta^2 < .001$. For images with large clusters, a linear fit to the Fourier spectrum (averaged over orientation and expressed on log-log axes) explained 50.0% (*SD* = 4.2%) of the variance, significantly less than for images with medium clusters, for which the fit explained 88.4% (*SD* = 1.4%) of the variance, $t(22) = 29.9$, $p < .001$, $d = 13.6$. The power function explained 97.6% (*SD* = 0.2%) of the variance for images with small clusters, significantly more than for images with medium clusters, $t(22) = 23.0$, $p < .001$, $d = 11.5$. Evidently, with these stimuli, increasing the size of the cluster, whether holes, bumps or a mixture of the two, increased the deviation from the statistical norms of natural images.

3.2.2. Spectral analysis of real images

The images from Experiment 2.2, some of which appeared on the trypophobia websites, and some of which were selected as unpleasant or neutral, were analysed in order to further examine the visual characteristics of trypophobic images. The 512 x

[3] The Fourier spectrum refers to the Fourier amplitude across spatial frequency bands, which was obtained using the Fast Fourier Transform function in MATLAB©. Due to the log-transformation of the axes, a power function was used to assess the linear fit between the amplitude and spatial frequency. Thus, the variance not accounted for by this function is a measurement of how much the images deviated from natural statistics (i.e., a straight slope for log amplitude versus log spatial frequency).

512 images were rendered in grey level using the rgb2gray function in MATLAB©. Again, the mean pixel grey level was set to 128 and the standard deviation to 50, and the Fourier amplitude was obtained in spatial frequency bands that were equal in size on a logarithmic scale. Each band differed from its neighbour by a factor of two, and 16 bands were analysed in total. The maximum spatial frequency band was 256 cycles per image (cpi). The power spectra of neutral images, unpleasant images and trypophobic images are illustrated in Figure 3.2.

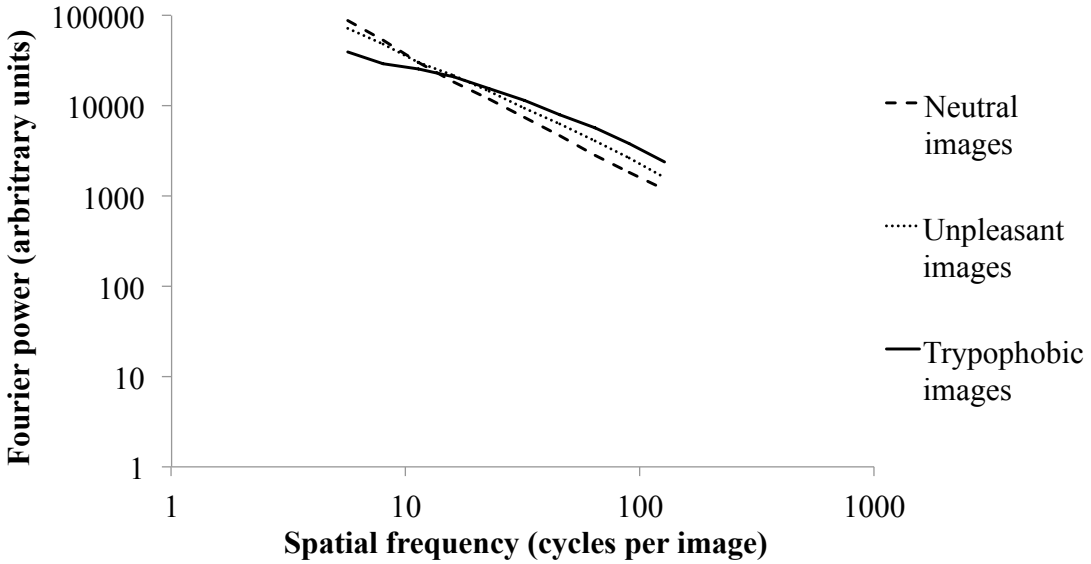


Figure 3.2. Power spectra of trypophobic images (solid line), neutral images (broken line) and unpleasant images (dots).

The power function (linear on log-log axes) accounted for more than 99% of the variance for both neutral images and unpleasant images. For trypophobic images, however, the power function accounted for "only" 96.5% of the variance. A one-way ANOVA found a statistically significant difference between image category, $F(2, 57) = 12.31$, $p < .001$, $\eta^2 = .298$. Three planned comparisons were conducted to investigate the differences between the image categories in terms of variance explained by the power function. For trypophobic images, the fit explained 93.3%

(*SD* = 7.62) of the variance, which was significantly less than for both neutral images (*M* = 99.4, *SD* = .63), $t(19) = 3.61$, $p < .01$, $d = 1.5$, and unpleasant images (*M* = 99.3, *SD* = 1.31), $t(19) = 3.36$, $p < .01$, $d = 1.3$. Furthermore, there was no significant difference between neutral and unpleasant images in terms of the variance explained by the power function, $t(19) = 0.54$, $p = .597$, $d = 0.1$.

Multiple comparisons (Bonferroni corrected) across all spatial frequency bands (in total 16 comparisons) between trypophobic and neutral images in terms of Fourier amplitude revealed that trypophobic images had significantly greater energy at spatial frequencies between 45 – 181 cpi, ts(38) > 3.26, ps <.001, ds < 1. Because most photographic images subtend 10 – 30° of our visual angle (Cole & Wilkins, 2013), the excess energy in trypophobic images was within 1.5 cycles per degree (cpd) (i.e., 45 cpi divided by 30°) and 18 cpd (i.e., 181 cpi divided by 10°). These results were similar to those reported in Cole and Wilkins (2013).

3.2.3. Interim discussion

The current experiment demonstrated that the clusters of objects that induce the highest level of discomfort among individuals who reported high levels and/or number of trypophobia symptoms are the images that deviated most from the statistical norms of natural images. Furthermore, images that appear on the trypophobia websites and have been reported to induce trypophobia were found to possess significantly higher contrast at mid-range spatial frequencies compared to neutral and generally unpleasant images. These findings therefore demonstrated that the images that are trypophobic in nature, whether artificially created or obtained from the web, possess image characteristics that deviate from the norms of images from nature (Field, 1987).

Experiment 3.3. The role of unnatural image statistics in trypophobia

Following the findings in the previous experiment, and in conformity with the hypothesis proposed by Cole and Wilkins (2013), the current experiment investigated whether the unnatural images statistics in trypophobic images were responsible for the condition. Here, trypophobic and neutral images were filtered so that the excess energy at mid-range spatial frequencies was reduced, so as to investigate the effect of filtering[4].

3.3.1. Methods

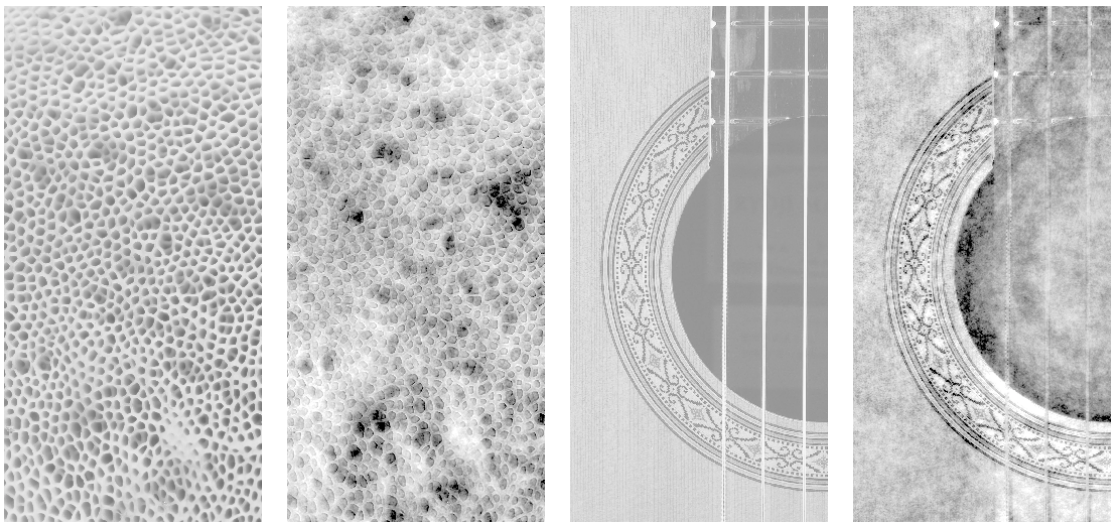
Participants. The participants in Experiment 2.3 also served in the current experiment. In addition, 18 volunteers (one male) were invited to take part in the current experiment on the basis of their TQ score (M = 38.6, SD = 5.26, range = 32, 48), which were obtained from an external survey. Fifteen of the invited participants had previously taken part in Experiment 3.1. The University of Essex ethics committee granted ethical approval for the current experiment.

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

Materials. The 20 images associated with trypophobia and 20 non-trypophobic images of holes (neutral images) from Experiment 2.2 were rendered in

[4] We acknowledge the contribution of Professor Paul B. Hibbard with regards to the filtering of images.

grey level using the rgb2gray function in MATLAB©. The mean pixel grey level was set to 128 and the standard deviation to 50. These images comprised the unfiltered set. The Fourier amplitude spectra of the images were then obtained and given a slope of -1. This was achieved by performing a Fast Fourier Transform of the images and adjusting the amplitude spectrum to be 1/f. The inverse Fourier Transform was then obtained and the images that resulted from this transformation were then re-normalised so that the mean pixel grey level was 128 and the standard deviation 50. These images comprised the filtered set, saved as TIFF files. In total, 40 unfiltered images and 40 filtered images were obtained (see Figure 3.3)



a b c d

Figure 3.3. Illustration of (a) and (c) unfiltered images, and (b) and (d) filtered images, both for (a) and (b) trypophobic and (c) and (d) neutral images.

Design. Images were presented as a slideshow. In total, 80 images (40 unfiltered, 40 filtered) were included in a fixed random order. The first 40 trials included one version (unfiltered or filtered) of each image, which was randomly determined. The last 40 trials (second half) included the versions of the images that

were not included in the first half. As a result of this, the minimum separation between presentations of two versions of an image was three slides.

Procedure. Participants were seated facing away from the experimenter and used a chin-rest in front of the screen. The room was otherwise dark. Each image was presented for three seconds, after which a 9-point scale was provided on a grey background replaced the image. The scale ranged from "extremely repulsive" through "repulsive", "very unpleasant", "unpleasant", "neither unpleasant or pleasant", "pleasant", "very pleasant", "attractive" to "extremely attractive" (the same as that in Experiment 2.2). Participants were asked to give their response verbally.

3.3.2. Results and discussion

Twenty-five students met the criterion for trypophobia (i.e., TQ score > 31; trypophobic group), whereas 35 students did not (control group). The ratings of unpleasantness were coded numerically from -4 through 0 to +4, a low score indicating unpleasantness (i.e., -4 = *extremely repulsive*; +4 = *extremely attractive*). The average ratings are illustrated in Figure 3.4.

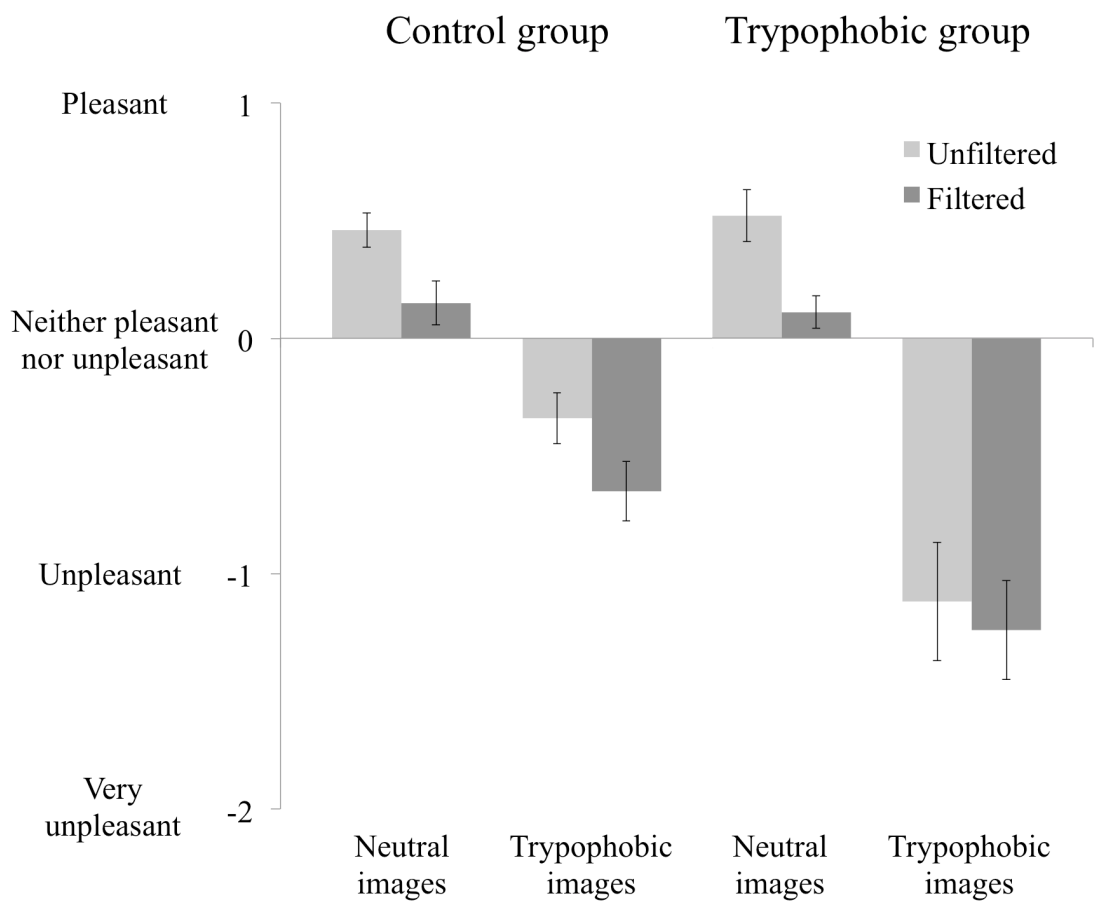


Figure 3.4. Mean ratings for images. Error bars represent 1 standard error.

A three-way ANOVA with image type and filtering as within-subjects factors and group as between-subjects factor revealed that there was a significant three-way interaction, $F(1, 58) = 7.89$, $p < .01$, $\eta^2 = 0.09$. Two repeated-measures ANOVAs, separated by groups, were conducted to investigate the effect of image type (trypophobic vs. neutral) and filtering (filtered vs. unfiltered) on the rating of images.

Control group. There was no statistically significant interaction between image type and filtering, $F(1, 34) = 1.41$, $p = .243$, $\eta^2 < .001$. A main effect was found for image type, $F(1, 34) = 30.43$, $p < .001$, $\eta^2 = .049$, and filtering, $F(1, 34) = 51.99$, $p < 001$, $\eta^2 = .530$. This suggested that image type and filtering had an effect on the ratings, which was investigated further. Two composite scores were obtained by averaging the scores for all filtered and unfiltered images (across image type), so

as to investigate the main effect of filtering across participants. A paired-samples t-test revealed that filtered images (M = -0.29, SD = 0.52) overall received a lower (more unpleasant) score compared to their unfiltered (M = -0.02, SD = 0.45) counterparts, $t(34) = 5.52$, $p < .001$, $d = 0.6$. Furthermore, two composite scores were obtained by averaging the scores for all trypophobic and neutral images (across filtering), so as to investigate the main effect of image type across participants. As expected, a paired-samples t-test revealed that trypophobic images (M = -0.62, SD = 0.73) overall received a lower (more unpleasant) score compared to neutral images (M = 0.30, SD = 0.42), $t(34) = 7.21$, $p < .001$, $d = 1.6$.

The results suggested that, for control participants, filtering the images had a negative effect. Manipulating the images decreased the overall rating of the images, indicating more unpleasantness. Presumably, the reduction of pleasantness for filtered images was due to the degradation of the images as a result of the manipulation (Figure 3.3b and Figure 3.3md illustrates the loss of image quality). As there was no significant interaction, it can be suggested that filtering images had the same effect for both trypophobic and neutral images. Hence, excess energy in images did not seem to have a negative effect on control participants, as they showed a preference for those images compared to the images where excess energy was removed.

Trypophobic group. There was a statistically significant interaction between image type and filtering, $F(1, 24) = 19.78$, $p < .001$, $\eta^2 = .004$. Significant main effects for image type, $F(1, 24) = 107.74$, $p < .001$, $\eta^2 = .98$, and filtering, $F(1, 24) = 16.36$, $p < .001$, $\eta^2 = .02$, were found. To investigate the interaction, two paired-samples t-test were conducted to examine the differences between filtered and unfiltered images in terms of rating, separated by image type. For neutral images, a paired-samples t-test revealed that filtered images (M = 0.34, SD = 0.68) overall

received a significantly lower (more unpleasant) score compared to unfiltered images (M = 0.76, SD = 0.78), $t(24) = 5.06$, $p < .001$, $d = 0.6$. For trypophobic images, however, a paired-samples t-test revealed that there was no significant difference between filtered (M = -1.51, SD = 0.34) and unfiltered (M = -1.38, SD = 0.74) images, $t(24) = 1.93$, $p = .066$, $d = 0.2$.

The results shows that, for the trypophobic group, filtering neutral images had a negative effect whereas filtering trypophobic images did not, as indicated by the significant interaction. Thus, it was evident that the trypophobic group behaved in the same manner as the control group when it came to neutral images, because the filtered versions of the images were rendered less pleasant compared to the unfiltered versions. Importantly, there was a difference between the two groups in terms of trypophobic images. Control participants significantly disliked the degraded images compared to the images with excess energy at mid-range spatial frequencies (unfiltered images), whereas the trypophobic participants did not. The absence of such an effect of degradation for the trypophobic group in respect of the trypophobic images suggests that the excess energy in such images did have an effect on these particular individuals. The current experiment therefore demonstrated that visual characteristics could be partially responsible for trypophobia. However, it is also clear that there are more important factors beyond the amplitude spectrum that contribute to the aversion, because normalising the spectra did not have a dramatic effect on unpleasantness as anticipated.

3.4. Summary of chapter

Although trypophobia is commonly known as the fear of holes, Experiment 3.1 demonstrated that the nature of the objects, whether concave or convex, is trivial. Importantly, it was demonstrated that the larger the cluster became (i.e., more objects

within a cluster), the greater the discomfort reported. Subsequently, it was found that increasing the cluster size led to a higher excess energy at mid-range spatial frequencies, which has been associated with discomfort (Fernandez & Wilkins, 2008). Cole and Wilkins (2013) reported that trypophobic images possess these types of visual characteristics, which was replicated in Experiment 3.2. This prompted the idea that there could be a link between the phobia and the physical spectral composition of the images that these types of stimuli possess. The results from Experiment 3.3 suggested that the processing of excess energy at mid-range spatial frequencies might be considered a mediating mechanism of trypophobia. However, as noted by Cole and Wilkins (2013), the spectral characteristics of the images cannot be a sufficient explanation: there are many images that are not trypophobic, but nevertheless have an excess energy at mid-spatial frequencies.

