Avoiding the Problem: A study on the generalisation of avoidance behaviour

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“Avoidance is prolonged suffering disguised as safety”
– unknown

General Abstract

Anxiety disorders are the most common mental health conditions worldwide, affecting over 61 million people in Europe alone. Since the COVID-19 pandemic, these numbers have risen, with a growing prevalence among younger individuals and children. Avoidance is a defining characteristic of all anxiety disorders, yet it has remained relatively understudied due to an overemphasis on fear mechanisms. However, recent years have seen a resurgence of research in this area. Studies suggest that avoidance is a strong predictor of treatment outcomes and may be the missing link in improving current therapeutic approaches. Understanding avoidance behaviour can provide valuable insights into the underlying mechanisms of anxiety. One prominent notion in the literature is that anxiety may stem from the overgeneralisation of fear, that is when fear extends beyond the original threat to similar stimuli. This is a well-documented phenomenon, with research consistently showing that individuals with high trait anxiety or anxiety disorders exhibit heightened fear generalisation. It has been proposed that avoidance behaviour may function similarly, leading individuals to avoid situations and stimuli resembling the original fear-inducing experience. While research indicates that fear and avoidance are distinct processes, studying generalisation in avoidance behaviour is essential for a more comprehensive understanding of anxiety and its treatment.

The goal of this thesis was to understand different aspects of avoidance behaviour with a focus on generalisation. We developed tasks to study avoidance behaviour both online and within the laboratory, so that a range of experiments could be conducted with different populations. Strictly speaking, we assessed different sources of generalisation of avoidance behaviour, by manipulating warning signals, stress, safety signals, and the context. Chapter 1 gives an introduction and literature review of research within anxiety, avoidance and generalisation. This gives an overview of current research and highlights the gaps within the field. In addition, Chapter 5 presents a review on relief and the role that signals associated with it play in avoidance behaviour. This also links with the safety signals aspect of the thesis.

Chapter 2 assessed whether the contiguity between the warning signals and an aversive outcome can influence the shape of the generalisation gradient. The hypothesis based on previous literature was that a trace procedure would result in a broader generalisation gradient relative to a delay procedure. Interestingly, for individual differences in trait anxiety, the immediate (delay) condition was more sensitive to detecting differences based on trait anxiety levels compared to the trace group. Chapter 3 assessed whether perceived or induced stress have an effect on the generalisation of avoidance behaviour. These experiments found that neither perceived nor induced stress influence the generalisation of avoidance. Chapter 4 revealed that age can influence the shape of a gradient using a Space Invaders avoidance task in children. This was one of the first experiments assessing avoidance generalisation in children aged 5-11 years old.

Chapter 6 investigated safety signals and the concept of relief. These experiments showed first that safety signals reinforce avoidance behaviour. In addition, such reinforcement can generalise to similar safety signals, but not to dissimilar signals. This was the first study to investigate the reinforcing properties of safety signals within humans. Finally, Chapter 7 investigated the generalisation of avoidance behaviour to variations in contextual cues (background colour) and documented a systematic relationship between avoidance behaviour and the similarity of testing to training contexts. Across experiments, there were no meaningful relationships between the generalisation (in its different forms) of avoidance behaviour and participant's trait anxiety levels. Overall, this thesis demonstrates that different factors can influence avoidance behaviour in terms of warning signals, safety signals and the context. Together, these results provide insights into the underlying mechanisms of avoidance behaviour and sheds light on the potential effects of individual differences such as stress and anxiety. The findings of this thesis provide a much need understanding on the factors that affect generalisation of avoidance behaviour in humans. This knowledge could potentially assist clinicians when developing treatments and interventions that include avoidance as well as fear.

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Work within this thesis that appears in master's theses or undergraduate dissertations:

- I was a co supervisor of a master's student (Aakriti Bhardwaj) who completed a placement and their theses alongside my PhD supervisor Dr Gonzalo Urcelay. In Chapter 2 Experiment 4 was a part of the placement assignment and Experiment 1 in Chapter 3, was the master's theses.
- I co supervised a Masters Distance Learning Conversion student (Luke Hanley) and the data from Experiment 4 in Chapter 6 was included within their dissertation. The student made the safety signal stimuli used in this experiment and processed the data. I made the experiment, collected the data, instructed the data breakdown and analysed the data.
- I co supervised a group of three undergraduate students (Caixia Rao, Liam Brant and Mengyi Yang) In Chapter 7, Experiment 1 was included in their dissertations. The students collected and processed part of the data. I made the task, instructed the data processing and analysed the data.

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Chapter 1

General Introduction

1.1 Introduction

Anxiety is one of the most prevalent mental health disorders worldwide, affecting millions of individuals across all age groups. It can be characterised by excessive worry, fear, and physiological arousal (World Health Organisation [WHO], 2023). Collectively, these can significantly impair daily functioning and quality of life. Despite the widespread prevalence of anxiety, research into its behavioural components, such as avoidance, remains relatively underexplored although the last decade has seen a resurgence of interest on it (LeDoux et al., 2017). Avoidance behaviour, a hallmark of anxiety, involves evading situations, activities, or thoughts perceived as threatening, which can perpetuate and exacerbate anxiety symptoms (Urcelay, 2024). While avoidance is well-documented as a key maintaining factor in most theoretical models of anxiety (Pittig et al., 2021), empirical investigations into its specific mechanisms have been limited. Understanding avoidance in greater depth is critical to developing more effective, targeted interventions for anxiety disorders.

1.2 Anxiety

1.2.1 Anxiety definition

Anxiety is term which can be defined in multiple ways depending on perspective and the area of research. The American Psychological Association defines it as psychological feelings of tension and worry and physiological changes such as increased heart rate and blood pressure (American Psychological Association, 2024). When defining

anxiety, there is a tendency to focus on when anxiety becomes maladaptive, although anxiety clearly serves a biological purpose in triggering the threat and danger detection system (Bateson et al., 2011). Therefore, anxiety can be seen as a spectrum from adaptive to maladaptive. This thesis will consider the definition of anxiety to be in line with this spectrum severity continuum characterised by progressive negative affectivity (Lang & McTeague, 2009).

1.2.1.1 Symptoms of anxiety

Since Covid-19 there has been an increase in people reporting anxiety symptoms (Santabárbara et al., 2021). Overall, the symptoms of anxiety can broadly be separated into physical, emotional and behavioural symptoms (World Health Organisation [WHO], 2023). Physical symptoms include increased heartbeat, faster breathing, restlessness, headaches and stomach aches. Emotional symptoms include sense of danger and worry, irritability and difficulty concentrating. The behavioural symptoms include difficulty in sleeping, avoidance and withdrawing. Anxiety exists on a spectrum and individuals may experience these symptoms as part of everyday life or during specific stressful times such as exam periods, when going through a life change such as moving house, or starting a new job (Miloyan et al., 2018). However, when these symptoms being to influence day to day functioning, work and produce social distress, then this could indicate clinical anxiety.

1.2.1.2 Cost of anxiety

In addition to the effects on the individual, it is estimated that lost work due to anxiety results in a loss of $4 billion in the workplace, in the US (Harder, 2016). Furthermore, in the UK the cost of mental health disorders was 300 billion from economic costs (losses to workplaces) human costs (reduced quality of life) and health care costs

(public services such as support and treatment programmes) (Cardoso & McHayle, 2024). This, along with the individual effects of anxiety show why there is a pressing need to investigate how to explain the development of anxiety, and drivers of behavioural features of anxiety in hopes of improving treatment, creating prevention strategies, and interventions to reduce the economic costs, ultimately improving people's quality of life.

1.2.2 Clinical anxiety

Clinical anxiety can be defined as deviating from the normal levels of anxiety in terms of the excessiveness and the persistence of symptoms. The diagnostic and statistical manual (DSM-5) describes anxiety as a "excessive worry and apprehensive expectations, occurring more days than not for at least 6 months, about a number of events or activities, such as work or school performance" (American Psychiatric Association [APA], 2013). Furthermore, to be a diagnosed anxiety disorder, the feelings of worry need to be accompanied by avoidance which is persistent.

1.2.2.1 Anxiety disorders

The term 'anxiety disorders' refers to a cluster of disorders which share symptoms mainly related to fear and avoidance. Approximately 12.7% of the US population have been diagnosed with an anxiety disorder (Szuhany & Simon, 2022). Globally, in 2017 284 million individuals had a diagnosed anxiety disorder making them the most prevalent psychiatric disorder (Mind, 2024). Women are affected by anxiety disorders more than men and onset of symptoms can often occur during childhood and adolescence but also can occur later in life (after a stressful event) (Lijster et al., 2017).

There are 7 different disorders which fall under the anxiety disorder category in the DSM 5. Each of these disorders has specific symptomology beyond the above. Notably there were changes from the previous version of the DSM in that post-traumatic stress

disorder (PTSD; anxiety causes flashbacks of traumatic events) and Obsessive Compulsive Disorder (OCD; involuntary obsessive thoughts drive repetitive behaviours) have been removed from this category. Some older research discussed in this thesis will include both of these disorders within the term 'anxiety disorders' whereas newer research makes the distinction between them.

The other 7 disorders include separation anxiety which involves inappropriate levels of anxiety and fear from being separated from an attached individual. Selective mutism involves persistent reluctancy to speak in situations this is required, such as school. Specific phobias are related to anxiety and fear, but linked to a specific object, person or concept. Social anxiety is the fear and anxiety in social situations which interferes with daily life. Panic disorder is reoccurring and unexpected panic attacks. Agoraphobia is characterised by the perception of an environment being unsafe and unescapable. Finally, there is generalised anxiety disorder (GAD) which is a persistent and excessive worry that effects daily living.

The main focus of this thesis is concerned with every day and trait anxiety which is most similar to GAD within the anxiety disorders classifications. All the above disorders, whilst having differences, share a characterisation of excessive fear and avoidance behaviour.