Another possible suggestion is therefore that there exist evolutionary factors that explain the prevalence and specificity of trypophobia. In support of this, Cole and Wilkins (2013) demonstrated that the Fourier amplitude spectrum of images of poisonous animals (e.g., blue-ringed octopus or box jellyfish) also have a "bump" at mid-range spatial frequencies. Furthermore, it has been demonstrated that acquisition of avoidance behaviour is particularly easy towards species that have posed a survival threat during human evolution (Cook & Mineka, 1989), which demonstrates the importance of the nature of the stimuli. This may therefore suggest that trypophobia could arise because the images coincidently possess spectral features associated with dangerous species, and that trypophobia is a generalisation from this, because it is easier to acquire fear for certain characteristics, and these elementary characteristics can be more rapidly processed. Some of these aspects were further investigated in the next chapter, where potential aetiological factors for trypophobia were identified.

CHAPTER 4. REFINING THE RESPONSE CONCEPTS

"If I saw something inorganic, like wallpaper pattern or clothing, that had these sorts of patterns, at most it would cause me discomfort, if any. But if it was organic, like seeds or insect homes, then I would get a reaction"

D. L., personal communication, 2013

In the current chapter, four experiments were conducted to investigate the aetiological aspects and response concepts related to trypophobia. Although the condition previously has been conceptualised as fear, it may in fact be more related to disgust. For example, an individual reported "a strong feeling of revulsion and disgust as opposed to fear" (F. L. M. B., personal communication, 2014) upon confrontation with relevant stimuli. Furthermore, the symptoms in the TQ also include aspects that resemble disgust responses, such as "Vomit" or "Feel sick or nauseous".

In Experiment 4.1, individuals with and without trypophobia were compared in terms of how much they were bothered about various sources of harm, so as to investigate the aetiological aspects. This provided useful information about the appropriate response towards trypophobia. The TQ and its relationship to measures of common animal fears (i.e., snakes and spiders) and disgust were investigated in Experiments 4.2 and Experiment 4.3. Furthermore, since emotions (e.g., fear and disgust) bias cognitive processes in different ways, Experiment 4.4 also investigated whether trypophobic images distorted the cognitive processing of time estimation, so as to ascertain the response concepts related to trypophobia.

Experiment 4.1. Potential aetiological aspects related to trypophobia

Cole and Wilkins (2013) proposed that trypophobia arises as a consequence of an evolutionary trait with survival value. By analysing images associated with trypophobia, they found that those images share the same low-level visual

characteristics found in poisonous organisms (e.g., the blue-ringed octopus), as reflected in the amplitude spectrum. This led them to suggest that although trypophobic images are generally innocuous and seemingly pose no threat, they coincidentally share certain low-level visual characteristics associated with dangerous species, hence such images are potentially over-generalised and thus perceived as aversive. Based on this, the authors suggested that trypophobia could be a characteristic that contributes to an unconscious survival response, which originated via evolution. This response enables a fast detection of low-level visual characteristics, before the recognition of the actual content, and facilitates a rapid avoidance mechanism.

Another possible cause of trypophobia concerns its possible relationship to skin lesions. This idea was prompted by the similarities between trypophobic stimuli and skin conditions. For example, chickenpox, medically known as varicella (Heininger & Seward, 2006), is a relatively mild illness that arises mainly in young children. It is highly contagious and contact susceptibility ranges from 61-100%. While symptoms such as fever or headache arises as a result of the illness, the diagnosis is based on the characteristic features of the vesicular varicella rash that occurs on skin, with an average of 200-400 skin lesions in immunologically naïve patients. The skin lesions tend to look like small, red dots generally concentrated on the face and trunks, and resemble the configurations of objects in trypophobic images. Aversion to skin conditions, especially if they are contagious, may serve as a trait with survival value. In support of this, one individual reported that “skin rashes and other maladies are the absolute worst” (J. K., personal communication, 2013) when describing the trypophobic stimuli that were particular offensive.

In contrast, unblemished skin has been suggested to be one of the most universally desired human feature (Morris, 1967), and Symons (1995) argued that female skin free of lesions, eruptions, warts, moulds, cysts, tumors, acne, and hirsutism, is sexually most attractive to males. From this point of view, trypophobia could be considered as a result of an evolutionary selection pressure to avoid skin disease for survival, or perhaps a preference for skin features that indicate good health for reproductive purposes. Testimonials provided by individuals with trypophobia indicated that some were especially susceptible to images when the configurations of objects appeared on skin. For example, one individual stated that "it gets worse when they're photoshop(p)ed on human skin" (D. R., personal communication, 2013) (see also Cole & Wilkins, 2013). In support, one of the common images associated with trypophobia represents a female with the configuration of holes from the lotus seed head superimposed on her forearms and knees.

Another disease avoidance behaviour that was hypothesised to account for trypophobia was disgust sensitivity. Disgust has been suggested to be elicited by factors such as visual stimuli (Darwin, 1872), which is consistent with Cole and Wilkins (2013), who reported that it is the visual perception of trypophobic images that is responsible for the condition to occur. The possible relationship between disgust and trypophobia was prompted by the symptoms that comprise the TQ, some of which resemble behaviour related to disgust (e.g., "Feel sick or nauseous" or "Vomit"). Importantly, disgust has been demonstrated to account for other phobias such as spider phobia (Matchett & Davey, 1991; Mulkens, de Jong, & Merckelbach, 1996; Sawchuk, Lohr, Tolin, Lee, & Kleinknecht, 2000; Woody, McLean, & Klassen, 2005), blood-injection-injury type phobias (Tolin, Lohr, Sawchuk, & Lee, 1997) or

contamination-related obsessive-compulsive disorder (OCD) (Olatunji, Lohr, Sawchuk, & Tolin, 2007; Tolin, Woods, & Abramowitz, 2006). The current experiment therefore investigated the role of disgust. Spoiled or decayed foods have been reported to be offensive and a common elicitor of disgust (Martins & Pliner, 2005; Rozin, Fallon, & Mandell, 1984; Tybur et al., 2009), and were included as the disgust-related items.

In the current experiment, individuals with and without trypophobia were asked whether they were averse to mental images of fear-relevant stimuli (i.e., animals commonly associated with phobia, skin conditions and decay of organic matter) and fear-irrelevant but unpleasant stimuli (e.g., breakdown of inorganic matter). We investigated whether objects that were harmful from an evolutionary point of view affected individuals with trypophobia to a higher degree relative to controls.

Kosslyn, Ganis, and Thompson (2001) described mental imagery as an experience of "seeing with the mind's eye" (p. 635), which occurs through perceptual information accessed from memory. Furthermore, Bruce and Sanderson (1998) argued that mentally engaging in phobic stimuli can trigger the phobia. Mental images can therefore be considered a way to provide the offensive stimulus without the interference of physical properties of images that may mediate the negative experiences, such as image properties associated with visual stress (Wilkins, 1995) that was demonstrated to have a mediating effect in Experiment 3.3.

4.1.1. Methods

Participants. The sample included 151 individuals (50 males, 101 females) from a panel of Essex student and staff volunteers, aged from 18 to 51 (M = 22.85,

SD = 5.36). The University of Essex ethics committee granted ethical approval for the current experiment.

Materials. Fourteen descriptions of various mental images were created, from five different categories. These are summarised in Table 4.1.

Table 4.1. Descriptors for mental images, separated by category.

Category	Item
Skin conditions	Chicken pox on arm
	Acne on cheek
	Eczema on neck
	Measles rash on chest
Trypophobic objects	Sponge on a bathtub
	Cheerios cereal in a bowl
	Honeycomb in a jar
	Barnacles on rocks
Decay of organic matter	Mould spores on bread
	Rotting apples in a tub
Breakdown of inorganic matter	Torn cloth on sweater
	Rusty metal on a bike
Common animal phobia	Spider on a wall
	Snake on a tree

Procedure. Qualtrics (Qualtrics Labs Inc, 2013) was used to present the experiment. At first, participants were presented with a welcome screen informing them about the procedure. They were told that the images used for illustrative purposes might be found aversive. Consent was obtained by choosing either “Agree” or “Disagree”, the former indicating that the information had been read, that participation was voluntarily and that the participant was 18 years or older.

In the experimental task, the participants were asked to imagine the various mental images, with the purpose of rating how bothered they were by them. The exact instructions given were:

"In this task, you will be asked to read descriptions of images, and create them in your mind (see illustration below). Once you have created them, your task is to rate the individual image in terms of how much it bothers you. We are NOT interested in how much the object(s) itself bothers you, just in how upsetting you find the overall image. You may not find them upsetting at all, or you may find some of the configurations or patterning disturbing."

A figure was included below the instructions illustrating a face with a thought cloud, indicating that the task was to create the described images mentally. The participants were then asked to rate how bothered they were for each mental image, using a scale from 1-7 (1 = "Not at all bothered", 4 = "Somewhat bothered", and 7 = "Extremely bothered"). Subsequently, the participants were given the TQ.

4.1.2. Results

In total, 37 participants met the criterion (TQ score > 31) for trypophobia (trypophobic group) and 114 participants did not (control group). For each mental image, the average rating was obtained for both groups (see Table 4.2). The differences in rating between groups were investigated using a 14 (mental images) x 2 (group: trypophobic vs. control group) mixed ANOVA, with repeated measures on the first factor. There was a statistically significant interaction between mental images and group, $F(13, 1937) = 2.693$, $p < .01$, $\eta^2 = .011$. Furthermore, there was a significant main effect of group, $F(1,149) = 43.435$, $p < .001$, $\eta^2 = .023$, and a significant main effect of mental images, $F(13, 1937) = 72.42$, $p < .001$, $\eta^2 = .32$. To further investigate the interaction, fourteen independent samples t-tests were conducted to investigate the differences between groups across the mental images with Bonferroni correction for multiple comparisons ($p < .0036$). The results are

illustrated in Table 4.2, which suggested that individuals with trypophobia were significantly more bothered by some mental images compared to control participants.

Table 4.2. Mean (SD) rating of mental images, effect size and t-values.

Variable	Mean (SD)		Effect size (*d*)	t-value
	Trypophobic group	Control group		
Spider on a wall	5.38 (1.75)	3.10 (1.90)	1.2	6.40*
Snake on a tree	3.81 (1.85)	2.70 (1.77)	0.6	2.37
Measles rash on chest	5.46 (1.19)	4.22 (1.77)	0.8	3.74*
Eczema on neck	4.84 (1.54)	3.68 (1.75)	0.7	3.45*
Chicken pox on arm	5.08 (1.38)	3.80 (1.86)	0.8	3.57*
Acne on cheek	4.68 (1.62)	3.70 (1.76)	0.6	2.75
Barnacles on rocks	3.16 (1.88)	1.90 (1.23)	0.8	4.43*
Honeycomb in a jar	2.76 (2.07)	1.47 (1.07)	0.8	4.60*
Cheerios cereal in a bowl	1.78 (1.46)	1.19 (0.65)	0.6	2.86
Sponge on a bathtub	2.30 (1.43)	1.61 (1.30)	0.5	2.19
Rotten apples in a tub	4.89 (1.65)	3.50 (1.83)	0.8	3.82*
Mould spores on bread	5.05 (1.56)	3.92 (1.99)	0.6	3.12*
Torn cloth on a sweater	3.22 (1.58)	2.44 (1.50)	0.5	2.47
Rusty metal on a bike	3.08 (1.44)	2.30 (1.53)	0.5	2.40

Note. $N = 158$. Asterisks denote significant differences between the two groups (Bonferroni corrected).

4.1.3. Interim discussion

The current experiment was conducted as a preliminary investigation of whether overgeneralisation from harmful objects can account for the origins of trypophobia. As expected, individuals who met the criterion for trypophobia reported that mental images of trypophobia (e.g., “barnacles on rocks”) were significantly more bothersome, although these images were not necessarily those most commonly associated with trypophobia (i.e., the lotus seed head). This was consistent with the argument advanced by Bruce and Sanderson (1998), who proposed that engaging with the phobic stimuli in thought is enough to trigger the phobia. However, two descriptors within the trypophobia category, “Cheerios cereal in a bowl” and “Sponge

on a bathtub", did not significantly differ between groups. This may be related to the range of which trypophobic images induce aversion, where some objects induce a stronger reaction relative to others[5].

A similar relationship was reported for the mental images of skin conditions. While "Measles rash on chest", "Eczema on neck" and "Chicken pox on arm" were significantly more bothersome for individuals with trypophobia, "Acne on cheek" did not significantly differ between the two groups. On balance, this is consistent with the hypothesis that trypophobia arises from aversion to skin conditions or preference for certain skin traits. For common animal phobias, the results were partially consistent with Cole and Wilkins (2013), who proposed that trypophobia arises as an overgeneralisation of poisonous species. The current results showed that only one mental image concerning common animal phobias, "Spider on a wall", was significantly more bothersome for individuals with trypophobia compared to controls, whereas "Snake on a tree" was not. This suggested that the link between poisonous species and trypophobia may not be as straightforward as proposed by Cole and Wilkins (2013). The last aspect in the current experiment was related to disgust and disease avoidance behaviour. Both items related to this category, "Rotten apples in a tub" and "Mould spores on bread", were reported to be more bothersome for the trypophobic group.

As the only category not associated with threat, mental images of breakdown of inorganic matter (i.e., "Torn cloth on a sweater" and "Rusty metal on a bike") did not yield any differences between the two groups. Consistent with the hypothesis,

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[5] Post-hoc analyses of the data obtained in Experiment 2.2 confirmed that the images of barnacles (M = -3.49, SD = 0.89) and lotus seed head (M = -3.20, SD = 1.10) were significantly more unpleasant than the image of a sponge (M = -1.61, SD = 1.43), $t(137) = 17.4$, $p < .001$, $d = 1.6$, and $t(137) = 12.8$, $p < .001$, $d = 1.3$, respectively.

individuals with trypophobia did not find mental images of objects that were not harmful more bothersome compared to control participants. Overall, this supported the hypothesis that trypophobia arises as a overgeneralisation from evolutionary traits with survival value, as one would not expect "Torn cloth on a sweater" or "Rusty metal on a bike" to fall into the category of potential danger.

Overall, three relevant ecological aspects were identified; (a) avoidance of poisonous animals/species (i.e., spiders), (b) avoidance of skin-conditions and (c) avoidance of rotten foods (i.e., possible contamination sources). The following three experiments in this chapter will further investigate the aspect of common animal phobia and contamination disgust in trypophobia.

Experiment 4.2. Common animal phobias and trypophobia

In Experiment 4.1, it was reported that individuals who met the criterion for trypophobia were significantly more bothered by mental images involving spiders, but not snakes. Here, the relationship between trypophobia and common animal phobias was further investigated using established measures of specific animal fears (Klorman et al., 1974).

4.2.1. Methods

Participants. The sample included 52 individuals (21 males, 31 females) from a panel of Essex student and staff volunteers, aged from 19 to 60 (M = 24.96, SD = 7.75). The University of Essex ethics committee granted ethical approval for the current experiment.

Materials. The 31-item Spider Questionnaire (SPQ) and 30-item Snake Questionnaire (SNAQ) developed by Klorman et al. (1974) were used to measure fear of spiders and snakes. Statements such as "I dislike looking at pictures of spiders in a magazine" or "I avoid going to parks or on camping trips because there may be

snakes about." were given true/false responses. Both measures have shown good reliability in previous research (Fredrikson, 1983; Klorman et al., 1974). Furthermore, the TQ was included as a measurement of trypophobia.

Procedure. The order of the questionnaires was randomised for each participant. Qualtrics (Qualtrics Labs Inc, 2013) was used to present the questionnaires.

4.2.2. Results

Similarly to previous experiments, Tukey's method (Tukey, 1977) was used to detect outliers in the sample in terms of TQ score, again using an r factor of 1.5. The purpose was to remove individuals who were highly susceptible to trypophobic stimuli, as the current experiment used a general sample of students, hence removing the individuals with extreme TQ scores would yield much more generalizable results. Three outliers were revealed (score above 35) and excluded from further analysis. Similar results were obtained when the outliers were included in the analyses.

The relationship between the TQ and SPQ showed a Pearsons's correlation coefficient of $r(47) = .46$, $p < .01$, which suggested that there was a moderate and positive correlation between the two measurements. Furthermore, the relationship between TQ and SNAQ revealed a weak and non-significant Pearsons's correlation coefficient of $r(47) = .22$, $p = .133$. SNAQ and SPQ showed no correlation, $r(47) = .11$, $p = .474$. The scatterplots are shown in Figure 4.1.

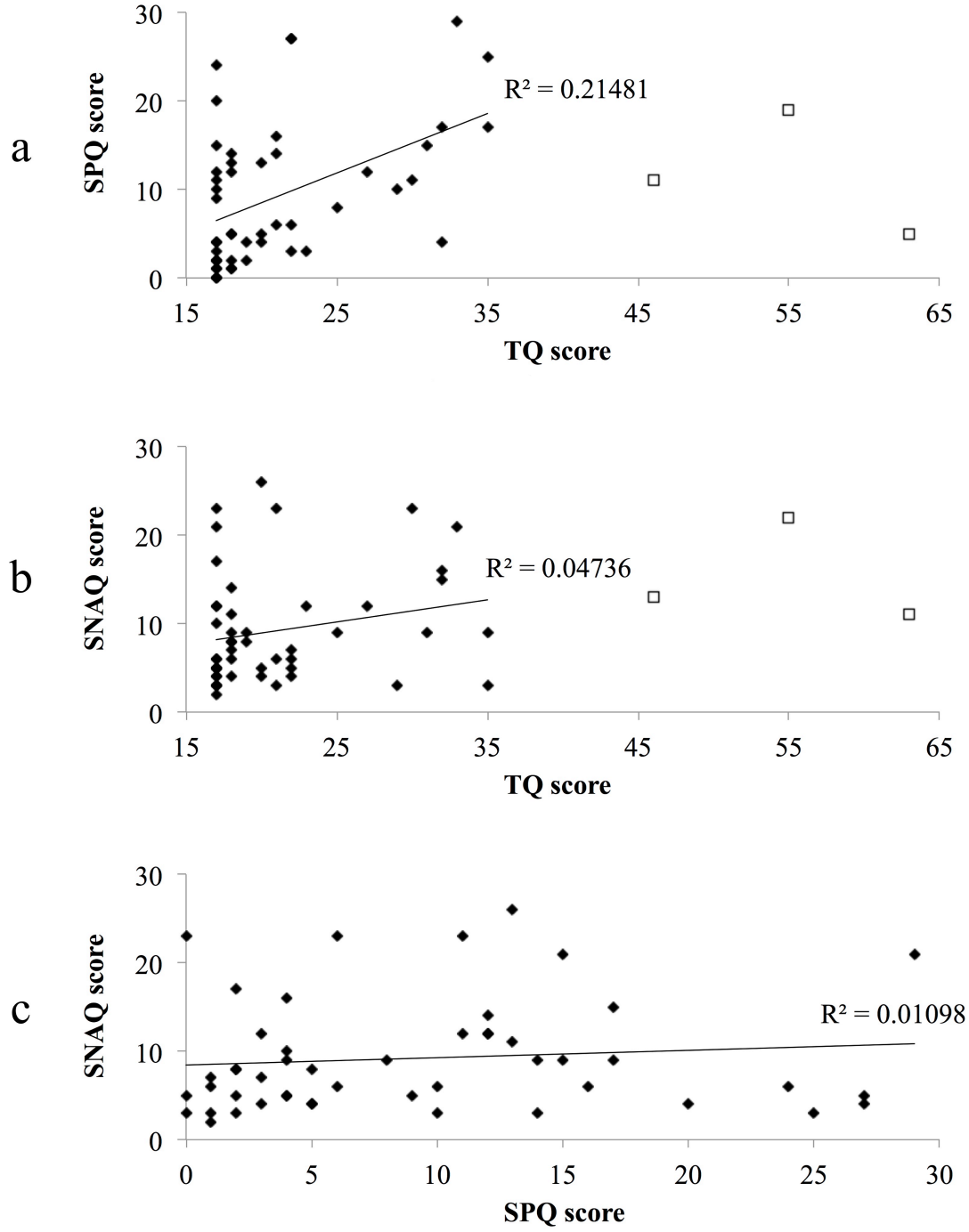


Figure 4.1. Scatterplot for the relationships between (a) SPQ and TQ, (b) SNAQ and TQ, and (c) SNAQ and SNQ. For a and b, the white squares represent the outliers in terms of TQ score.