1.2.3 Sub Clinical Anxiety

High levels of anxiety can be experienced without meeting the threshold for a clinical diagnosis. Sub clinical anxiety is defined as a high functioning anxiety in that people may experience symptoms related to anxiety disorders, but they are able to manage them in terms of day-to-day functioning. This area is not well studied. However, there seem to be many different types of symptoms that could be considered subclinical,

including mild symptoms. In contrast, most DSM diagnoses require symptoms to be at least moderate in severity. Also, these symptoms may affect some aspects of life but not others such as sleep or appetite. Different measures have been developed to investigate these subclinical levels of anxiety, one such measure is the Spielberger State and Trait Anxiety Inventory (Spielberger, 2010). The STAI has been used in psychological and health research since being developed, with it being cited over 3,000 times. When evaluating research investigating the relationship between fear, avoidance and subjective levels of anxiety, the majority of studies use the STAI (Sep et al., 2019). However, it also noted that the STAI has faced criticisms about whether it captures anxiety alone, there has been some suggestion that what it measures may also have overlaps with depressive symptoms (Bados et al., 2010). They suggest that instead a better description would be a scale for negative effect. The STAI is split into two subscales state and trait anxiety. Both scales have 20 questions on a 4-point Likert scale which goes from not at all, somewhat, moderately and very much.

1.2.4.1 State and Trait anxiety

State anxiety can be defined as a temporary emotional state marked by physical arousal and a conscious awareness of feelings like apprehension, dread, and tension (Endler & Kocovski, 2001). State anxiety can be manipulated with different situations and stressors and research within both the anxiety and stress literature do this successfully (Schwabe & Schächinger, 2018). Meanwhile, Trait anxiety can be defined as an individual's predisposition to anxiety. This is more stable and cannot be manipulated like state anxiety. As trait anxiety is stable, higher levels have been linked to diagnoses in anxiety disorders (Van Dam et al., 2013) As this distinction is more stable over time, this is better

used to investigate individual differences in anxiety in healthy populations (Sep et al., 2019).

1.2.4 Fear

Fear and anxiety are sometimes used interchangeably and some researchers believe they are undistinguishable (Daniel-Watanabe & Fletcher, 2022) whilst others believe that whilst they have similarities they are different phenomena (Steimer, 2002). Whilst both function to trigger a response to threat or danger (Steimer, 2002) anxiety is considered to be future orientated and long acting whereas fear is a response to an imminent threat in terms of increased a (American Psychological Association, 2024). There is also evidence that fear and anxiety are separate constructs in terms of the physiological measures (heart rate) and subjective anxiety (nervousness). Within this empirical study they found that when analysing the results, a two-factor model separating the constructs was better than a model incorporating them as one factor (Joiner et al., 1999). This highlights that these constructs are similar and are highly correlated but also have distinct properties (Craske et al., 2011). Furthermore, a recent review has highlighted that in some aspects particularly, the neurobiological data seems to be mixed with evidence for and against there being a distinction (Daniel-Watanabe & Fletcher, 2022). However, they also highlight that much of the behavioural data seems to suggest there may be a distinction between fear and anxiety. Whilst fear could be considered a distinct concept from anxiety it is a core symptom of all anxiety disorders so traditionally anxiety research has focused on fear being a driver of anxiety and its' symptomology

Therefore, clinicians have focused on ways to eliminate fear to alleviate the symptoms those with anxiety struggle with. As a result, therapies such as cognitive behavioural therapy (CBT; and in particular exposure therapies) were developed and used

to treat and manage these disorders (Foa & Kozak, 1986) . Approximately 61 % of people with anxiety do not seek or receive treatment (Alonso et al., 2018). Whilst these have been useful in this management of anxiety disorders there is still a large relapse rate; a longitudinal study found that in the year following CBT, 53% of people experienced a relapse episode (Ali et al., 2017). This suggests that eliminating fear alone is not sufficient and that treatments could be failing to target other possible drivers of the behaviour resulting in the high relapse rates. Exposure therapy is centred on the logic that fear drives avoidance, meaning that by repeatedly confronting feared stimuli in a safe environment, fear will decrease, and avoidance behaviours will also extinguish (Craske et al., 2014). However, a growing body of research suggests that avoidance can persist even when fear is no longer present, challenging this foundational assumption. Rachman and Hodgson (1974) first proposed that avoidance behaviours might become independent of fear through mechanisms such as habit formation or secondary reinforcement. Mineka (1979) expanded on this, showing in animal models that avoidance responses could be sustained by learned safety signals rather than by a direct fear response to the threat itself. More recent work further supports this idea (Vervliet & Indekeu, 2015), demonstrating that avoidance can be maintained even in the absence of conscious fear, potentially due to ingrained action patterns or a preference for perceived safety. These findings highlight that avoidance does not follow the same behavioural patterns as fear and that treatments may need to incorporate an avoidance focused aspect to reduce relapse, however, the current literature on avoidance behavioural is limited.