4.2.3. Interim discussion

The current experiment aimed to further investigate the relationship between trypophobia and common animal fears (i.e., snake and spider). The findings

suggested that trypophobia was related to fear of spiders but not snakes. This was consistent with results reported in Experiment 4.1, where individuals who met the criterion for trypophobia found mental images of spiders, but not mental images of snakes, more bothersome relative to controls. Subsequently, there was no correlation between snake and spider fear. The latter finding was consistent with Wiens, Peira, Golkar, and Öhman (2008), who reported a non-significant and weak correlation (r = .12) between SNAQ and SPQ, which was comparable to the current results.

Thus, a disassociation between trypophobia and snakes has been demonstrated by two experiments, suggesting that trypophobia does not simply arise as an overgeneralisation of poisonous species overall, but a very specific species (i.e., spiders). One important aspect, and central to the current interpretation of these results, is the fundamental differences between fear of spiders and snakes in terms of the mechanisms responsible. More specifically, fear of animals has been hypothesised to evolve as a way of solving adaptive problems related to predators, resulting in a predatory defence system (Öhman & Mineka, 2001). Snakes, as the first predators that preyed on early mammals (Isbell, 2006), have been regarded as the founding species for predatory fears (Soares, 2010). However, it has been questioned whether the predatory defence system accounts for spiders (Soares, Esteves, Lundqvist, & Öhman, 2009), as they have been regarded as fear-relevant but non-predatory (Davey, 1991; Sawchuk et al., 2000). Rather, Matchett and Davey (1991) suggested that spider aversion is more likely to be related to avoidance behaviour due to the danger of contamination, as mediated by *disgust*, relative to avoidance of potential physical harm, as mediated by *fear*. The link between disgust and spider phobia was also suggested by Watts (1986), and subsequently supported by de Jong, Andrea, and Muris (1997), who reported that girls with spider phobia displayed higher levels of

disgust sensitivity, as measured by the Disgust Questionnaire (Rozin et al., 1984), compared to non-phobic children (see also Merckelbach, de Jong, Arntz, & Schouten, 1993).

This was also consistent with the interplay between fear and disgust in other anxiety disorders. As already described, spider phobia has been associated with both disgust and fear (de Jong et al., 1997), which can be related to the nature of the stimuli. Although spiders involve a contamination aspect, in which a disgust response may be necessary to motivate avoidance, they are also *moving* objects, in which fear responses may be necessary to facilitate escape. However, the overall consensus regarding other anxiety disorders such as BII phobia or contamination-related OCD is that disgust is the main response (Cisler, Olatunji, & Lohr, 2009). This can be directly related to the nature of the stimuli associated with those conditions, which are relatively static. Therefore, rapid escape or avoidance may not be necessary, because a sufficient distance between the self and the contamination source is enough to ensure "safety". In a similar vein, it is clear that trypophobic stimuli are generally inanimate and static (e.g., barnacles or honeycomb), thus one would not expect a fear response to be necessary. This was also consistent with the argument that disgust is dependent on contact or proximity (Ahmed, 2013).

Evidently, there is evidence suggesting that there is an association between disgust and fear of spiders, however little peer-reviewed research has been published regarding disgust and fear of snakes. This indicates that there might be a dimension within aversion of spiders that is less present within aversion of snakes, namely disgust. In this case, it would make sense that trypophobia related only to aversion of spiders, and not snakes, given that Experiment 4.1 found that individuals with trypophobia were significantly more bothered by mental images of decay of organic

matter (i.e., disgust-related items). Trypophobia may therefore be related to disgust-sensitivity, and the next experiment investigated this relationship in more detail.

Experiment 4.3. Pathogen disgust and trypophobia

As mentioned, spoiled or decayed foods have been reported to be offensive and an elicitor of disgust (Martins & Pliner, 2005; Rozin et al., 1984; Tybur et al., 2009). Experiment 4.1 reported that individuals who met the criterion for trypophobia found mental images involving decayed foods, such as "rotten apples in a tub", significantly more bothersome compared to control participants. This prompted the idea that trypophobia might be related to disgust-sensitivity. Tybur et al. (2009) described disgust as a heterogeneous component with three domains, namely (a) pathogen, (b) moral and (c) sexual disgust. Here, their instrument was used as a measurement of disgust. The hypothesis was that whereas pathogen disgust should be related to trypophobia, the other two domains should be poor predictors of how individuals experience trypophobic images, as measured by the TQ.

4.3.1. Methods

Participants. The sample included 71 undergraduate psychology students (9 males, 62 females) who participated for course credit, aged from 18 to 36 (M = 20.1, SD = 3.34). Those participants had not taken part in the earlier experiments in this thesis. Thirteen participants (one male, 12 females), aged from 18 – 26 (M = 20.5, SD = 2.79) were invited back on the basis of their TQ score (M = 40.4, SD = 6.70, range = 32, 52), which were obtained from Experiment 4.1. The total number of participants was 84. The University of Essex ethics committee granted ethical approval for the current experiment.

Materials. The Three-Domain Disgust Scale (Tybur et al., 2009) comprises 21 actions that the participants rate in terms of disgust, ranging from "not at all

disgusting" (0) to "extremely disgusting" (6). The scale consists of three domains, pathogen (e.g., "stepping on dog poop"), sexual (e.g., "hearing two strangers having sex") and moral (e.g., "deceiving a friend"), and was used as a measurement of disgust. In addition, the TQ was used as a measurement of trypophobia.

Procedure. The two questionnaires were presented in random orders. The items comprising the Three-Domain Disgust (Tybur et al., 2009) were presented in a random order as a list, and the participants were asked to rate each item in terms of disgust (0="Not at all disgusting", 6="Extremely disgusting").

4.3.2. Results

Tukey's method (Tukey, 1977) was used to detect outliers in the sample in terms of TQ score, again using an r factor of 1.5. Two outliers were revealed (score above 54) and excluded from further analysis. The three subscales of the Three Domain Disgust scale (Tybur et al., 2009) were used in a standard regression analysis to predict TQ score. The correlations of the predictor variables are shown in Table 4.3, which indicated acceptable correlation coefficients with respect to multicolliniarity (i.e., correlation coefficient above .7) (Meyers et al., 2012). Importantly, Tybur et al. (2009) reported similar relationships between the disgust subscales, also reported in Table 4.3.

Table 4.3. Correlation of the variables in the analysis. The correlation coefficients reported in Tybur et al. (2009) are provided in brackets.

Variable	2	3
1. Pathogen disgust	.13 (.20)	.43** (.40)
2. Moral disgust	- -	.32* (.36)
3. Sexual disgust		- -

Note. $N = 82$, * $p < .01$, ** $p < .001$

A significant model emerged: $F(3, 78) = 3.93$, $p < .01$. This model accounted for 13.1% of the variance in TQ score (Adjusted $R^2 = .097$). Table 4.4 summarises the predictor variables entered in the model. As demonstrated, pathogen disgust was associated with TQ score. The (significant) positive beta suggested that a higher level of pathogen disgust was related to a higher TQ score. Furthermore, moral disgust and sexual disgust were not significant predictors for TQ score.

Table 4.4. The effect of predictor variables on TQ score.

Model	B	SE-B	*β*
Constant	11.6	5.97	
Pathogen disgust	2.64	1.08	0.29*
Moral disgust	-0.74	0.80	-0.10
Sexual disgust	1.06	0.91	0.14

Note. * $p < .05$

4.3.3. Interim discussion

Consistent with the hypothesis, the current experiment demonstrated that only pathogen disgust, and not moral or sexual disgust, was a significant predictor of TQ score. These findings suggested that a higher sensitivity to trypophobic images was associated with a higher level of pathogen disgust (i.e., disease avoidance), which can be related to the findings of Experiment 4.1, where individuals with trypophobia were significantly more bothered by items related to disgust. This provided more support for the argument that trypophobia is not necessarily a fear, but rather, a disgust response. The next experiment investigated the cognitive bias in subjective time estimation related to trypophobia, so as to further investigate the emotional response related to this condition.

Experiment 4.4. Subjective time estimation of stimulus duration

Past research has established that time estimations are on average accurate, and that there is a linear relationship between the variability of estimates and the length of the interval being estimated (Droit-Volet, 2013). Such demonstrations have been taken as evidence that humans, as well as animals, possess a specific mechanism that can be used to measure time (Droit-Volet & Gil, 2009). Indeed, a part of our daily life involves processing of information regarding time. But while objective time has been universally accepted to progress linearly and in constant units (e.g., seconds, minutes, etc.), James (1890) suggested that the "emotional feeling accompanying the intervals of time […] harmonize(s) with different mental moods" (p. 618), suggesting that subjective time estimation depends on various factors such as external stimulation or cognitive states (Droit-Volet & Meck, 2007). Thus, under the influence of some emotions, our ability to judge time can be extremely inaccurate, and the literature has reported many cases demonstrating this.

In terms of fear, the overall consensus is that fear-related stimuli are related to an overestimation of time. Bar-Haim, Kerem, Lamy, and Zakay (2010) compared anxious and non-anxious individuals in terms of subjectively experienced time when presented with threat related versus non-threat related stimuli. In this study, the participants were presented with faces of actors who displayed either fearful or calm expressions for 2, 4 or 8 seconds, and they were subsequently asked to reproduce the duration of the face stimulus. The authors reported that anxious individuals tended to overestimate the duration when exposed to short (i.e., 2-second) presentations relative to non-anxious individuals. This group difference was, however, not apparent for longer exposures. Grommet et al. (2011) investigated the time estimation bias using fear relevant and irrelevant (i.e., neutral) images from the International Affective

Picture System (IAPS) (Lang, Bradley, & Cuthbert, 1997). An association between fearful cues and overestimation of time duration was found, suggesting that stimuli associated with fear distort individuals' ability to judge the time duration of the stimuli. Other studies have also replicated that facial expressions of fear are associated with an overestimation of time (Gil & Droit-Volet, 2008).

On the contrary, studies investigating the role of disgust in time estimation have found contradicting results. First of all, Gil and Droit-Volet (2012) used the IAPS pictures of mutilated bodies and burned victims to demonstrate that disgust-inducing stimuli also was associated with an overestimation of time. Second, when it comes to facial expressions, disgust-related stimuli was not associated with any effect on time estimation (Droit-Volet & Meck, 2007), as demonstrated in a temporal bisection task (as described below). Third, Gil, Rousset, and Droit-Volet (2009) investigated how liked and disliked foods affected time perception, and reported that the duration of disliked food was underestimated when compared to preferred food. It therefore would appear that the nature of the disgusting stimuli is important (Droit-Volet & Gil, 2009). However, there are many aspects about these studies (i.e., Droit-Volet & Meck, 2007; Gil et al., 2009) that have to be considered before a conclusion can be reached as to the relationship between disgust and subjective time estimation.

As mentioned, Gil and Droit-Volet (2012) used particularly extreme images that may not be uniquely related to disgust. Arguably, images of mutilated bodies and burned victims are more extreme than facial expressions of disgust or disgusting foods, as used by Droit-Volet and Meck (2007), and the former types of images may also involve some aspect of immediate danger (i.e., fear). In support, Ekman et al. (1987) argued that mutilation films elicited both disgust and fear. Others (e.g., Weinberg & Hajcak, 2010) have purposely distinguished between mutilation stimuli

and disgust stimuli. Thus, although mutilation is indeed related to disgust, it is also evident that fear is another emotion associated with these types of images. Therefore, although Gil and Droit-Volet (2012) reported that mutilation and other related stimuli were associated with an overestimation of time, it is unclear which aspect (fear or disgust) was responsible for this cognitive bias, suggesting that the relationship between disgust and time estimation cannot be concluded from this study.

Gil et al. (2009) based their conclusion on the significant difference between the bisection points for liked and disliked foods, which led them to suggest that disliked food was underestimated in terms of time duration. This is ambiguous: it depends on the stimuli in which they compared disliked foods (i.e., disgusting stimuli) with. In their case, liked food (i.e., attractive) was used in order to investigate whether disgust affected the estimation of time duration. Hence, it can be argued that disliked food was actually not underestimated, but liked food was overly overestimated, which led to the significant difference. Importantly, other studies reporting the effect of disgust (and other emotion) on temporal distortion commonly used neutral stimuli as a comparison, such as Gil and Droit-Volet (2008) who compared faces expressing disgust with neutral faces, and found no time distortion for disgusted faces. Since it has been reported that pleasant/positive images can cause overestimation (e.g., Angrilli, Cherubini, Pavese, & Manfredini, 1997; Droit-Volet, Brunot, & Niedenthal, 2004), it is questionable whether liked foods were actually suitable as comparison stimuli. Rather, Gil et al. (2009) should have included another group of stimuli (i.e., neutral foods), which would provide less ambiguous results.

Overall, fear and disgust seem to differ in terms of how the emotions bias time estimation (for review, see Droit-Volet & Gil, 2009). Whereas fear tends to show a robust effect of overestimation, there is some inconsistency with disgust. The current

experiment investigated the bias in time estimation of trypophobic images, although the elaboration above might suggest that disgust is not associated with a distortion of time estimation. Because fear has consistently been associated with an overestimation of time, demonstrating that trypophobia does not cause this direction of cognitive bias will provide further support for the argument that trypophobia is not predominantly a fear response.

One important aspect to consider is the time duration of the targets in experiments, which varies in the literature. Studies (e.g., Angrilli et al., 1997) have demonstrated that the effect of emotion on temporal judgement disappears if the stimuli events are longer than four seconds, which is consistent with Bar-Haim et al. (2010). Furthermore, two paradigms have been widely used to investigate time perception, namely prospective and retrospective judgement (Hicks, 1992). In the former paradigm, the participant is aware that (s)he will be asked to judge the duration of a stimulus event, whereas in the latter paradigm, the participant is not (Bar-Haim et al., 2010). From this point of view, the retrospective judgement paradigm can be considered to be a memory-related task, whereas the prospective judgement paradigm involves attention and arousal (e.g., Zakay, Nitzan, & Glicksohn, 1983). It can therefore be suggested that prospective judgement is a suitable paradigm with regards to the current rationale.

The current experiment aimed to investigate whether individuals with trypophobia are biased in their cognitive processing of the time estimation of trypophobic stimulus. Evidently, individuals generally demonstrate bias in time estimation of stimuli associated with some emotions (i.e., fear, anger or happiness) but not others (i.e., disgust) (Gil & Droit-Volet, 2008). This paradigm was used to investigate whether trypophobic images were associated with any cognitive

processing, so as to investigate the underlying emotional response. Here, the temporal bisection task (Allan & Gibbon, 1991) was used, where the participants were presented a short target (e.g., 400ms) and a long target (e.g., 1600ms) as anchor durations. Subsequently, they were presented trypophobic or neutral stimuli that varied in duration (i.e., 600, 800, 1000, 1200 or 1400ms) and asked whether the stimuli presented had a duration closer to the short (400ms) or long (1600ms) anchor. Droit-Volet et al. (2004) proposed that durations less than two seconds can prevent counting strategies employed by participants.

4.4.1. Methods

Participants. Eighty-one (14 males, 67 females) students from the University of Essex, aged from 18 to 36 years (M = 20.4, SD = 3.34) took part for course credit (Psychology undergraduates) or small reimbursement (other undergraduates and postgraduates). Within the sample, six individuals were invited back on the basis of their TQ scores (M = 39.5, SD = 9.29, range = 33, 58), which were obtained from an external survey. None of these participants had taken part in the earlier experiments reported in this thesis. The University of Essex ethics committee granted ethical approval for the current experiment.

Apparatus. The experiment was presented on a 24” Apple iMac. A chin rest was used to ensure the distance (0.4 m) between participants and the screen.

Materials. Eighteen trypophobic and eighteen neutral images (512 x 512 pixels) were included (from Experiment 2.2), in addition to the TQ.

Procedure. The first part of the experiment involved a demonstration of the anchor durations in which the participants were presented 512 x 512 grey squares in the middle of the screen for either 400ms (short) or 1600ms (long). The durations were demonstrated in the following order; short – long – short – long. A fixation-

cross appeared in the middle of the screen for one second before each square appeared.

After the anchor demonstration, the participants underwent a training session in which ten grey squares (five for each anchor duration) were presented in a random order. The participants were asked to indicate the correct durations of the squares by pressing either the button labelled “400ms” (the “z”-button on a UK keyboard) or the button labelled “1600ms” (the “m”-button on a UK keyboard). The participants were given accuracy feedback after each response, by the words “Correct” or “Incorrect” appearing for two seconds. In order to proceed, the participants had to respond correctly for 9 (out of 10) trials.