1.3. Avoidance

1.3.1 Avoidance definition

Avoidance can be defined as any behaviour that can postpones or minimises exposure to situations that are threatening, fearful of unpleasant for an individual (Ball & Gunaydin, 2022). However, there is no universal definition used by all clinicians and researchers (Arnaudova et al., 2017). The DSM-5 defines avoidance as 'the act of keeping away from stress-related circumstances: a tendency to circumvent cues, activities and situations that remind the individual of a stressful event experienced' (DSM-5; APA, 2013). A newer and more encompassing definition of avoidance is 'any covert or overt action that functions to create, increase or maintain physical (spatial or temporal) or psychological distance between the agent and perceived or actual threat" (Arnaudova et al., 2017). A key part of this definition is the word 'perceived' as this allows for their individual differences in threat perception and also allows for the notion that safe situations can be perceived as stressful. It also considers that avoidance involves behavioural and cognitive components. Avoidance is an adaptive and natural response required for survival for both animals and humans (LeDoux et al., 2017). However, in those with anxiety disorders this is heightened and becomes excessive, and people avoid places, situations that are safe. Some researchers also struggle to draw a line between maladaptive avoidance and adaptive coping as there can be overlap (Arnaudova et al., 2017). This maladaptive avoidance can interfere with everyday life and leads to a cycle of avoidance that may breed anxiety *(see Figure 1.1)*.

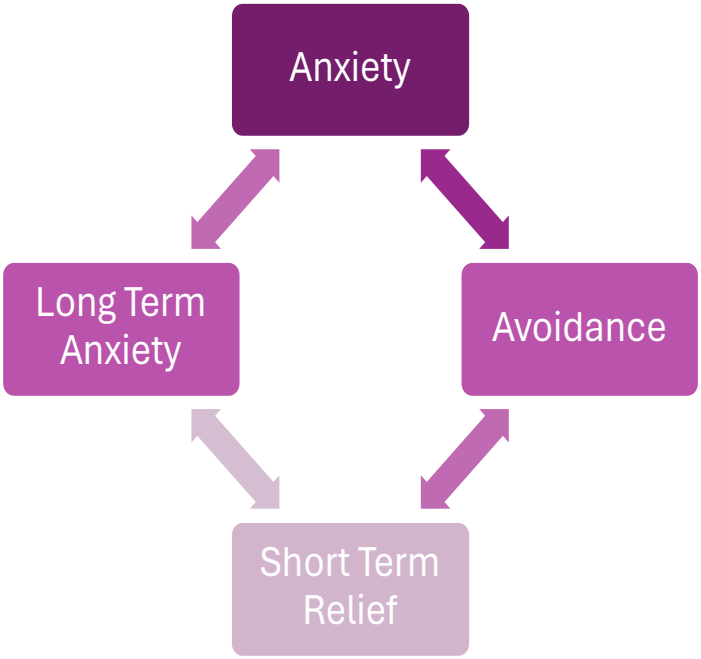

Figure 1.1
Anxiety and avoidance cycle: This figure depicts the anxiety and avoidance cycle in which individuals experience anxiety and then avoid a situation. This in turn results in short term relief, which could reinforce the avoidance behaviour. In turn this results in the maintenance of anxiety in the long term. This then results in more avoidance, and it becomes a cycle of behaviour.

Avoidance is a driver of anxiety as it can produce short term relief but can detrimental by never allowing individuals to encounter the feared situation as a safe one resulting in the maintenance of anxiety (Salkovskis, 1991; Ball & Gunaydin, 2022) . This highlights that avoidance is a key component to study in relation to anxiety. See *Chapter 5* for more on the relief aspect of the cycle.

1.3.2 Avoidance Research

Despite avoidance being highlighted as a potential driver of anxiety there has been a dearth of research into this phenomenon (LeDoux et al., 2017). In the early avoidance literature, research was conducted in animals using an avoidance conditioning paradigm which involves fear conditioning. In this procedure animals are trained with conditioned stimuli (CS's), one of which is paired with an aversive outcome (shock) and the other is

not. Once animals have learned which CS predicts the aversive outcome, they are given the opportunity to avoid this by performing a response. There are many different avoidance responses used within the literature including lever pressing (Sidman, 1955) moving to a different part of the experimental chamber (Bolles & Grossen, 1969) or onto a platform in the chamber (Diehl et al., 2019). In humans, again many different types of tasks have been used and there is no universal task that is considered to be the best way of assessing avoidance behaviour. There are many factors that need to be considered when conducting an avoidance task such as the measure of avoidance behaviour, the cost of the behaviour and the types of avoidance responses. Firstly, many tasks use a binary measure of avoidance (Lovibond et al, 2018;Vervliet et al., 2017) in that participants only need to make one response to avoid which limits the analyses that can be conducted. Other researchers such as Flores and collegues (2018) have utilised a task that requires participants to make multiple avoidance responses on a trial which allows a rate of responding to assessed. This is a more sensitive measure for assessing how avoidance changes to different stimuli and task parameters. Moreover, many tasks have little in terms of cost, meaning other than encountering the aversive outcome there is no consequence of avoiding or not avoiding. In the real world the cost of avoidance can be great in that individuals may miss out on opportunities both financial and social and impacts daily life for those with anxiety disorders. Therefore some work has attempted to introduce costs into the procedures such as Pittig & Scherbaum (2020) who introduce a monetary loss for avoidance responses. Moreover, the pain avoidance literature also uses cost in that an avoidance response requires more effort and discomfort (Meulders et al., 2016). Finally, another factor that needs to be considered is the type of avoidance responses that are used, most use tasks that involve a button press however, other

researchers have utilised designs that require more effort. One such is the robotic arm tasks which involves participants manoeuvring a robotic arm to a target via various pathways which have varying levels of successful avoidance and effort (Meulders et al., 2016, 2024).

Whilst the research into avoidance behaviour is limited the role of avoidance behaviour has also been thought about by clinicians and behavioural researchers together. Some have taken a more nuanced view of avoidance behaviour such as Hofmann and Hay (2018). They highlight that avoidance behaviour has both negative and positive aspects and that if properly integrated into treatment, then it could enhance treatment outcomes. Furthermore, others have highlighted that tailoring treatments to target both fear and avoidance whilst also considering both individual factors such as trait anxiety and contextual factors such as stress levels and engagement with treatment may increase treatment outcomes (Pittig et al., 2020). It is also highlighted that in combining fear and avoidance treatments could also reduce relapse rates by minimising the context shift between the therapy room and the real world and therefore reduce renewal of fear (Craske et al., 2022). Future lines of research have been suggested in the hopes of being able to progresses the enhancement of treatments such as examining the effects of anxiolytics on avoidance behaviour (Treanor & Barry, 2017). Overall, avoidance has been highlighted as a key area of research within the anxiety literature by both researchers and clinicians.

1.3.3 Theories of avoidance

As avoidance behaviour is a central symptom of anxiety, the theoretical interest in understanding and explaining this behaviour has increased. Over the decades, there has been several theories to explain the mechanisms underlying instrumental or active

avoidance, each offering unique perspectives on the processes that drive and maintain this behaviour. These theories range from classical conditioning models that emphasise learned fear responses, to cognitive frameworks that highlight the role of distorted thoughts and beliefs, as well as biological and evolutionary models that suggest an innate predisposition to avoid certain threats. Understanding these different theories is crucial for developing effective interventions to address avoidance behaviours in clinical settings. Each theoretical model offers distinct insights into what sustains avoidance and how it can be disrupted. By integrating knowledge from behavioural, cognitive, and biological perspectives, clinicians can tailor treatments, such as exposure therapy, cognitive restructuring, or pharmacological support, to better match the underlying mechanisms at play in each individual. Moreover, a solid grasp of these theories enhances our ability to predict treatment outcomes, prevent relapse, and adapt interventions across diverse populations and disorders. This section will explore the major theories of avoidance behaviour, highlighting their contributions and limitations in explaining how avoidance develops and is maintained.

1.3.3.1 Two factor theory

In the 1930's Mowrer attempted to study avoidance in relation to fear and influenced the paradigm and empirical research in this field (Mowrer, 1951). Mowrer took inspiration from Pavlov's and Freud's writings, and devised his own theory of avoidance behaviour (LeDoux et al., 2017). He proposed that there were two factors involved in avoidance behaviour one of these is based on pavlovian conditioning and the other is based on instrumental conditioning. The first factor gives rise to the emotional state of fear which is triggered by an association between a CS (conditioned stimulus) and an aversive outcome. Factor two is then when the instrumental avoidance response occurs,

aiming to reduce fear elicited by the CS. Therefore, this results in a pavlovian link between CS and the outcome which results in fear and the instrumental link between the avoidance response and fear which in turn terminates the fear. An example of this within a spider phobic person, would assume that the spider is the CS and the fear feeling is the aversive outcome and then the individual avoids situations where spiders could be around, that terminates the fear response.

This theory suggests the main driver of avoidance behaviour is fear, therefore behaviour that reduces fear should results in reduced avoidance. Solomon and Wynne's (1953) shuttle box experiment provide strong empirical support for Mowrer's two-factor theory of avoidance. In the study, dogs were placed in a shuttle box with a barrier and exposed to a sequence where a light (conditioned stimulus, CS) was followed by an electric shock (unconditioned stimulus, US). Initially, the dogs only jumped to the other side of the barrier after the shock began, displaying escape behaviour. However, with repeated trials, the dogs began to jump pre-emptively upon seeing the light, avoiding the shock altogether. This transition illustrates the two-factor theory in action: classical conditioning caused the light to become associated with fear, while operant conditioning reinforced the avoidance behaviour. By jumping, the dogs effectively terminated their exposure to the fear-inducing light which served as a negative reinforcer. This study highlights the interaction between fear acquisition and reinforcement processes, central to the two-factor explanation of avoidance. Furthermore, one of the predictions of Two factor theory is that avoidance will only be learned when the response terminates the warning signal (CS+). Support for this finding comes from Kamin (1957) in this study they trained four groups of rats using a shuttle box avoidance paradigm. In one of the groups the avoidance response terminated the signal in one of the others there was no

termination of the signal and in a further control the signal terminated but it did not avoid the shock (the shock). The results indicated just as predicted by two factor theory the avoidance responding was strongest in the group where the response terminated the signal. Avoidance responding was significantly lower in the other three groups which indicates that the termination of the warning signal (signal predicts the occurrence of an aversive or negative event; *see section 1.6 below*) that predicts is significant in avoidance responding.