Once the testing phase had been completed, the participants who were eligible to proceed (based on their training score) underwent the testing procedure. The images were presented once for each anchor duration (400ms and 1600ms), in addition to the five intermediate durations (600, 800, 1000, 1200, and 1400ms). In total, seven blocks of 36 trials were included in the testing phase, and each block contained all the images with random durations. A total of 252 trials were presented to the participants. For each trial, a fixation cross was presented for one second, after which the stimulus flashed for the determined duration. After the presentation of the stimulus, the participants were asked to indicate whether the stimulus had duration closer to the 400ms (short) or 1600ms (long) anchor, by pressing the buttons labelled “400ms” or “1600ms”, respectively. After a response was made, the screen would go blank for two seconds, after which a new trial would commence. No feedback was given. After completing a block, the participants were allowed to rest, or otherwise proceed until all seven blocks were completed.

4.4.2. Results

Overall, 20 individuals met the criterion for trypophobia (TQ score > 31) and comprised the trypophobic group, whereas 61 individuals did not and formed the control group. All participants scored 9 (out of 10) or above for the training session, and were eligible to proceed to the experimental task. For each participant, the number of "long" responses was obtained for each image type and duration, which was out of 18 possible trials. Two 7 (image duration) x 2 (image category) repeated-measures ANOVAs were conducted in order to investigate the differences between the image categories in terms of subjective estimation over the various durations, separated by groups.

Trypophobic group. There was no statistically significant interaction between duration and image category, $F(3.66, 69.5) = 0.463$, $p = .746$, $\eta^2 < .001$. A main effect for duration was found, $F(2.76, 52.4) = 245.0$, $p < .001$, $\eta^2 = .91$, but not for image category, $F(1, 19) = 0.145$, $p = .707$, $\eta^2 < .001$. As expected, increase in stimulus duration led to more "long" responses, however no differences were found between the two image categories, suggesting that the time estimation for both trypophobic and neutral images was the same for this group (see Figure 4.2a).

Control group. Similar results were also reported for neutral images. Again, there was no statistically significant interaction between duration and image category, $F(3.96, 237.6) = 0.89$, $p = .504$, $\eta^2 = .001$. A main effect for image duration was found, $F(3.04, 182.6) = 683.1$, $p < .001$, $\eta^2 = .90$, but not for image category, $F(1, 60) = 0.04$, $p = .848$, $\eta^2 < .001$. As expected, increase in stimulus duration led to more "long" responses, however no differences were found between the two image categories, suggesting that the time estimation for both trypophobic and neutral images was the same for the control group as well (see Figure 4.2b).

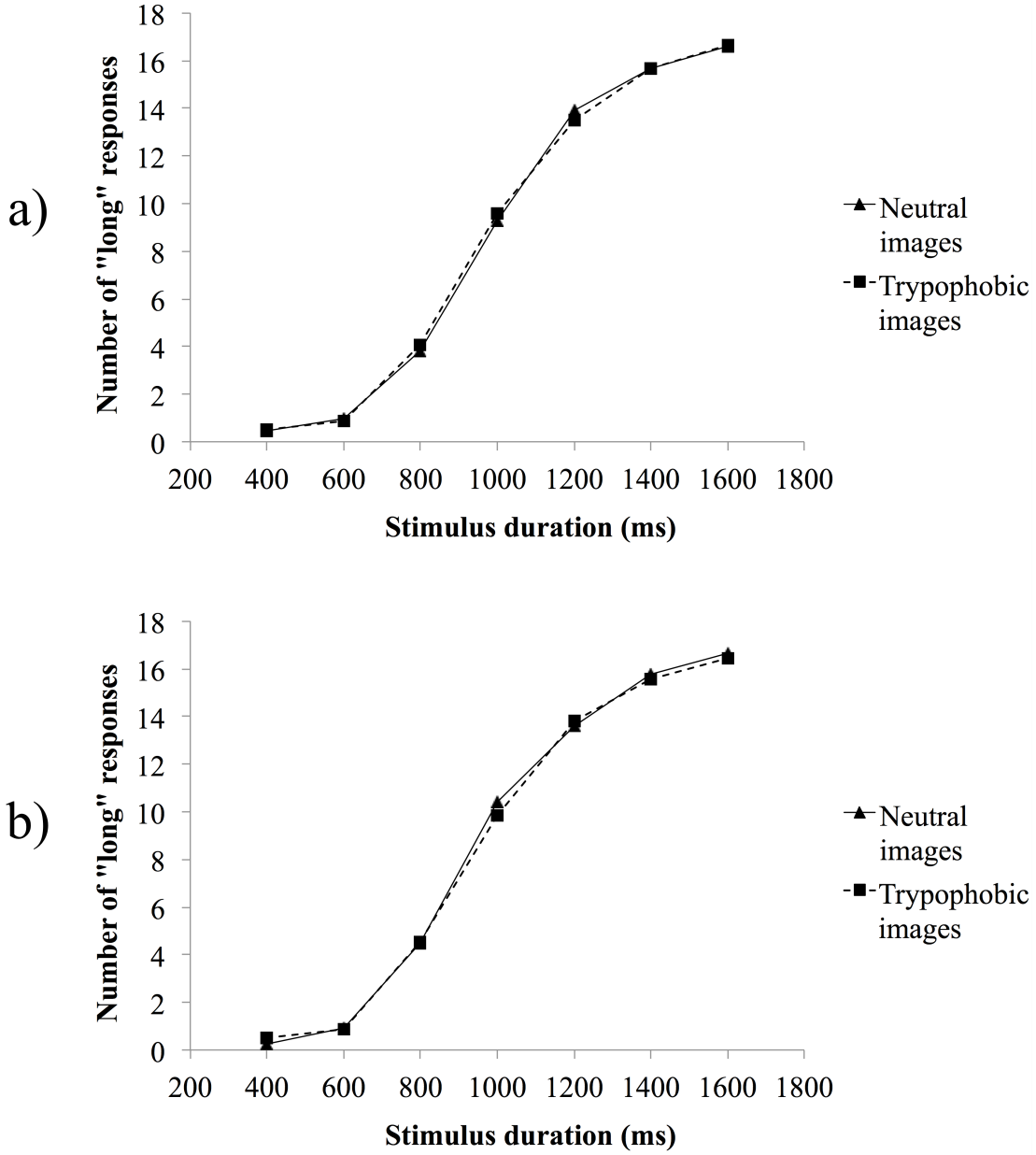


Figure 4.2. Plots for the "long" responses over the various durations for neutral images (solid lines) and trypophobic images (broken lines), separated by (a) trypophobic group and (b) control group.

Bisection point. An index commonly used in bisection studies (e.g., Buetti & Lleras, 2012; Droit-Volet & Gil, 2009; Gil et al., 2009), the bisection point (BP), was calculated with the purpose of making the current data more comparable with other similar investigations. The BP can be described as the point of subjective equality,

where the frequency of "short" and "long" responses was equal (i.e., p[long] = .5) (Gil et al., 2009). The method used was the same as described in Church and Deluty (1977). A regression relating the number of "long" responses and the three central durations (i.e., 800, 1000 and 1200ms) was obtained for each participant (for both trypophobic and neutral images). By using the regression equations, the duration associated with 9 (out of 18) "long" responses (i.e., 50% "long" responses), was calculated and reported as the point of bisection. This is summarised in Table 4.5.

Table 4.5. Means and standard deviations for the Bisection Point for trypophobic and neutral images, separated by group.

	Control group		Trypophobic group	
Stimuli	*M*	*SD*	*M*	*SD*
Neutral images	956.25	389.17	946.02	371.64
Trypophobic images	965.37	441.48	968.12	196.45

A 2 (image category) x 2 (group) mixed ANOVA, with repeated-measures on the first factor, revealed that there was no statistically significant interaction, $F(1, 79) = 0.07$, $p = .792$, $\eta^2 = .008$. Furthermore, no main effect was found for image category, $F(1, 79) = 0.89$, $p = .527$, $\eta^2 = .05$, or group, $F(1, 79) = .001$, $p = .970$, $\eta^2 < .001$. This suggested that there was no statistically significant difference between the two groups in terms of bisection point, across image category.

The Bayesian approach was employed to further examine the lack of effect, where the Bayes factor (BF) and its associated posterior probability operate as indicators of how much more likely given data is under the null-hypothesis than under the alternative-hypothesis. Following the methods described by Masson (2011), the posterior probabilities for the null- and alternate-hypothesis were $pBIC(H_0|D) = 0.90$ and $pBIC(H_1|D) = 0.10$, respectively. Based on the classification provided by

Raftery (1995), the posterior probabilities suggested that the data were in favour of the null-hypothesis over the alternate-hypothesis.

4.4.3. Interim discussion

In the current experiment, participants were presented trypophobic or neutral stimuli for various durations, and asked to judge whether the durations of the stimuli were closer to a short (400ms) or a long (1600ms) anchor. The purpose was to investigate whether individuals with trypophobia showed any bias when estimating the duration of trypophobic stimuli compared to control participants. The current results showed that there was no evidence to suggest that trypophobic stimuli affect individuals in terms of how they estimate time durations. Relative to neutral images, trypophobic images were not given more "long" responses at any signal durations, as confirmed by the non-significant interaction. Furthermore, no main effect was found for image category, which was evident for both groups, suggesting that trypophobic and neutral images did not significantly differ in terms of how they affected time estimation. In addition, the bisection point for each image category showed no significant difference, again for both the trypophobic and control groups.

Importantly, and central to the current interpretation of the results, Droit-Volet and Gil (2009) suggested that fear and disgust do not have the same effect on time estimation, although both fall into the category of "a high-arousal and an unpleasant emotion" (p. 1946). In support, Gil and Droit-Volet (2008) reported that faces expressing anger, fear, happiness and sadness led to an overestimation of time, however the facial expression of disgust did not involve any time distortion (i.e., neither over- or underestimation) (see also Droit-Volet & Gil, 2009). Importantly, the current experiment used a direct replication of the temporal bisection task used by Gil and Droit-Volet (2008), with similar sample size and yet no cognitive bias was found

for trypophobic images. Although these findings were inconsistent with Gil et al. (2009), who reported an underestimation of disliked foods relative to liked foods, their conclusion was not as unambiguous as they proposed, as described in the introduction. In addition, a further inspection of their data revealed that the bisection points for liked foods (M = 904.1, SD = 129.4) and disliked foods (M = 943.7, SD = 183.0) were comparable to the ones reported in the current experiment, at least from a directional point of view. Importantly, the bisection point for disliked food was the closest one to 1000ms (i.e., true middle point, between 400ms and 1600ms), which was also found for trypophobic images in the current experiment. What this may suggest is that disliked foods and trypophobic images, both hypothesised to elicit disgust, actually showed least bias in terms of estimation of duration, as the bisection points for both types of stimuli were closest to 1000ms.

As mentioned, some extreme types of disgust stimuli have been reported to bias time estimation in terms of overestimation, as demonstrated by Gil and Droit-Volet (2012). However, the nature of the images used in that particular study represented mutilated bodies and burned victims, and it is possible to argue that such scenes also involve fear, at least to some extent. On the contrary, trypophobic images can be considered to be less extreme (e.g., honeycomb, barnacles or crumpets), suggesting that there is a difference between the two classes of images. Although further work has to be done so as to compare trypophobic images and the images used by Gil and Droit-Volet (2012), it may be argued that the inconsistency in time estimation bias is due to those differences.

Overall, the earlier experiment in the current chapter suggested that trypophobia arises as a disgust response. Here, trypophobic stimuli did not cause temporal distortion, which is consistent with investigations of emotional faces, where

faces expressing disgust did not show an effect on time estimation. Importantly, trypophobic images did not show the same cognitive bias associated with fear, which provided evidence to dissociate the two.

4.5. Summary of chapter

The research described in the current chapter investigated the response characteristics associated with trypophobia, in order to understand the appropriate emotion(s) that individuals experience when confronted with trypophobic stimuli. First of all, it was demonstrated that individuals with trypophobia were more sensitive to spiders (relative to controls), but not snakes (Experiment 4.1 and 4.2), which provided important clues as to the response characteristics associated with trypophobia. This was because snakes, despite being poisonous, have been predominantly associated with a predatory threat (Isbell, 2006; Soares, 2010). Spiders, however, have been linked to contamination threat (de Jong et al., 1997; Matchett & Davey, 1991; Watts, 1986). Thus, whereas both species have been associated with the emotion of fear, researchers have also implied that disgust is important in relation to spiders as well (de Jong et al., 1997). This apparent link between disgust and spiders (but not snakes) provided evidence to suggest that trypophobia is a disgust response towards specific visual characteristics. This was further supported in Experiment 4.3, where the relationship between trypophobia and three domains of disgust (i.e., pathogen, moral and sexual disgust) was investigated. Consistent with the hypothesis, only pathogen disgust was related to trypophobia.

To further dissociate fear and trypophobia, Experiment 4.4 investigated the bias in cognitive processing related to trypophobia. It has proved possible to demonstrate that some emotions (e.g., fear) consistently tend to bias subjective time estimation of stimulus, whereas other emotions (e.g., disgust) generally do not (e.g.,

Droit-Volet & Meck, 2007; Gil & Droit-Volet, 2008). Here, it was demonstrated that trypophobic images were not associated with distortion of time estimation. This provided important clues regarding the underlying emotion related to trypophobia, which again was pointing in the direction of disgust rather than fear.

In sum, based on its relation to sources of contamination, pathogen disgust, and (lack of) cognitive bias, the work in the current chapter is consistent with the view that trypophobia is a disgust response to possible sources of contamination. In the next chapter, this will be further supported by physiological evidence (i.e., heart rate and its variability). Therefore, the earlier claims that trypophobia is a *fear* of holes may not be accurate, and future reference to this condition should take this into consideration.

CHAPTER 5. PHYSIOLOGICAL RESPONSES TO TRYPOPHOBIC IMAGES

"I had heart beat acceleration, for hours I could not think of anything else than the pictures, and at night I think I had a kind of panic attacks."

F. O., personal communication, 2015

The spectral analysis of images in Experiment 3.2 showed that the images responsible for trypophobia possess low-level visual characteristics that have been associated with discomfort, namely excess energy at mid-range spatial frequencies. Experiment 3.3 further suggested that these particular spectral characteristics, although not likely to be a sufficient explanation, could be partially responsible for trypophobia. Cole and Wilkins (2013) noted that it is the visual perception, rather than physical presence of the offensive object, that is triggering the phobia, which raises the question as to whether the excess energy at mid-range spatial frequencies in trypophobic images is associated with an abnormal cortical response, as demonstrated for other images that have been reported to be uncomfortable. Such findings would further support the idea that trypophobia is a visually induced condition.

Emotional states have been associated with physiological changes/responses (Caponetti, Buscicchio, & Castellano, 2011; Healey, 2014; Pierre-Yves, 2003; Scherer, 1993). Marked changes in variables such as heart rate, piloerection (i.e., goosebumps), or sweating have been demonstrated to accompany emotional events (Purves et al., 2001). Many investigators have examined the physiological mechanisms underlying phobic reactions: Watson, Gaind, and Marks (1971) reported a pilot study in which they desensitized phobic patients through prolonged exposure to phobic stimuli (both imaginative and practice sessions), with the purpose of

measuring clinical and physiological changes. Ten adults who were distressed and "disabled" as a result of their phobias (e.g., cats, spiders, thunder, balloons, etc.), and who requested treatment from their general practitioner, served as participants. Clinical changes were apparent as all patients improved after prolonged exposure, especially after practice sessions. Furthermore, it was also demonstrated that physiological improvement was achieved, because phobic imagery was associated with less of an increase in heart rate and less prominent skin-conductance activity after treatment. This suggested that the physiological responses were modulated by the strength of the phobia experienced by the individual.

Measures of cardiovascular reactivity (e.g., heart rate and its variability) have been employed to study the fundamental links between emotions and physiological functions (Berntson et al., 1997). First of all, heart rate (HR) refers to the number of times the heart beats (usually expressed as beats per minute), and negative emotions such as fear, anger and anxiety have consistently been associated with a higher HR (for review, see Kreibig, 2010). In the case of disgust, however, the results reported in the literature have been heterogeneous. While some have found both an increase (e.g., Vrana, 1994) and decrease (e.g., Gross, 1998), others have also found no changes in HR as a function of disgust (e.g., Ekman, Levenson, & Friesen, 1983). These inconsistencies have led researchers to investigate the nature of the disgusting stimuli more closely, because "disgust" is a relatively broad term. According to a review by Kreibig (2010), there are differences between contamination disgust and mutilation disgust. Whereas the first type has been associated with an increase (or no change), the latter type has been associated with a decrease in HR. This was supported by Rohrmann and Hopp (2008), who demonstrated that a vomiting film (i.e., contamination) induced significantly higher HR relative to an amputation film (i.e.,

mutilation), which demonstrates the importance of the disgust source. In a similar vein, Gerlach et al. (2006) suggested that a decrease of HR was only evident when the stimuli were related to blood and physical injuries. Because trypophobic stimuli do not generally represent blood or physical injuries, it can be hypothesised that a decrease in HR is unlikely. More importantly, an increase in HR would strengthen the claim that trypophobia is a disgust response related to contamination, as argued in Chapter 4.

In the case of heart rate variability (HRV), investigations of negative emotions have found distinct differences between fear and disgust (Harrison, Kreibig, & Critchley, 2013) and this observation is central to the argument developed in this chapter. More specifically, fear has been associated with a *decrease* in HRV (Gilissen, Bakermans-Kranenburg, van Ijzendoorn, & van der Veer, 2008; Kreibig, 2010). In contrast, Rohrmann and Hopp (2008) found that a film showing vomiting (i.e., core/contamination-related/ingestive disgust) significantly *increased* heart rate variability relative to a control condition (Gross, 1998). Importantly, they also found that a film showing amputation (i.e., extended/body-boundary-violation disgust) significantly *decreased* heart rate variability. As argued in Chapter 4, trypophobia seems to be related to a disgust mechanism, based on the relationship between trypophobia and disgust-related animals (Experiment 4.1 and 4.2). Furthermore, the difference between the types of disgust in terms of HRV can also be related to Experiment 4.3, which suggested that trypophobia is related to a specific domain of disgust, namely pathogen disgust (Tybur et al., 2009). Thus, HRV can provide important clues as to the emotion related to trypophobia, in particular which branch of disgust.

Here, the physiological responses induced by trypophobic stimuli, in terms of

cardiovascular reactivity and haemodynamic responses in the occipital areas, were investigated. Even though both disgust and fear fall into the same category of negative emotions, they have been associated with increased and decreased HRV, respectively. If trypophobic images are associated with a higher HR and HRV, despite the fact that the two measurements usually correlate negatively (Ramaekers, Ector, Aubert, Rubens, & Van de Werf, 1998), then the hypothesis that trypophobia is a disgust mechanism against contamination and pathogen will be further supported. Furthermore, the literature also suggested that there is an association between cortical responses and certain low-level visual characteristics. It was therefore hypothesised that trypophobic images, given their possession of excess energy at mid-spatial frequencies, induce a larger haemodynamic response compared to neutral images that resemble natural scenes in terms of Fourier amplitude.

Experiment 5.1. Haemodynamic response and cardiovascular reactivity

5.1.1. Methods

Participants. Thirty-two (10 males, 22 females) psychology students from the University of Essex participated for course credit, aged 18 – 39 (M = 22.3, SD = 4.47). In addition, ten females were invited on the basis of their high TQ score (M = 39.4, SD = 6.70, range = 32, 48) obtained from Experiment 4.1, aged from 18 - 26 years (M = 21.2, SD = 2.74), and participated for reimbursement. The University of Essex ethics committee granted ethical approval for the current experiment.

Materials and Apparatus. Ten (random) trypophobic and ten neutral images from Experiment 2.2 were used in the current study. A PowerPoint slideshow was created with similar parameters to those used by Haigh et al. (2013): the duration for each stimulus was 16s, and stimuli were separated by a grey slide having a random duration of between 27 – 36 seconds. A white/black square (approximately 3 x 3 cm)

was placed on the lower right corner for each stimulus/grey slide, because a photo diode was used as a trigger for the NIRS system. The slideshow was presented on a Dell UltraSharp 2408WFP Widescreen 24" LCD monitor (60HZ refresh rate) at 50% brightness level (white screen 101 $cd.m^{-2}$).

An Oxymon MK II (Artinis Medical Systems BV, Zetten, The Netherlands) was used for NIRS. A NeXus 10 device (Mind Media BV, The Netherlands) and an associated Blood Volume Pulse (BVP) sensor were used for photoplethysmography.

Procedure. An 8-channel split-receiver NIRS system was used to measure the haemodynamic responses, and sampled at a rate of 10Hz. The optode placement for the posterior channels included two receivers and six transmitters. The receivers were placed 30mm from either side of the midline 20mm above of inion. For the left hemisphere, three transmitters were placed 35mm from the receiver, at 0°, 45° and 90°. The symmetrical system was applied for the right hemisphere. The optode placement for the frontal channels included two receivers and two transmitters. The receivers covered positions FP1 and FP2 of the 10-20 system of electrode placement. Both transmitters were placed 35mm above from their respective receiver. This setup was a close replication of that used by Haigh et al. (2013). The BVP sensor was secured on the middle finger of the non-dominant hand.

The participants were seated approximately 0.7m from the screen. They were asked to watch the slideshow whilst keeping movement to a minimum. Their non-dominant hand was rested on their lap, because the BVP sensor can be particularly sensitive to movement artefacts. Although there are many other factors that have been suggested to affect cardiovascular reactivity, such as age, posture, physical fitness or breathing frequency (van Ravenswaaij-Arts, Kollee, Hopman, Stoelinga, & van Geijn, 1993), the current design only investigated the within-subject differences,

hence these factors were not taken into account. After viewing the presentation, the participants were asked to fill out the TQ.

5.1.2. Data Analysis

Haemodynamic response. Zhao et al. (2002) reported path length factors (DPF) of 7.25 (central forehead) and 8.75 (occipital areas; 10 mm above the inion), and those values were used in the following analyses to obtain the optical density. The raw signal for each channel was filtered using the *medfilt1* function in MATLAB©, which applied a median filter. Here, the data was filtered with a running median of 31 samples to remove cardiac artefacts. The *detrend* function, also in MATLAB©, subtracts the best-line fit (least-squares) from the data, and was applied to the filtered data in order to remove any systematic drift in the signal.

The baseline was calculated from the response 10s before stimulus onset for a period of 10s, and the stimulus response was calculated 6s from the stimulus onset for a period of 10s. This was to allow the signal to reach its maximum (Haigh et al., 2013). An overall signal amplitude was obtained by subtracting the baseline response from the signal during the last 10s of the stimulus. However, failure to record is a potential problem related to NIRS-measurements. For example, because the technique is based on the transmission and reception of light, NIRS is dependent on stability of the optodes. Changes in position and/or angles of the transmitters and receivers (relative to the scalp), perhaps due to participant movement, may prevent transmission and/or reception of the light. Other factors (e.g., hair obstruction) can also be problematic for the optodes, which may result in non-responding channels.

In order to differentiate between responding and non-responding channels, a criterion similar to Haigh et al. (2013) was used, where the signal amplitude for the stimulus was compared to the variation in the baseline. If the ratio of the signal

amplitude to the standard deviation of the baseline was less than 0.5 (for oxyhaemoglobin) or above -0.5 (deoxyhaemoglobin), in relative terms, then the channel was considered as unvarying and rejected from the analysis. Importantly, Haigh et al. (2013) used a ratio of 1 as a criterion, which was higher than in the current analysis. However, McIntosh, Shahani, Boulton, and McCulloch (2010) reported the absolute oxygenated haemoglobin response (measured in μM) in the visual cortex to stimulus (checkerboard; $M = 26.8$, $SD = 3.9$) and "control condition" (grey screen; $M = 25.9$, $SD = 3.9$), in which the ratio of the signal amplitude (i.e., 26.8 – 25.9 = 0.9) and the standard deviation of the baseline (i.e., 3.9) was ≈0.25. This suggested that the criterion used by Haigh et al. (2013) was relatively high. The criterion used here (i.e., half a standard deviation) was a compromise between the previous work, where the ratios of 0.25 (McIntosh et al., 2010) and 1 (Haigh et al., 2013) were within one octave of 0.5.

To assess the relationship between oxyhaemoglobin and deoxyhaemoglobin, the average amplitude across all images was obtained for both measurements. As in the study by Haigh et al. (2013), a strong, negative and significant correlation between oxyhaemoglobin and deoxyhaemoglobin responses ($r(34) = -.75$, $p < .001$) was found for those participants who had at least one varying signal for both measurements. Given this result, the subsequent analyses were conducted using only the oxyhaemoglobin responses. Thus, for each participant, the average oxyhaemoglobin amplitude (from the varying channels) was obtained for each image category.

Cardiovascular reactivity. Figure 5.1a illustrates a typical PPG signal, and the two circles represent two consecutive heartbeats. From this signal, it is clear that the detection of heartbeats is challenging, due to the surrounding waveforms. To

overcome this, the second derivative wave of the PPG signal, also known as the acceleration plethysmogram (APG; see Figure 5.1b), can be used (e.g., Elgendi et al., 2011). The peaks of the APG signal (the largest positive value) represent heartbeat onset, as illustrated by the circles. These peaks are more prominent and easier to identify, thus the APG signal was used to detect heartbeats. Russoniello, Pougtachev, Zhirnov, and Mahar (2010) reported that PPG signals were as effective as traditional ECG signals in measuring the parameters of HR and HRV (see also Dennis, 2000).

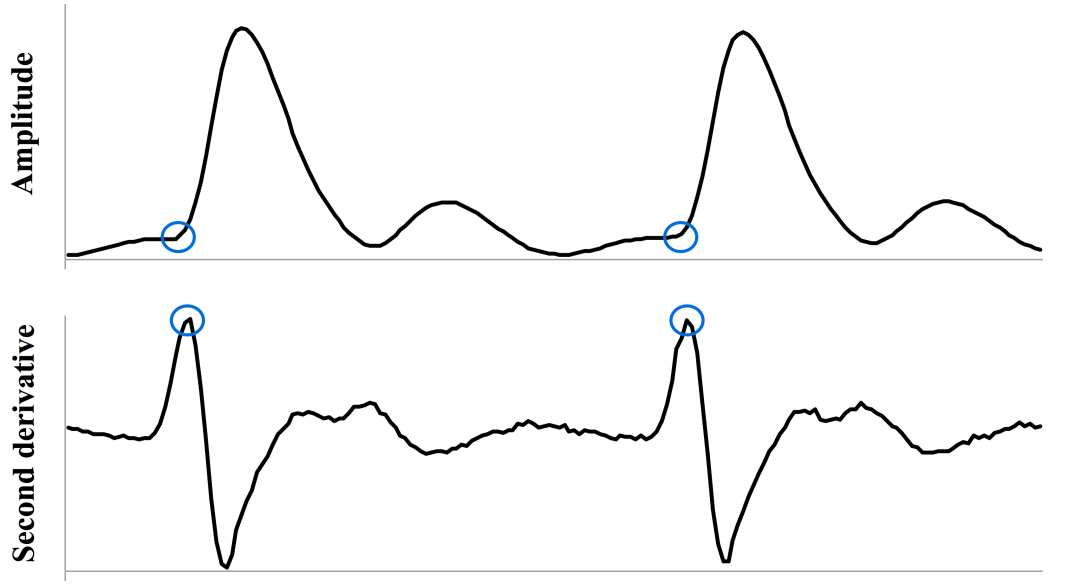


Figure 5.1. Example of (a) PPG signal and (b) moving average filtered APG signal. The circles illustrate two successive heartbeats.

A moving average filter was applied to the APG signal by using the *smooth* function in MATLAB© (see Equation 1). This filter averages a number of consecutive samples from the original signal to replace corresponding samples in the filtered signal. Lao et al. (2012) used a moving average ($N = 21$) to filter their PPG signal (sampled at 250Hz) in order to remove high-frequency noise (low-pass filter).

Given that the current sample rate (128Hz) was approximately half of that reported by Lao et al. (2012), a moving average using $N = 11$ was implemented.

$$y_i = \frac{1}{N} \sum_{j=-(N-1)/2)}^{(N-1)/2} x_{i+j} \qquad \text{Equation 1}$$

Vasoconstriction is described as a constriction of the blood vessels (Calvo, D'Mello, Gratch, & Kappas, 2014), which can increase as a response to certain emotions/sensations (e.g., pain, hunger or fear) or decrease as a response to quiet relaxation (Healey, 2014). The blood flow therefore increases or decreases as a function of the changes in vasoconstriction, which in turn affects the reflected PPG reading of a blood volume pulse signal. The relative amplitudes of the PPG peaks are therefore likely to change over time. Due to the variation of amplitude, a single threshold for peak-detection was considered as insufficiently sensitive to detect all the peaks over a full signal (see Figure 5.2 for a comparison between two time series within a subject), because this would either result in a too conservative threshold (thus missing true peaks) or too liberal (thus detecting minor peaks). A threshold was therefore determined by manual visualising of the data for each image, which accounted for the changes in vasoconstriction. In sum, a peak was defined as a second derivative value larger than both the preceding and succeeding data point, and above the threshold set for the specific time interval.

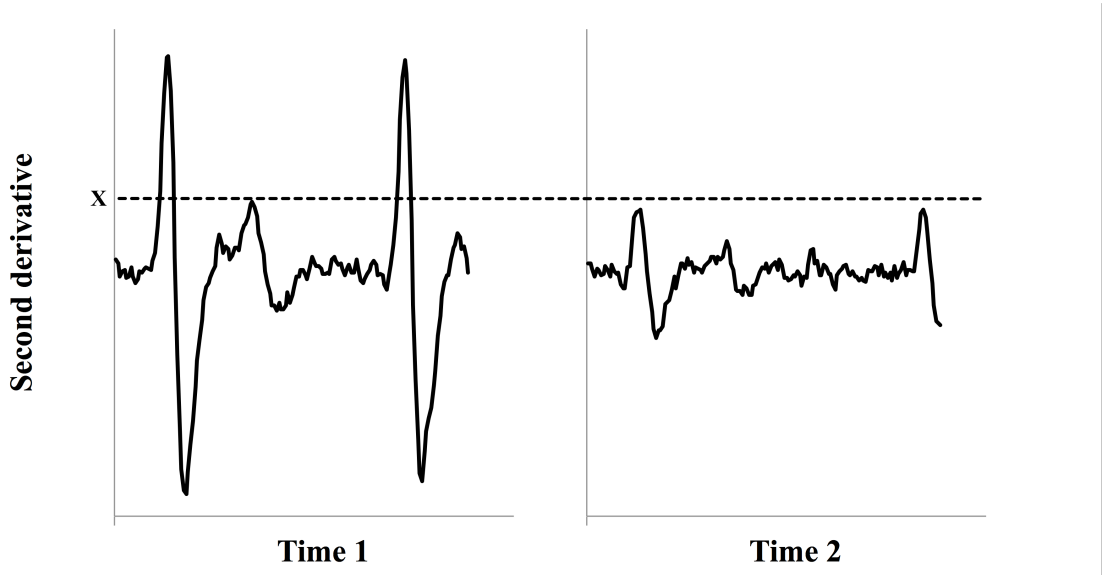


Figure 5.2. Example of two time series within a subject. The dotted line represents threshold = x, which was the minimum for Time 1 without detecting minor peaks. This threshold was too conservative for Time 2, because an increase in vasoconstriction caused a narrowing of the envelope of the signal.

HR was obtained by counting the number of peaks within the time windows of interest (during stimulus presentation). The number of peaks (i.e., beats) within each timeframe was multiplied with 3.75, because HR is usually expressed as beats per minute (BPM), and the stimulus duration in the current experiment was 16 seconds. By multiplying the number of peaks with 3.75 (i.e., 60 sec / 16 sec), an estimated BPM was obtained, so as to provide a measurement that is generally more comparable.

As for HRV, the intervals between consecutive peaks within the time windows of interest were obtained and converted into time units (milliseconds). Intervals less than 0.4 seconds or greater than 2.0 seconds were considered as physiologically impossible (Mietus, Peng, Ivanov, & Goldberger, 2000) and removed from the dataset. The Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996) summarised some

of the common methods that are used to measure heart rate variability, usually categorized as time-domain methods and frequency domains methods.

The current experiment used time-domain methods, which involve descriptive statistics such as range, standard deviation or variance to characterise the distribution of periods of heart beats to quantify HRV. The root mean square of the successive differences (RMSSD, see Equation 2) (Cacioppo, Tassinary, & Berntson, 2007; Nussinovitch et al., 2011; Thong, Li, McNames, Aboy, & Goldstein, 2003) uses the successive differences between normal-to-normal (NN) intervals, and has been recommended as an estimate of the short-term components of heart rate variability (Task Force, 1996). It is also one of the most frequent reported measures in the literature (Cacioppo et al., 2007), and successfully derived from APG signals (Elgendi et al., 2011). Importantly, RMSSD has been reported as a reliable parameter for assessing HRV from so-called "ultra-short" recordings of 1 minute or even 10 seconds (Nussinovitch et al., 2011; Thong et al., 2003), which was suitable for the current experimental design. For each participant, the HRV was calculated for each image, twenty in total. The average RMSSD was then obtained for each image category (trypophobic and neutral).

$$RMSSD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}[I_i - I_{i+1}]^2} \qquad \text{Equation 2}$$

5.1.3. Results

Haemodynamic response. The first analysis was conducted to investigate whether viewing trypophobic images resulted in a systemic cortical response. A paired-samples t-test was conducted to compare the effect of optode positions on the

magnitude of the oxyhaemoglobin responses for the ten participants who had both frontal and posterior channels that met the criteria for varying channels. The results suggested that the magnitude of the oxyhaemoglobin responses was significantly higher for posterior channels ($M = 0.21$, $SD = 0.09$) compared to anterior channels ($M = 0.05$, $SD = 0.07$), $t(9) = 5.93$, $p < .001$, $d = 1.9$, thereby demonstrating that the cortical response to visual stimuli is localised in the occipital areas.

Based on the previous results, the following analysis was conducted using only the posterior channels, in which 38 participants obtained at least one responsive channel and were accepted for further analysis. The average number of responding channels was 4.6 (out of 6), which was comparable to the proportions reported by Blasi et al. (2007) and Haigh et al. (2013), i.e., 24/30 and 3.8/6 (respectively). The mean (SD) amplitudes are summarised in Table 5.1.

Table 5.1. Mean (SD) amplitude for trypophobic and neutral images, separated by group (control or trypophobic).

	Control group	Trypophobic group
Trypophobic images	0.17 (0.15)	0.30 (0.28)
Neutral images	0.18 (0.12)	0.16 (0.14)

For each participant, the haemodynamic response for neutral images was subtracted from the haemodynamic response for trypophobic images, so as to obtain the difference between the two types of images. A positive value indicated a higher response to trypophobic images, and the mean differences are illustrated in Figure 5.3.

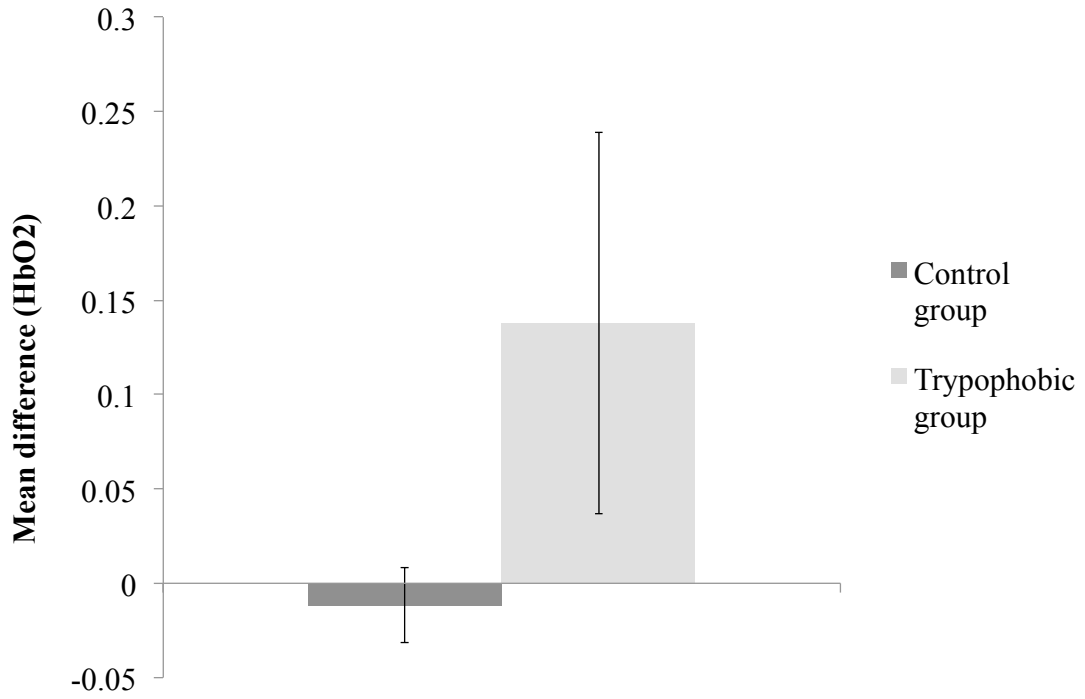


Figure 5.3. Mean difference between trypophobic and neutral images in terms of haemodynamic response, separated by group. Error bars represent 1 standard error.

An independent samples t-test revealed that the mean difference in haemodynamic response between trypophobic and neutral images was significantly larger for the trypophobic group (M = 0.14, SD = 0.34) than the control group (M = -0.01, SD = 0.10), $t(36) = 2.03$, $p < .05$, $d = 0.7$. This suggested that the trypophobic images induced a higher cortical response among those who met the criterion for trypophobia, relative to controls.