1.3.3.2 Critiques of Two factor theory

This theory resulted in a wealth of research into the research area until the 1980's when the research diminished. This was partly due to the paradigm issues of this theory with the biggest concern being that fear is the driver of avoidance behaviour (LeDoux et al., 2017). The theory suggests that fear reduction is the driver, or reinforcer, of avoidance behaviour however there are several issues with this. Whilst the early research in avoidance behaviour supported the ideas of two factor theory subsequent research posed issues.

Firstly, one of the most notable issues with two factor theory is that it struggles to account for free operant avoidance. Rats were presented with foot shocks in at varied intervals and only depressing a lever could delay the shock for 20 seconds (Sidman, 1953) . It was found that rats learned to avoid by depressing a lever without a warning signal present, furthermore these findings have also been found in humans (Higgins & Morris, 1984). Two factor theory would argue this could never happen as there needs to be a discrete pavlovian warning signal however, these findings suggest that avoidance behaviour can be maintained by preventing the aversive event alone.

In recent years there has been human research which has demonstrated that avoidance behaviour does not always align with fear, in line with earlier observations in the clinical literature (Hodgson & Rachman, 1974) . Research has illustrated that, in both rodents (Mineka, 1979) and humans (Jacobs & Nadel, 1985; Vervliet & Indekeu, 2015), once fear has been extinguished avoidance behaviour still persists. According to two factor theory if fear is the driver avoidance, then reducing fear should also attenuate avoidance behaviour, but this is not always the case indicating that perhaps there are other underlying mechanisms that maintain avoidance behaviour. This indicates that therapy and interventions that tackle fear do not necessarily have a strong impact on avoidance behaviour and it remains resilient. This highlights that the fear and avoidance are separate constructs, at odd with the predictions of two-factor theory. Therefore, subsequent theories have been developed to navigate some of the issues of two factor theory.

1.3.3.3 Species-Specific Defence Reactions Theory

It has been proposed that there is an evolutionary basis for responding to threats with innate behaviours, such as freezing, fleeing, or fighting, that are specific to a particular species. It has been suggested that organisms are better prepared to learn when aversive outcomes are paired with biologically relevant stimuli (LeDoux et al., 2017). These instinctive responses are triggered automatically by warning signals and can be difficult to override. There is evidence which shows that stimuli such as spiders are easier to group than non-threatening stimuli such as plants (Öhman & Mineka, 2001). Moreover, it has been proposed that this may be the case for behavioural responses such as avoidance. There is evidence that acquisition is quicker when using a response such as moving to the other side of a compartment compared to pressing a lever (Grossen &

Kelley, 1972). This led to the development of Species-Specific Defence Reactions Theory (SSDR). This theory was created by Bolles (1971) who argued that when in fearful situations organisms are predisposed to perform specific responses that are specific to their species. For example, upon seeing a predator an organism may freeze or run. He also suggested that these responses do not need to be reinforced the organism just needs to learn that a stimulus predicts an outcome for the defence reaction to be elicited (LeDoux et al., 2017). Conversely, learning avoidance behaviours that conflict with SSDRs, such as staying immobile in an unsafe environment, is much harder, highlighting the strong influence of instinct on avoidance learning. Furthermore, based on this Bolles argued that because these behaviours are instinctive and innate that therefore instrumental behaviour does not play a role in avoidance behaviour. Moreover, this is argued as he states that it is the type of behaviour that is selected those influences how this behaviour is reinforced and maintained (Bolles, 1971). He highlights that research has shown that there are no differences in avoidance behaviour (moving to a different compartment in the shuttle box) when comparing rats who terminate the CS (white noise) and those that instead receive a safety signal (lights turned off for 3 seconds) (Bolles & Grossen, 1969). This suggests that CS termination may lead to avoidance learning because it provides feedback as opposed to the reduction of fear. This is supported by findings such as Bower et al. (1965) who conditioned rats in a shuttle box with a tone and then subsequently the CS was played at different reduced intensities (between subjects) after an avoidance response was made. The groups included one in which the CS was terminated immediately following the response, one group had no reduction, and the tone continued to play for 10-second and finally the last group had a 57% reduction in the tone intensity, and this was played for 10 seconds following the response. They found a relationship between acquisition of

avoidance behaviour and the degree of change in the CS in that the greater degree of change (i.e termination of the CS as opposed to no reduction of 57% reduction) lead to more avoidance responses, in this sense the change in CS acts as feedback.