Cardiovascular reactivity. One participant refused to wear the sensor and thus PPG data for this participant was not obtained. Forty-one participants were therefore included in the following analyses. Consistent with the literature, the relationship between HR and HRV was negative (across groups and image type), rs > .72, ps < .05. The mean HR and HRV for each image category, separated by group, are summarised in Table 5.2.

Table 5.2. Mean (SD) heart rate (BPM) and heart rate variability (RMSSD) for trypophobic and neutral images, separated by group (control or trypophobic).

	Image category	Control group	Trypophobic group
BPM	Trypophobic images	73.7 (11.8)	78.1 (14.2)
	Neutral images	73.7 (12.2)	75.9 (13.4)
RMSSD	Trypophobic images	51.9 (23.9)	63.7 (43.3)
	Neutral images	53.0 (25.0)	56.7 (32.2)

Again, for each participant, the HR/HRV for neutral images was subtracted from the HR/HRV for trypophobic images, so as to obtain the difference between the two types of images. A positive value indicated a higher HR/HRV to trypophobic images (vice versa), and the mean differences are illustrated in Figure 5.4.

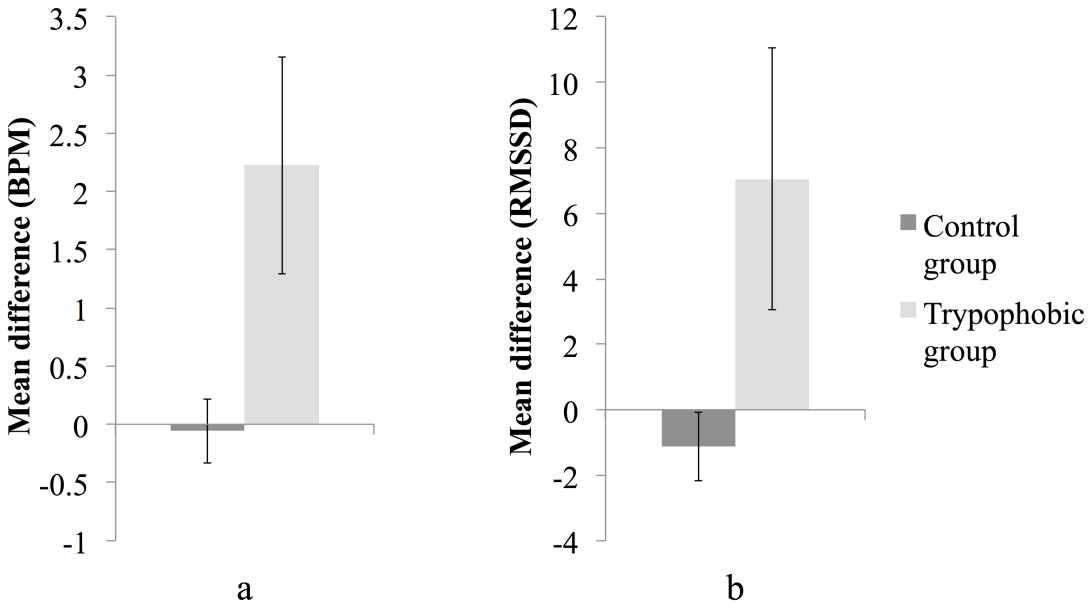


Figure 5.4. Mean difference between trypophobic and neutral images for the two groups, separated by (a) heart rate and (b) heart rate variability. Error bars represent 1 standard error.

An independent samples t-test revealed that the mean difference in HR between trypophobic and neutral images was significantly larger for the trypophobic group (M = 2.23, SD = 3.48) than the control group (M = -0.06, SD = 1.44), $t(39)$ =

2.97, $p < .01$, $d = 0.9$. For HRV, an independent-samples t-test revealed that the mean difference between trypophobic and neutral images was significantly larger for the trypophobic group ($M = 7.05$, $SD = 14.9$) than the control group ($M = -1.12$, $SD = 5.42$), $t(39) = 2.55$, $p < .05$, $d = 0.8$. Overall, this suggested that trypophobic stimuli were associated with both a higher HR and HRV among those who met the criterion for trypophobia, relative to controls.

5.1.4. Discussion

The current experiment investigated the physiological changes associated with trypophobia. The rationale was to provide further evidence to strengthen the claims in Chapter 3 and 4. First of all, the haemodynamic response associated with trypophobia was measured, and the results suggested that trypophobic images were associated with a higher response in the occipital areas, relative to neutral images. Importantly, the abnormally large response was evident only for individuals who met the criterion for trypophobia, which relates to the existing literature regarding the relationship between sensitivity towards unnatural visual characteristics and cortical activity. For example, Huang et al. (2003) demonstrated that gratings with certain visual properties that were particularly uncomfortable/irritable for individuals with migraine were associated with hyperneurological activity. Furthermore, Haigh et al. (2013) reported that a large chromaticity separation of grating bars was associated with discomfort and larger haemodynamic response. Both of these studies used simple striped patterns with Fourier amplitude spectra that departed from the 1/f structure found in natural images (Field, 1987). This suggested that the images, due to their unnatural visual characteristics, place a strong demand on the occipital areas, and that the discomfort experienced may be a homeostatic response to reduce this excessive metabolism (Haigh et al., 2013).

Overall, there is a relationship between discomfort and the magnitude of the haemodynamic response, and the current results provided further support for this. Here, it was demonstrated that the neural computation of trypophobic images demanded an abnormally large haemodynamic response for those participants who were sensitive to these images. Thus, based on previous research, it was reasonable to suggest that, due to the physical properties of the images, trypophobic stimuli also induce discomfort partly as a potential homeostatic response that encourages withdrawal. In addition, this further supported the role of the visual characteristics in trypophobic images, as argued in Chapter 3.

The current experiment also investigated the HR and HRV associated with trypophobic experiences. Here, trypophobic images were associated with a higher HR and HRV among individuals with trypophobia. This can be related to the differences between fear and disgust in terms of this type of cardiovascular reactivity, in which fear is associated with a decrease in HRV (Gilissen et al., 2008; Kreibig, 2010), and disgust is associated with an increase in HRV (Gross, 1998; Rohrmann & Hopp, 2008). More specifically, the higher HR elicited by trypophobic images in the trypophobic group provided subsequent evidence to suggest that this condition is related to a specific type of disgust. Based on previous demonstrations that two domains of disgust, namely contamination and mutilation, elicit increased and decreased HR, respectively, it was clear that trypophobic images were more related to contamination disgust, and not mutilation. In addition, this was consistent with the findings in Experiment 4.4, where trypophobic images did not bias subjective time estimation.

CHAPTER 6. TREATMENT OF TRYPOPHOBIA

"I was recently introduced to a method of drawing / doodling which has proved to be a very useful for easing anxiety and mindfulness among other things and … I had a compulsive need to draw/doodle holes … as if I was trying to desensitize while fighting the compulsion to keep looking at the picture. I'm not sure it makes sense … but I have created a wonderful array of "art" by drawing holes, bubbles, eyeballs in the meantime."

C. O., personal communication, 2015

In this chapter, the effect of graded exposure therapy (Foa & Kozak, 1986) in the treatment of trypophobia was examined. Because individuals with phobias react inappropriately and/or have distorted beliefs and expectations, the objective of exposure therapy is to provide the "correct" information regarding the phobia, which will enable them to think and behave more realistically in relation to the phobic stimuli (Zane, 1982). Usually, these types of therapies involve identifying various phobic and avoided situations that are ranked in terms of difficulty (i.e., a fear hierarchy), so that patients and/or therapists can control the degree to which the phobia occurs. By encountering their phobias in a step-by-step manner, it is hoped the patients will habituate to the phobic situations. It has been suggested that therapies based on exposure are the most successful in treating specific phobias (Chambless & Ollendick, 2001).

With development in technology, computer-mediated therapies have been offered (Marks, Shaw, & Parkin, 1998), and there has also been an increase in the use of the Internet in search for self-help treatment (Ritterband et al., 2003). The following experiment aimed to provide a 20-session online treatment procedure for individuals with trypophobia to go through in a systematic order, involving exposure to trypophobic stimuli. Importantly, it is generally not a specific object that triggers

trypophobia. Rather, the composition of several objects in close proximity is responsible, and there are many visual scenes that have been associated with trypophobia. Given the diverse nature of trypophobic stimuli, it was not possible to identify a universal object that is common for every individual who reported this condition. Thus, images that appeared on the trypophobia websites were used as stimuli. In addition, the abstract images of clusters of objects from Experiment 3.1 were also included. The purpose of these was to include images that were less aversive compared trypophobic images, so that participants could habituate to images with basic trypophobic characteristics before proceeding to the (presumably) more aversive trypophobic images. Experiment 3.1 demonstrated that discomfort increased with the size of clusters, suggesting that the treatment sessions should start off with small clusters, followed by large clusters and trypophobic images, so as to establish the fear hierarchy between image classes. Experiment 2.2 provided data regarding the discomfort ratings for trypophobic images, which were used in order to establish a fear hierarchy across the trypophobic images and to determine which trypophobic image belonged to which session.

Because Cole and Wilkins (2013) reported that trypophobic images possess excess contrast energy at mid-range spatial frequencies, visual characteristics that are associated with uncomfortable stimuli (Fernandez & Wilkins, 2008), images in the current experiment were also manipulated in terms of contrast. Wilkins et al. (1984) reported that gratings with high luminance contrast were associated with visual illusions/distortions and discomfort. On this basis, it was hypothesised that the visual characteristics associated with trypophobia would become more and more prominent with increasing contrast level (and vice versa). By starting from the low contrast level images, participants gradually worked up to the high contrast levels and ultimately

full contrast level (i.e., original image) for each stimulus. This resembles the anxiety stimulus hierarchy commonly used in exposure, where phobic stimuli are ranked from least fearful (e.g., small, stationary spider) to most fearful (e.g., large, moving spider). Thus, fear hierarchies were established both across and within images.

Experiment 6.1. Treatment of trypophobia using exposure therapy

6.1.1. Methods

Participant. A total of 36 individuals who used the trypophobia Facebook page (Trypophobia: Fear of Clusters of Holes, n.d.) responded to a request for participants who were willing to try a treatment procedure. They were sent the instructions for the treatment procedure. From that sample, 18 individuals (3 males, 15 females) aged from 26 to 68 (M = 36.4, SD = 13.0) started the treatment procedure. Out of the 18 individuals who started the treatment procedure, seven females finished, aged from 25 to 46 (M = 35.6, SD = 8.30). The University of Essex ethics committee granted ethical approval for the current experiment.

To remain anonymous, each participant was provided a random participant number. Importantly, the numbers were sent by e-mail, and the names of the participants were therefore not directly associated with the data recorded by Qualtrics. Thus, the number was only associated with an age and gender. In addition, access to the data was restricted by a username and password.

Materials. Twenty trypophobic images were obtained from Experiment 2.2, in addition to four images of small clusters and four images of large clusters of holes from Experiment 3.1. All the trypophobic images were rendered in grey level using the *rgb2gray* function in MATLAB©. The images of clusters of objects were already in grey levels. The images were then manipulated in terms of contrast, using the open-source software GIMP (version 2.8.10, www.gimp.com). The contrast function

in the "Brightness-Contrast tool" adjusts the contrast levels of the active layer, and ranges from the arbitrary values of -127 (lowest contrast), 0 (original contrast) and +127 (highest contrast). In order to establish the relationship between contrast level and the contrast tool value, the luminance values of white and black Powerpoint slides presented on a 13" Apple MacBook Pro (1280 x 800 pixels) were measured across contrast values, from -125 to 0 (in increments of 5). A Minolta LS-100 photometer was used to measure the luminance. Michelson contrast values [(maximum – minimum contrast)/(maximum + minimum luminance)] were obtained and plotted against the contrast tool value (see Figure 6.1).

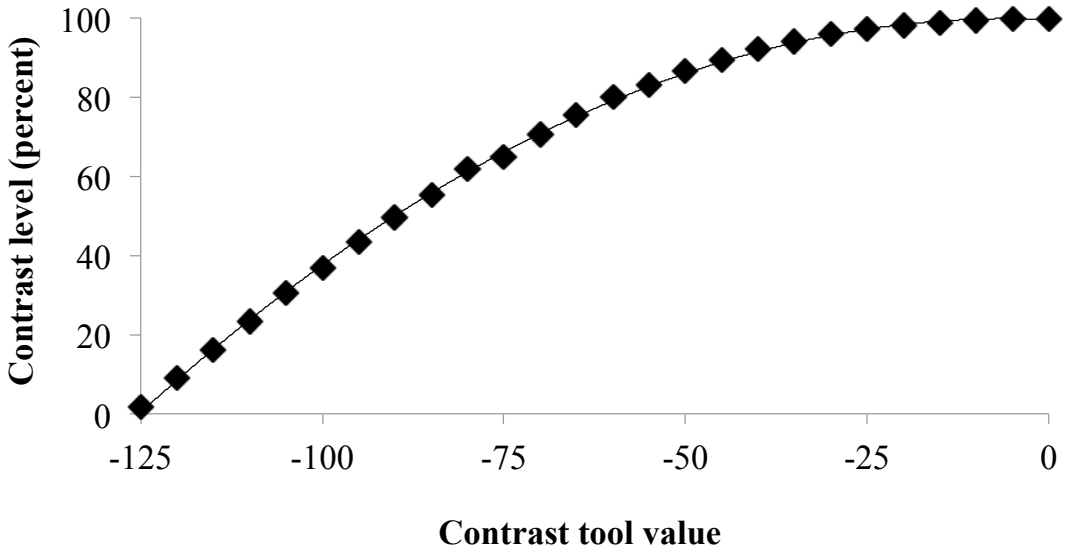
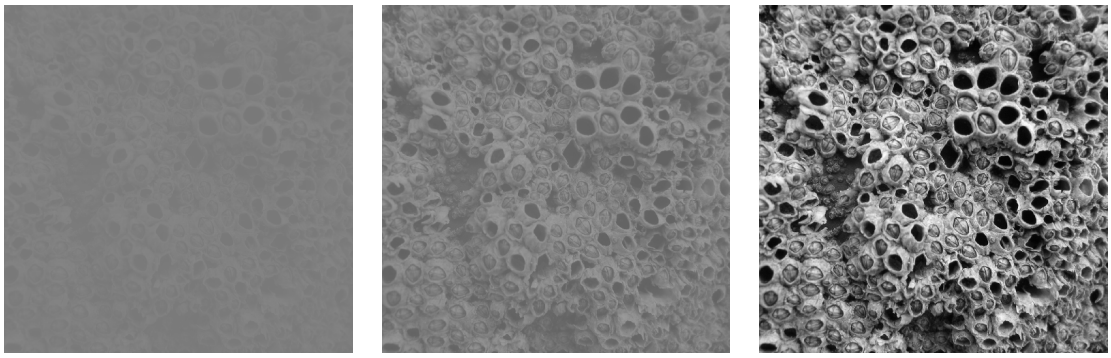


Figure 6.1. The relationship between contrast tool value and contrast level (percent).

A curve estimation (non-linear regression) analysis revealed that a second-order polynomial curve provided a good fit between the contrast tool value and contrast level (percentage), $F(2, 25) = 35621.7$, $p < .001$, and explained more than 99% of the variance. The equation for this quadratic function was expressed as

$$y = -0.007x^2 - 0.074x + 99.62 \qquad \text{Equation 3}$$

where y is the contrast level (percentage) and x is the contrast tool value. For each image, seven versions were created, with contrast levels of 12.5%, 18%, 25%, 37.5%, 50%, 75% and 100% (see Figure 6.2 for illustration).



a b c

Figure 6.2. Illustration of contrast levels at (a) 12.5%, (b) 50% and (c) 100% for the image of barnacles.

To support the use of low-level contrasts (i.e., 12.5% and 18%), twenty trypophobic images were randomly paired with twenty neutral images (from Experiment 2.2). Nine independent (two males, seven females) observers from another group on the Facebook website (Trypophobia Triggers, n.d.), aged 35 – 78 (M = 26.6, SD = 8.0), and who met the criterion for trypophobia (TQ score: *M* = 51.4, *SD* = 15.1, range = 35, 78), were shown the pairs of images, one trypophobic and one control, and asked to identify which image in each pair was trypophobic. When the images were reduced to 12.5% contrast, six (out of nine) participants scored 100%. Similarly, when the images were reduced to 18% contrast, seven (out of nine) participants scored 100%. Overall, this demonstrated that although the images were at

the two lowest contrast levels, the trypophobic features were still present in the images.

Design. Twenty sessions were created in total, and each session consisted of four sets of images; (1) a random set of small clusters, (2) a random set of large clusters and (3 and 4) two sets of trypophobic images. The trypophobic images were ordered in a fixed sequence, i.e., the first session included the two least unpleasant images, whereas the next session included the two next images in the unpleasantness sequence. In order to determine the sequence in which trypophobic images were presented, an overall rating of each trypophobic image was obtained using the results from Experiment 2.2. Thus, over the ten first sessions, the participants would have gone through all twenty trypophobic images. After the first ten treatment sessions, the original sequence was repeated throughout the last ten treatment sessions.

Procedure. Participants who were unsure about how contrast manipulation works were provided a demonstration of how the contrasts changed across pictures. More specifically, a picture of a flower was manipulated in terms of contrast (in similar fashion the trypophobic images), and this was used as an example. This created a platform in which participants could familiarise themselves with the changes involved in contrast manipulations, so that they knew what to expect when observing trypophobic images.

Participants were requested to use computers and/or laptops, and not smartphones and other similar devices, when doing the treatment sessions. For each session, each image was presented separately, and the participants were asked to rate them in terms of discomfort, on a scale from 1 (Not at all uncomfortable) to 10 (Extremely uncomfortable). The sets of images were presented from low to high contrast. Importantly, participants were asked to abort a set of images if they reached

a level of contrast in which made them feel too uncomfortable. They were then allowed to abort the levels of contrast (if applicable), and transferred to the next set of images (if applicable) in the session, again starting over at a low contrast level. The participants were also asked to fill out the TQ before the first session, and after the last session. Qualtrics (Qualtrics Labs Inc, 2013), was used to present the treatment sessions.

6.1.2. Results

The dropout across treatment sessions is summarised in Figure 6.3. In total, seven participants finished all the treatment sessions, and the subsequent analyses were based on this sample. Because the participants had the choice to abort the exposure at any point, some of the images in the contrast series were not rated. When the participants decided to abort an image before they reached the full contrast level (i.e., 100%), the missing data (1% of the total) for the subsequent images in the series were replaced with scores of ten (i.e., maximum score). Thirty-nine replacements were made, all for trypophobic images. Importantly, the findings reported below were replicated when the missing data were not replaced and the average scores were based upon the provided responses only.

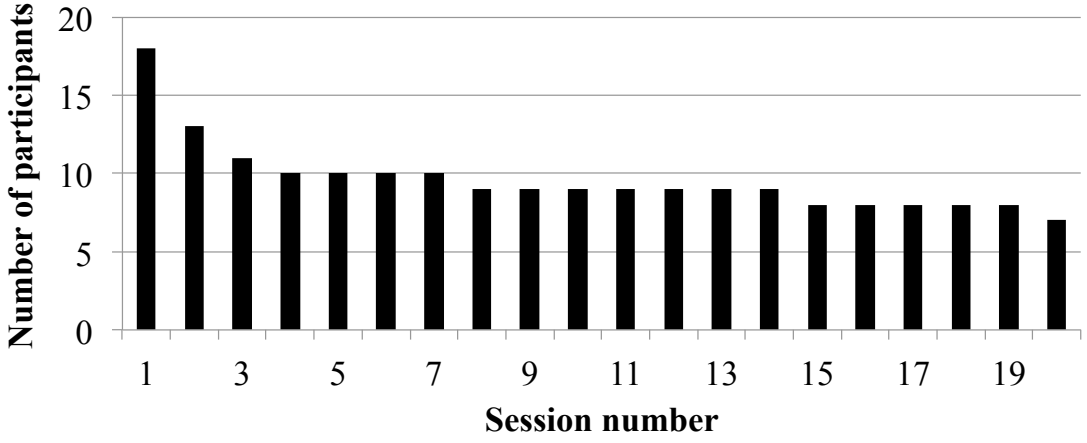


Figure 6.3. Total number of participants who participated in the different sessions.

Trypophobia symptoms. Each participant completed the questionnaire prior the first treatment session and after the last session. A paired-samples t-test indicated that the TQ score decreased significantly between pre-therapy ($M = 50.4$, $SD = 15.4$) and post-therapy ($M = 41.3$, $SD = 11.0$), $t(6) = 2.07$, $p < .05$ (one-tailed), $d = 0.7$, suggesting that the exposure therapy had a positive outcome on number and/or symptoms reported, at least for those seven who completed the therapy.

Sensitivity to images. In order to investigate whether there were differences between the two types of abstract images (i.e., small and large clusters) and the trypophobic images, composite scores (across contrast level) for the three categories were obtained for each participant. To account for any potential effect on the discomfort rating due to exposure therapy, only the data from the ten first ten sessions were included in the current analysis. A repeated-measures ANOVA determined that the mean discomfort ratings were significantly different between image categories (see Figure 6.4), $F(2, 12) = 14.2$, $p < .01$, $\eta^2 = .70$. Paired-samples t-tests using Bonferroni correction (alpha = .05/3) revealed that the discomfort rating for small clusters ($M = 2.45$, $SD = 1.70$) was not significantly different from the discomfort rating of large clusters ($M = 2.40$, $SD = 1.60$), $t(6) = 0.25$, $p = .815$, $d = 0.02$. The discomfort ratings for trypophobic images ($M = 5.10$, $SD = 2.11$), was significantly higher than the discomfort rating of small clusters, $t(6) = 3.69$, $p < .01$, $d = 1.4$, and large clusters, $t(6) = 3.98$, $p < .01$, $d = 1.4$. This suggested that trypophobic images, as predicted, were generally more uncomfortable for individuals with trypophobia, which justified the order of which image classes were presented.

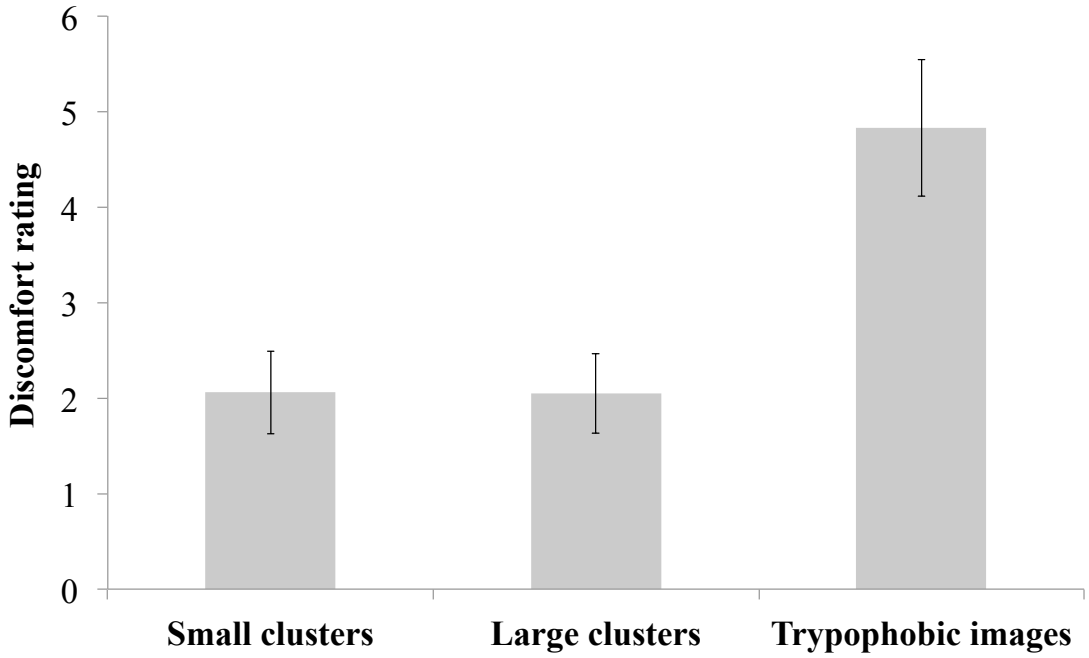


Figure 6.4. Discomfort ratings for the three image types. Error bars represent 1 standard error.

Sensitivity to contrasts. Based on the previous findings, only the ratings for trypophobic images were used in the next analyses. Each series of images included the same image at seven levels of contrast, in order of increasing contrast. The first analysis investigated the relationship between discomfort and contrast level. The discomfort ratings for the trypophobic images were obtained for each contrast level (i.e., 12.5%, 18%, 25%, 37.5%, 50%, 75% and 100%), separated by the first cycle (i.e., ten first treatment sessions) and the last cycle (i.e., ten last treatment sessions). The base-10 logarithms of the contrasts levels were obtained, and plotted against the discomfort ratings (Figure 6.5). Regression analyses revealed that the log contrast level explained approximately 99% of the variance in discomfort ratings for both cycles, and that the linear trends were significant for the first cycle, $F(1, 6) = 469.2$, $p < .001$, and the second cycle, $F(1, 6) = 804.0$, $p < .001$.

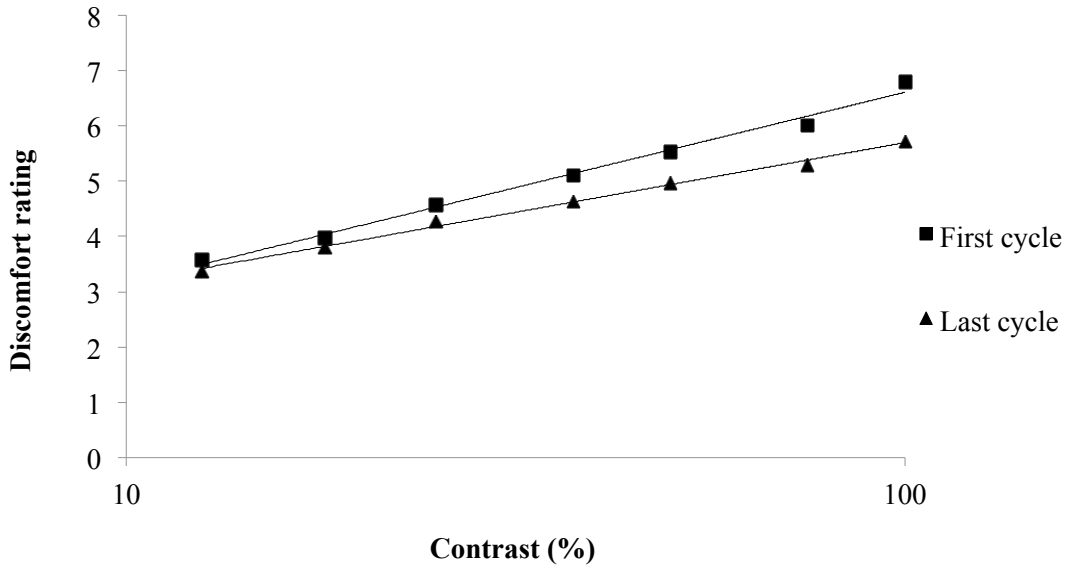


Figure 6.5. Relationship between discomfort rating and percent contrast (logarithmic scale), separated by cycle (i.e., first and last).

In order to investigate the effect of exposure therapy, the slopes of the linear trend between log contrast level and discomfort were obtained for each participant, separated for each cycle (first and last). A paired-samples t-test revealed that the slope between log contrast level and discomfort was significantly higher in the first cycle ($M = 3.45$, $SD = 2.27$) than the last cycle ($M = 2.52$, $SD = 2.81$), $t(6) = 2.88$, $p < .05$, $d = 0.4$. This demonstrated that after going through the ten initial sessions of exposure therapy, participants were less affected by the increase of contrast level in the last cycle, which suggested that exposure therapy had a positive effect.

To further investigate whether exposure therapy had an effect on overall discomfort, the ratings associated with the mid-point of contrast level (i.e., 1.548) were calculated from the linear regression equation for both the first and last cycle. A paired-samples t-test revealed that the discomfort ratings associated with the mid-contrast level were not significantly different between the first ($M = 5.05$, $SD = 2.10$) and the last cycle ($M = 4.56$, $SD = 1.86$), $t(6) = 1.06$, $p = .331$, $d = 0.2$. The reduction in overall discomfort ratings was not significant.

6.1.3. Discussion

The current experiment investigated exposure therapy as a potential treatment method for trypophobia. By manipulating trypophobic images in terms of contrast level, the aim was to expose participants to series of phobic stimuli that increased in terms of aversion, from low to high contrast (i.e., a fear hierarchy). The results suggested that exposing the participants to trypophobic images in a systematic manner over time had a positive effect on their scores on the TQ, which significantly reduced after 20 sessions of exposure treatments. It was also found that discomfort increased as a function of contrast level, which suggested that fear hierarchies can be established by manipulating the images in terms of contrast. Importantly, the slopes of the trend lines were significantly larger in the first cycle compared to the last cycle of images, suggesting that participants were significantly less sensitive to the increase in contrast in the second cycle, again suggesting that exposure had a positive effect. However, it is also clear that the discomfort rating was not significantly different between the two cycles at the mid-point, suggesting that the exposure therapy did not reduce the discomfort. This may be due to the participants becoming familiar with the images and their respective responses, which may have influence their responses in the second cycle. In relation to this, it is also important to acknowledge that there was a directional trend with respect to reduced discomfort rating. Overall, the preliminary data of this experiment showed promising results, and some of the issues related to low sample size and other shortcomings are discussed below.

Because the general attitude towards treatment for phobias is far from optimal, and most individuals who suffer from phobias do not seek treatment (Agras, Sylvester, & Oliveau, 1969; Boyd et al., 1990; Magee et al., 1996), the treatment sessions in the current experiment were designed to be convenient (i.e., online) and

(presumably) not time consuming with 28 images (maximum) per treatment session. The median time (approximated to the nearest minute) taken for each of the sessions was 4 minutes. Despite this, a high drop-out rate in the current experiment was evident, which generally tends to be the case for exposure therapy (Marks, 1978). All participants who dropped out were subsequently contacted via e-mail and asked if they could provide any particular reason as to why they decided not to go through with the procedure, but only one participant provided an explanation. This participant described early on that (s)he felt "itchy and the side effects", that (s)he "cannot continue the trial as it is fairly disgusting", and stated that "I find [that by] doing the test I go further than I need to and am going to prefer guided counselling." (J. S., personal communication, 2014). This suggested that, for some participants, therapy starting off by exposing them to images was too much. Because phobias also can be induced by imagining the stimuli in thought (Bruce & Sanderson, 1998), which was demonstrated in Experiment 4.1, it can be suggested that those techniques are more suitable for those participants who are particularly susceptible to trypophobic stimuli, perhaps as a first step before exposure to real images.

One possible way to make it even less time consuming could be to only include the trypophobic images, and remove the images of clusters of abstract objects. The purpose of including the abstract images was to start each session with images that were relatively less averse before participants were exposed to the trypophobic images. Furthermore, one of the participants expressed that (s)he "got bored of them [the abstract images] after about the 5th session. (…) I found myself thinking: (…) Challenge me!" (C. M., personal communication, 2014), which suggests that removing these types of images could make the sessions less time consuming. In addition, another possibility would be to replace the abstract images

with trypophobic images, thereby including four series of trypophobic images per session. This would mean that participants would have gone through all 20 trypophobic images in five sessions, and not ten as it currently stands. This would decrease the overall number of treatment sessions, which also might reduce the attrition.

There is growing evidence that computer-based programs can be efficient in treating mental health problems (Gilroy et al., 2000), and that such programs increase the convenience, confidentiality, cost-effectiveness and reduce the sigma (Ghosh & Greist, 1988; Kenwright, Liness, & Marks, 2001; Marks & Cavanagh, 2009). However, there are also some disadvantages associated with this type of mental health aid. Because professionally trained therapists offer an external source of intervention in the case of negative incidents, which is something computer-based therapies cannot match, there is a disadvantage related to safety (Kaltenthaler & Cavanagh, 2010). Here, the participants in the current experiment were instructed to close their web-browser should they reach a level of discomfort above their threshold: intervention depended solely on their subjective feeling. It is clear that assessment from a therapist during exposure therapy could offer a valuable safety net, especially if the cases are severe.

Because the current treatment method was designed as a convenient method in which individuals could work on their aversion to trypophobic stimuli, the on-line platform was created in a basic manner in which only exposure to stimuli was used. Given that components such as relaxation techniques have been found to be successful (Wolpe, 1958), it is important for future research to investigate whether these aspects could be incorporated in a trypophobia treatment procedure, although this would not be possible with online therapy. Evidently, several changes could be

implemented in order to create treatment methods more suited to each individual, such as exposure type (e.g., imaginal versus in vivo exposure) or number of images/sessions. However, this would involve a deeper understanding of the participants in terms of the severity of their reactions, in addition to the time they wish to invest in the procedure, which was outside the scope of the current experiment. In conclusion, the results of this preliminary experiment were encouraging overall, and suggested that graded exposure in its basic form should be considered as a viable option as a first step towards treating trypophobia.

CHAPTER 7. GENERAL DISCUSSION

"A disease known is half cured"

Thomas Fuller, *Gnomologia,* 1732

This thesis addressed some of the questions that were raised when the condition of trypophobia was first introduced to the scientific literature. Trypophobia is often referred to as the "fear of holes" (e.g., Cole & Wilkins, 2013; Skaggs, 2014), and has on this basis been suggested to be a specific response (i.e., fear) towards stimuli containing specific visual characteristics (i.e., holes). The main motivation behind this thesis was to provide a theoretical framework for this condition beyond the assumptions that originated from the media. The psychological instrument developed as a means of identifying trypophobia (Chapter 2) allowed us to first refine the stimulus characteristics (Chapter 3) and response concepts (Chapter 4). In support, we also investigated the physiological correlates associated with trypophobia (Chapter 5), in addition to how exposure therapy can be used as a treatment method (Chapter 6). The inferences we can draw from this research will be discussed in subsections below.

The research reported in this thesis was largely based on a self-report questionnaire developed in Chapter 2, the TQ, in which trypophobia was measured and individuals were separated into either the "trypophobic group" or "control group". It is therefore important to investigate the number of individuals who are identified as "trypophobic" in a general population, based on the criterion set in Experiment 2.1 (i.e., TQ > 31), which is summarised in Table 7.1.

Table 7.1. Summary of the prevalence of individuals who met the criterion for trypophobia (TQ > 31) in separate studies.

Experiment	Population	Total N	Number identified	Proportion
2.1	1	117	16	13.6%
2.3	2	42	7	16.6%
3.1	1	102	21	20.5%
4.1	1	151	37	24.0%
4.2	1	52	8	15.3%
4.3	2	71	10	14.1%
5.1	2	32	2	6.3%

Note. 1 = Essex students and staff, 2 = Psychology students. None of the samples overlapped.

Table 7.1 shows that the proportion of individuals who met the criterion for trypophobia differed across experiments, especially between Experiment 5.1 (6.3%) and Experiment 4.1 (24%), although this was not significant, χ^2 (6) = 10.4, p = .108. Across experiments, the average proportion of individuals who met the criterion was 15.8%. This was slightly higher than for specific phobias (12.5%) (Kessler et al., 2005; see also Becker et al., 2007). Thus, a more stringent criterion for the TQ might be applicable for clinical use and diagnosis, although the clinical prevalence of this condition has to be established before such a decision can be made. It is also important to note that the current thesis did not attempt to establish a clinical estimation of prevalence. Rather, the criterion was based on the sensitivity and specificity analysis comparing individuals who report trypophobia and a more general sample (i.e., students and staff at a university), so as to segregate those who actively reported this condition from a subset that did not. Overall, the instrument and criterion estimated (on average) the prevalence of trypophobia similarly to Cole and Wilkins (2013), i.e., approximately 15% (11% of males and 18% of females).

7.1. Trypophobia as a disgust response

We aimed to refine the response characteristics associated with trypophobia, so as to investigate whether *fear* is the most appropriate response category. This was prompted by the fact that some of the items from the TQ developed in Chapter 2 resemble typical disgust responses, such as "Vomit" or "Feel sick or nauseous". In addition, testimonials from individuals also indicated that trypophobia might be a disgust response. In support, even though anxiety disorders have traditionally been thought to predominantly reflect fear and anxiety (Barlow, 2004), recent studies have indicated that disgust may be an important emotion (Woody & Teachman, 2000) in some conditions such as spider phobia (Matchett & Davey, 1991; Mulkens et al., 1996; Sawchuk et al., 2000; Woody et al., 2005), blood-injection-injury (BII) phobia (Tolin et al., 1997) or contamination-related obsessive-compulsive disorder (OCD) (Olatunji et al., 2007; Tolin et al., 2006). We presented three lines of evidence that were in favour of trypophobia as a disgust response.

First, based on findings from Experiment 4.1 and 4.2, the relationship between trypophobia and aversion to spiders, but not to snakes, was evident. Importantly, the distinction between snakes and spiders in terms of how they have been understood to affect our evolution provided central clues to the interpretation of trypophobia. While snakes have been regarded as predators predominantly associated with fear (Isbell, 2006; Soares, 2010), spiders have not been associated with the same type of uniform threat. Rather, the danger from a spider can also be due to the possibility of contamination (Matchett & Davey, 1991), which adds a distinguishing feature to spiders (relative to snakes), namely disgust. The relationship between trypophobia and aversion to spiders led us to suggest that the former, rather than being a fear response, is a disgust response to potential sources of contaminants.