To summarise, this theory suggests that avoidance responses are species-specific and have an evolutionary predisposition to aid survival (Bolles, 1971). Bolles (1971) argues that the feedback from avoidance behaviour could be seen as the equivalent of a safety signal. However, it is not entirely clear why this safety signal is assumed to be independent of instrumental learning processes. Clarification is needed on how such feedback, which appears to reinforce behaviour, would not involve instrumental mechanisms. Furthermore, while Bolles emphasised species-specific defence reactions, punishment also played a significant role in his theory. He posited that punishment and fear are key to shaping avoidance behaviours, as animals learn to avoid situations associated with aversive outcomes. Bolles further indicates that the termination of the conditioned stimulus (CS) provides feedback that facilitates avoidance, challenging Mowrer's earlier suggestion that fear reduction is the primary motivator.

1.3.3.4 Cognitive Model

The cognitive model of avoidance was originally proposed Seligman and Johnson, and it aimed to differentiated itself from earlier theories by emphasising the role of internal mental processes in avoidance (Seligman & Johnson, 1973). Instead of solely using behaviour response as the basis for the explanation as the above theories do, it incorporates cognitive process, particularly expectation. Expectation refers to the link

between the mental representations of specific actions and the outcomes of these. In this context there are two types of expectations that form. The aversive expectation is the preference for no-shock compared to shock. There is then the avoidance expectation in that there is a belief that performing an avoidance action then prevents this aversive outcome. The aversive preference then drives the avoidance expectation, and it is this belief that then drives the avoidance behaviour.

Aversive expectation has strong links to anxiety disorders and proposes that avoidance behaviour prevents an individual testing their belief that the aversive outcome will occur, explaining how avoidance is maintained in anxiety disorders. This theory also provides support for the current treatments of anxiety disorders such as cognitive behavioural therapy and exposure therapy. Both of these therapies revolve around teaching patients to change their cognitions and their thoughts about their behaviour (Springer et al., 2018). Furthermore, this theory also considers individual differences in anxiety disorders such as cognitive processing, the history of the person and time (Seligman & Johnson, 1973). As the focus of the theory is on cognitions and expectations it could help to explain why patients may form different mental representations between stimuli and outcomes hence why some arachnophobes may be able to be around spiders and some may not be able to look at images of spiders at all. It had been shown that different cognitive factors can have an influence on fear acquisitions such as intolerance to uncertainty, trait anxiety and neuroticism (Sjouwerman et al., 2020) and there has been evidence that these factors also influence avoidance behaviour (Flores et al., 2018; Lommen et al., 2010).

Whilst this is an influential theory in the avoidance literature, there are also some critiques. A major critique is that there is an overemphasis of cognitive processes, which

rules out reflexive and habitual behaviours as these are sometimes seen (Flores et al., 2018; Gillan et al., 2014, 2015). Moreover, a further critique of this theory is that it is difficult to empirically test the assumptions of the theory. Many studies have attempted to measure expectancy however this relies on self-reports which can be argued to be subjective. However, self-reports are prone to bias, raising concerns about the validity of data used to support the cognitive model, especially since these internal processes cannot be directly observed or independently verified. Furthermore, there has been empirical evidence that people's expectations and behaviour sometimes do not match. Healthy participants underwent fear conditioning, and they had to report their expectations of when a shock would occur whilst their skin conductance (fear response) was measured (Pérez & Soto, 2020). It was found that at times the participants displayed physiological fear even when they did not report to expect a shock. This demonstrates that fear-related behaviours (such as physiological responses) can be driven by implicit processes that do not align with consciously held expectations.

1.3.3.5 Expectancy Model

Since the Cognitive model others have further developed theories from this one, such as an expectancy theory of avoidance behaviour (Lovibond, 2006). This theory narrows down the cognitive model and places more emphasis on explicit conscious expectations. It states that avoidance is caused by an explicit knowledge of the contingencies between stimuli and the aversive outcome, and the avoidance response resulting in the absence of the aversive outcome. There is empirical support that when participants are aware of the contingencies between the avoidance response and the absence of the US, then US expectancy based on the CS decreases and when the avoidance response is unavailable these expectancies increase (Lovibond et al., 2008).

Furthermore, the current treatments of anxiety disorders which focus on changing people conscious thoughts and emotions, work in reducing fear and avoidance in a large number of people (Levy et al., 2022) .

A key difference between the cognitive model and the expectancy model is that whilst the cognitive model places some emphasis on expectancy it does not believe it to be a causal role in pavlovian conditioning and anxiety (Lovibond et al., 2008). The key features of the expectancy model are that fear and avoidance are governed by the same conscious expectation of threat therefore like two factor theory (Mowrer, 1951) the expectancy account would suggest that extinguishing these expectations should extinguish both fear and avoidance behaviour. However, evidence has shown that extinguishing fear does not lead to extinction of avoidance (Vervliet & Indekeu, 2015). Furthermore, avoidance behaviour can be extinguished when the individual learns that the aversive outcome no longer occurs (extinction) and this is observed best when the option to avoid is not available (Lovibond et al., 2009).