Furthermore, Experiment 4.3 investigated the relationship between the TQ and the Three-Domain Disgust scale (Tybur et al., 2009). We reported that trypophobia was related to a specific domain of disgust related to contamination, namely pathogen disgust, and not the other two disgust domains (i.e., moral and sexual).

Second, it has been established that certain emotional states can distort our judgement of time, and do so quite differently across different classes of emotions. Whereas fear-inducing stimuli have been reported to increase the subjective judgements of time (Bar-Haim et al., 2010; Hare, 1963), it has been suggested that stimuli associated with disgust generally do not distort this cognitive process (Droit-Volet & Meck, 2007). Consistent with this claim, Experiment 4.4 demonstrated that trypophobic images were not associated with a bias in time estimation. The failure to show that trypophobic images had an effect on subjective time estimation despite adequate experimental power provided empirical evidence to strengthen the argument that trypophobia is mainly a disgust response, and helps to dissociate trypophobia from fear.

Third, cardiovascular indicators have been demonstrated to distinguish between different emotional states (Harrison et al., 2013), and also between different domains of an emotion (i.e., contamination disgust and mutilation disgust). More specifically, fear and other negative emotions (e.g., anxiety or anger) have been associated with a decrease in heart rate variability (HRV) (Gilissen et al., 2008), whereas disgust has been found to increase HRV (Rohrmann & Hopp, 2008). In terms of disgust domains, contamination has been associated with a higher HR, and mutilation has been associated with a lower HR. Here, trypophobia was associated with both a higher HRV and HR. This provided further evidence to suggest that

trypophobia is more related to disgust than to fear (based on the HRV), and specifically to a particular domain of disgust, namely contamination (based on HR).

Three lines of evidence converge to suggest that trypophobia is not (primarily) a fear response. Based on (1) its relationship to aversion to spiders but not snakes, (2) how trypophobic images affected time estimation and (3) the physiological correlates (i.e., heart rate and its variability), it appears that trypophobia is related to disgust, and not fear as conceptualised earlier (Cole & Wilkins, 2013; Skaggs, 2014). Furthermore, this strengthens the claim that disgust is an important factor in many anxiety disorders (Cisler et al., 2009). In the case of trypophobia, disgust may therefore be the appropriate response towards stimuli that "seemingly pose no threat" (Cole & Wilkins, 2013, p. 1980), but may resemble stimuli associated with contamination (see 7.6. Further directions).

7.2. Discomfort from unnatural visual characteristics

Holes are not necessarily the only types of objects that are responsible for trypophobia, despite its name. We created images of clusters of objects that either were holes (i.e., concave) or bumps (i.e., convex) depending on the direction of the shading, and we found that images comprising holes did not induce significantly more discomfort than images comprising bumps. Evidently, the discomfort extended to classes of objects other than holes, suggesting that the characteristics of the objects (i.e., holes or bumps) was not critical to trypophobia. Our conclusion was that although a large subset of trypophobic images comprises holes, it is the clustering nature of the objects that is the mechanism behind the discomfort rather than the nature of the objects themselves. This led us to investigate the spectral composition of the images.

It has been suggested that the mammalian visual system process natural scale-invariant visual properties, i.e., a log-log relationship between spatial frequency and Fourier amplitude (Field, 1987), in an efficient manner (Field, 1994). On the contrary, deviation from those visual properties can induce discomfort (e.g., Fernandez & Wilkins, 2008; Juricevic et al., 2010; O'Hare & Hibbard, 2011; Wilkins et al., 1984). Drawing upon the work of Cole and Wilkins (2013), who demonstrated that trypophobic images possess statistics that deviate significantly from those of natural images, we further investigated the role of the physical properties of the images responsible for trypophobia.

We found that trypophobic images have greater energy at mid-range spatial frequencies than neutral images, thereby replicating the findings by Cole and Wilkins (2013). Importantly, our analysis also included another class of images, namely generally unpleasant images (e.g., sewage and cockroaches), and we found that trypophobic images also exceeded those images in terms of excess energy. Subsequently, by filtering images to have a 1/f amplitude spectrum by removing the excess contrast at mid-range spatial frequencies, we demonstrated that the physical properties associated with discomfort had an effect on the participants with trypophobia, and less so for control participants. Evidently, "[s]ome things are unpleasant […] because of their intrinsic physical properties" (Wilkins, 1995, p. 1), and similarly to other uncomfortable images such abstract art (Fernandez & Wilkins, 2008), trypophobic images possess physical qualities that are absent in natural scenes and associated with discomfort. We concluded that the excess energy at mid-range spatial frequencies in trypophobic images contributed to the condition.

It is also important to address the differences between trypophobic images and other uncomfortable stimuli. Based on the discussion above (section 7.1), we

proposed that trypophobic images induce disgust. On the contrary, although stimuli such as gratings also possess excess energy at mid-range spatial frequencies and have been reported to induce discomfort (Wilkins et al., 1984), they have not been associated with disgust. One possible reason for this might be the differences between the asymmetrical clusters of objects associated with trypophobia and the relatively symmetrical gratings and other stimuli associated with visual stress (Wilkins, 1995, p. 4). When considering sources of contamination, which were suggested to be the mechanism behind trypophobia, it is clear that the visual representations of the contaminants are asymmetrical patterns. For example, contagious diseases such as smallpox are often related to the lesions that appear on the skin. Those pimples tend to vary in terms of the distance between and the size/shape of the objects, thus comprising an asymmetrical cluster. In a similar vein, mould on bread is also usually a cluster of different shapes that are not of symmetrical nature. Thus, the visual properties of contaminants usually involve variability in the positioning of the objects that comprise the clusters, which is not the case for regular black and white bars. The differences between images that induce disgust (e.g., trypophobic images) and images that induce discomfort (e.g., stripes) may therefore be due to the fact that contaminants are often associated with irregular structures. Future work should therefore investigate the effect of irregularity in patterns.

7.3. Haemodynamic response and complex neural computation

To further understand the response to the visual characteristics, we demonstrated that trypophobic images were associated with an abnormal haemodynamic response in the occipital areas. Near infrared spectroscopy showed that individuals with trypophobia had a higher amplitude haemodynamic response to trypophobic images (relative to neutral images) than control participants. This

converged well with the growing evidence for a physiological basis for visual discomfort, where uncomfortable images that deviate from a 1/f structure have been associated with a non-sparse coding in the visual cortex (Hibbard & O'Hare, 2015) and abnormal cortical response. More specifically, studies using NIRS (Haigh et al., 2013) or fMRI (Huang et al., 2003) have shown that observing uncomfortable stimuli (i.e., gratings) induces an abnormal level of oxygenation in the visual cortex. The oxygenation is indicated by a cortical haemodynamic response reflected in both the Blood Oxygen Level Dependent (BOLD) response and the NIRS oxyhaemoglobin response. Furthermore, our results also add further empirical evidence for the argument that discomfort may be a homeostatic response to reduce the sustained metabolism on the visual cortex (Haigh et al., 2013; Wilkins & Hibbard, 2014).

An important aspect that has to be addressed is why trypophobic images did not induce a high haemodynamic response among control participants as well. One possible reason might be due to extent to which trypophobic images deviate from 1/f relative to gratings. Arguably, the excess energy possessed by gratings is greater than for trypophobic images in general. While the contrast between bars in gratings are usually high, this is less so for the clustered objects and backgrounds in trypophobic images. Furthermore, the distribution of energy in gratings is usually within one particular orientation, whereas the distribution in trypophobic images extends over many orientations. Therefore, gratings deviate more from 1/f relative to trypophobic images, which may explain why trypophobic images were not associated with a higher haemodynamic response among control participants.

It is also clear that there is a convergent response across physiological correlates, as demonstrated by cardiovascular reactivity and haemodynamic response, which indicates that it is a systemic response. Another important issue to address is

therefore whether there is a correlation between the two physiological markers. In the current thesis, it was argued that the cardiovascular reactivity was induced by the disgust evoked by trypophobic images, whereas the unnatural visual characteristics were responsible for the abnormal haemodynamic response. From this point of view, it can therefore be suggested that the two physiological systems are independent, although subsequent research has to be conducted in order to ascertain this. One possible approach could be to measure HR/HRV and NIRS response to the images used in Experiment 3.3. The filtered trypophobic images would provide stimuli with trypophobic features without the unnatural visual characteristics. Because the semantic properties of the trypophobic stimuli will still be present, similar cardiovascular reactivity should be expected (i.e., higher HR/HRV). On the contrary, the unnatural visual characteristics were removed from the filtered images, thus the NIRS response should be expected not to significantly differ from neutral images. Such a demonstration would provide further support for the independence of the two physiological markers.

7.4. Implications for treatment

As with most anxiety disorders, one of the most important questions regarding trypophobia is how to treat it. In Chapter 6, it was demonstrated that exposure therapy showed promising results in treatment of trypophobia. By going through sequences of images that increased in contrast and discomfort levels (i.e., fear hierarchies), individuals showed tendencies to habituate to trypophobic images, as sensitivity to the high levels of contrast decreased. More importantly, the TQ score was significantly reduced after 20 treatment session, suggesting that trypophobia, as with many other phobias, is sensitive to exposure therapy (Foa & Kozak, 1986). Some of the shortcomings are discussed below.

Based on the dropout rate, it was clear that this treatment method might not be suitable for everyone. Indeed, we acknowledged the different aspects that can be changed in order to provide treatment sessions in accordance to individual preferences and requirements, such as severity of stimuli and length of treatment sessions. In addition, our research investigated exposure therapy in its basic form, with no integration of aspects previously reported to be efficient, such as relaxation techniques (Wolpe, 1958). Presumably, interactions and discussions between therapists or other professionals and the individuals who suffer from trypophobia is a better way of identifying how treatment should start and progress, as it will make it possible to target the shortcomings outlined.

Given the current state of trypophobia, not many practitioners are familiar with the condition, which restricts the level of assistance individuals with trypophobia can get. For example, an individual reported that "I went to the doctor and I felt like he thought I was crazy because he had no idea what I was talking about" (N. D., personal communication, May 2015), which demonstrates the stigma around this condition and the challenges that some are experiencing. We therefore hope that the research described in Chapter 6 will be of benefit to those who require an open-access, anonymous and easily administered treatment method, perhaps as a first step towards treating trypophobia.

7.5. Similarities and differences between trypophobia and other phobias

As mentioned in the introduction, trypophobia has not been recognised as a phobia as defined by the DSM-5. However, there are some aspects of trypophobia that suggest that it resembles other phobias, and there are similarities between them beyond those examined in this thesis. First of all, phobias in general tend to co-occur, and as many as 75% of individuals who have phobias suffer from more than one

(American Psychiatric Association, 2013; Kendler et al., 2001). Because some phobias (e.g., spider phobia or BII-type phobias) are related to disgust and contamination, it is also reasonable to assume that those phobias are somewhat related, despite the fact that they might involve different objects. In a similar vein, we demonstrated that trypophobia correlated with spider fear (Experiment 4.2). It can therefore be hypothesised that, because high disgust sensitivity is important for trypophobia and spider phobia, the likelihood of them co-occurring is relatively high. Subsequent work demonstrating that trypophobia is related to some phobias such as BII-type phobia (i.e., disgust related) but not others such as claustrophobia (i.e., disgust unrelated) would provide further evidence to support this claim.

Second, according to the DSM-5, a specific phobia has to interfere with everyday functioning in order to be classed as a clinical phobia. One of the arguments against trypophobia is that the stimuli are predominantly accessed through active search on the web, which suggests that trypophobia might not be a problem affecting quality of life. However, as mentioned in the introduction, there have been cases where trypophobia has indeed inhibited individuals from taking part in activities (e.g., diving) or perform in academic settings (e.g., biology lessons). In addition, objects in daily life (e.g., aerated chocolate), architecture/design or adverts have also been reported to be offensive. Furthermore, although we do not know the extent to which trypophobic images affect everyday life, it can be compared to other conditions. For example, despite the relatively low likelihood of encountering snakes in the UK, ophidiophobia is a commonly accepted anxiety disorder among both professionals and the general population. In relation to trypophobia, it can be suggested that the two conditions are comparable with regard to how they impact everyday life.

There are also differences between trypophobia and other phobias that have to be taken into consideration. For prominent phobias such as spider- or claustrophobia, it is clear that the response is to objects/situations that are directly related to harm. In the case of trypophobia, however, the stimuli themselves usually comprise harmless objects (Cole & Wilkins, 2013), but perhaps coincidentally resemble harmful objects (e.g., sources of contamination). Overall, we proposed that trypophobic stimuli provide a second-order cue to threat, which is not usually the case for other phobias.

Another difference is that, as opposed to many prominent phobias that have been reported throughout history (e.g., agoraphobia), trypophobia has only recently been reported. And in contrast to other phobias that have emerged as a direct consequence of our development, such as those involving technology, we propose that trypophobia relates to a type of threat that has been present throughout our evolution. This raises the question of why it has not been reported earlier, an issue that was mentioned in the introduction. The relatively late report of trypophobia may be due to its indirect relationship to threat, which may have inhibited individuals to express their aversion due to the lack of any logical explanations. It is also reasonable to assume that the Internet and technology, outlets that have enabled individuals to mass-communicate in a non-stigmatising (and visual) way, were contributory in revealing condition. Thus, unlike many other phobias, trypophobia has been dependent on external factors in order to get recognition.

7.6. Future directions

We have provided a theoretical framework regarding the nature of the stimulus, in so far as trypophobic images comprise clusters of objects (and not exclusively holes) that yield a specific spectral feature related to discomfort. However, one of the most important questions is yet to be answered, namely why the

phobia actually occurs. Future research should therefore investigate on what basis the reaction to these patterns originated, i.e., what do trypophobic patterns resemble or represent that induce the phobic-like reactions many individuals experience? The results from Experiment 4.1 provided important clues for this, as we reported that overall individuals with trypophobia found mental images of skin-lesions significantly more bothersome compared to controls. This was consistent with some testimonials provided by individuals with trypophobia, suggesting that there may be something about the context in which the clusters of objects are present that is driving the reactions. One way to investigate this would be to create clusters of objects and artificially manipulate them on the skin and other inorganic surfaces (e.g., plastic or glass). This would allow the investigator to compare the aversion induced by clusters of objects on skin versus non-skin surfaces, and also provide a simple way to control for the effect of spectral compositions of clusters.

Another aspect that should be investigated is the relationship between trypophobia and other anxiety disorders. For example, a user of the Facebook group "Trypophobia: Fear of Clusters of Holes" wrote "I suffer from OCD and an anxiety disorder. My trypophobia was pretty well dormant for several years until I was diagnosed with these disorders". This suggested that there could be a possible association between trypophobia and OCD. More specifically, Abramowitz, Taylor, and McKay (2009) described five dimensions of OCD, two of which can be related to trypophobia: obsession for (a) symmetry and (b) contamination (in relation to washing and cleaning rituals). First of all, it is clear that some of the trypophobic images are of asymmetrical structure (e.g., barnacles). The lack of symmetry may therefore cause aversion among individuals who have a preference (i.e., obsession) for order. Second, the current thesis demonstrated that there is an association between

trypophobia and pathogen disgust. Because contamination is another subscale of OCD, it would be interesting to investigate whether an obsession for contamination can account for trypophobia. Here, we proposed that trypophobic images provide a second order cue to threat, in so far that they have been overgeneralised from other harmful sources (i.e., skin lesions). Individuals with trypophobia may therefore be oversensitive to visual structures that may resemble threat, which can be related to their overall obsession with avoiding contaminants.

Foa, Kozak, Salkovskis, Coles, and Amir (1998) described the "Obsessive-Compulsive Inventory – Revised" (OCI-R), an instrument in which identifies OCD from five different dimensions (i.e., washing, checking, ordering, obsessions and hoarding). Based on the discussion above, it would be interesting to investigate whether the "washing" (i.e., contamination) and "ordering" (i.e., symmetry) aspects of the OCR-R relate to trypophobia. In addition, Abramowitz et al. (2010) presented the Dimensional Obsessive-Compulsive Scale (DOCS), which describes four dimensions of OCD (i.e., contamination, unacceptable thoughts, symmetry and responsibility). Importantly, both contamination and symmetry persist as important dimension of OCD, similarly to other measurements. Overall, future work demonstrating that there is an association between trypophobia and the two mentioned OCD dimensions would further improve our understanding of the underlying mechanism that is responsible for trypophobia.

EPILOGUE

After the completion of this thesis, we received the e-mail below. It identifies some of the important findings of this thesis: how trypophobia is related to disgust rather than fear, the importance of abstract clusters of objects, particularly on skin and organic surfaces. This individual also describes the onset of this condition, and the reason for it.

"I wanted to reach out and give you an unbiased and personal short story of my experience with this real visual response that I have to shapes. First, I am an engineer / scientist … and have worked in the high tech industry (Electronics / Optics) for many years. … I am 63 years old. My first encounter with this trypophobic effect started about 10 years ago. I was watching on television an article about river animal life and they began discussing the life of the Surinam Toad.

I felt a sense of intense revulsion seeing the eggs hatch out of the toad's back that I don't recall ever feeling before. Of course, I remember as a child turning over a dead cat and observing maggots there and in the garbage can and feeling something like that, and certainly I have seen repulsive things in my lifetime like anyone else. However, this particular feeling stayed with me for several days until the visual picture in my mind died down.

I didn't think very much about it after that until I noticed one day walking into the grocery store, the asphalt had a depression in it with lots of cracks in a pattern that made me feel kind of queasy if I looked at it very long as I walked by. I stopped walking past that point thereafter. Since that time, in the past few years I began researching this effect to see if anyone else had these kinds of feelings. The easiest of

course was to Google this question and I hit the images tab. What the hell did I do that for? Up popped all of these different images that triggered this intense feeling of ***revulsion*** / ***repulsion***. I have had time to come up with words to describe it and these two words explain it the best. Fear, to me, is just a secondary effect where it is just a feeling that comes out of dread of seeing anything that triggers the ***revulsion / repulsion*** feeling. In one picture, someone had Photoshopped diamond shaped holes on the back of a person's forearms and their fingers. I couldn't shake that visual for several days. It was very interruptive to my daily activities and actually interfered with my sleep. …

Although organically associated patterns are definitely at the top of the list, I was surprised to find some very mechanically associated patterns trigger the effect as well. I found that a Coke can in an advertisement that had geometric patterns cut in it caused the effect. The effects do seem to have a have a degree of gradual magnitude depending on the shape, spatial frequency, and context.

I won't write a book here but I wanted to tell you this story in that it might help in your research and to give support to the psychological community that this effect is definitely real."

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"In memory, everything seems to happen in music."

TENNESSEE WILLIAMS, *THE GLASS MENAGERIE*