1.3.3.6 Relief

Another theory of avoidance behaviour is that of relief (*see Chapter 5 for a full review*). Relief is a positive emotion which is tied to the avoidance or escape of distress or anxiety (Leng et al., 2024). It is suggested that this positive feeling can serve as a reinforcer of avoidance behaviour and there are many different theories of relief (*see Chapter 5)*. There is evidence that after successful avoidance, participants have higher relief pleasantness ratings compared to stimuli that is unavoidable (Vervliet et al., 2017). Moreover, there is evidence in rats (Fernando et al., 2014) and in humans (Fisher & Urcelay, 2024) that stimuli that signal safety after avoidance (safety signals) can reinforce behaviour which could be used as behavioural evidence for the relief theory of avoidance.

Overall, there is no one theory of avoidance behaviour that can explain all the phenomena observed within the literature. Each theoretical framework possesses its own strengths, empirical support, and critical evaluations. While some theories are backed by substantial evidence, others face scrutiny and debate, highlighting the complexity of the subject and the need for continued research. Theories of avoidance behaviour highlight several key aspects such as fear, instrumental behaviour and consequences of behaviour. Theories which incorporate a pavlovian element such as two factor theory suggest that avoidance behaviour is driven by learned fear responses to specific stimuli, where associations between the cues and threat then prompt avoidance (Mowrer, 1951). In contrast, the solely instrumental learning theories, emphasise that avoidance behaviours are reinforced through negative reinforcement, where the individual avoids an unpleasant outcome or discomfort. Expectancy theory, as proposed by Lovibond (2008), suggests that organisms avoid situations based on expectations of harm or danger. Lastly, relief-driven models propose that the behaviour is motivated by the experience of relief that follows avoidance, suggesting that the consequences of the behaviour play a critical role in its reinforcement. These theories collectively offer a multi-dimensional view of avoidance behaviour, integrating both emotional responses and cognitive expectations. Therefore, when conducting research within this field the theoretical considerations should also be considered in the hope of being able to determine a model or theory that encompasses explanations for all the observed findings.

1.4 Generalisation

1.4.1 Generalisation definition

Once a response to a stimulus is learnt there is a tendency to respond to stimuli that resemble the training stimulus, this phenomena is referred to as stimulus

generalisation (Hilgard & Marquis, 1961). Generalisation has an adaptive function, because it is rare for the exact conditions of a previous experience to be replicated, so being able to respond to stimuli which are similar to those present during training, allows for more effective response decisions, particularly if this is to threatening stimuli. One of the earliest documentations of the concept of generalisation comes from (Pavlov, 1927), in which it was observed during appetitive conditioning that when trained with a tone as a predictor of food, dogs would salivate to the trained tone but also when they were presented with similar tones, indicating generalisation of the conditioned response.

A seminal experiment which investigated stimulus generalisation in pigeons used different light wavelengths (Guttman & Kalish, 1956). The subjects were trained using an appetitive paradigm in which they would peck at an illuminated key to gain food pellets. After training, the subjects were presented with other light wave lengths and their pecking responses were recorded. The results showed that pecking was strongest at the wavelength used during training, with responses systematically decreasing as the wavelengths diverged from the trained stimulus. This produced a bell-shaped generalisation gradient, with the lowest responses occurring at wavelengths furthest from the original. This experiment built on Pavlov's work and further illustrated the concept of generalisation gradients. Stimuli that were not directly reinforced could still elicit the conditioned response based on their similarity to the conditioned stimulus. Generalisation has since been demonstrated across various species and with different types of stimuli, spanning dimensions such as visual and auditory inputs (Ghirlanda & Enquist, 2003).

Stimulus generalisation is not limited to appetitive conditioning; it can also occur with aversive stimuli. A classic example of aversive generalisation is the infamous 'Little

Albert' study (Watson & Rayner, 1920). In this case study a young infant underwent pavlovian conditioning in which a loud noise was paired with the sight of a white rat. The pairing was successful, and the rat alone elicited a fear response (crying). Importantly, the infant also exhibited conditioned fear responses to other stimuli resembling the rat, such as a fur coat and cotton wool balls. This demonstrated that fear could generalise to similar stimuli—in this case, those that were white and furry. This suggests that the fear of the conditioned stimulus generalised to stimuli that resembled it, in this instance stimuli that were white and furry. Although this experiment has been criticised for its methodological and ethical shortcomings, it provides early evidence of fear generalisation occurring in real-world settings beyond controlled laboratory environments.

1.4.2 Generalisation Paradigm in aversive conditioning

Generalisation is widely studied across appetitive and aversive paradigms; the experimental design is similar across both of these. The generalisation protocol has been used to study fear and avoidance generalisation. A typical procedure (*see Figure 1.2*) involves training participants to associate a specific conditioned stimulus (CS+) with an outcome, such as a rewarding food or an aversive shock, while another stimulus (CS-) is not paired with the outcome. These CSs may exist on the same sensory modality, or they could be different such as using a light and tone. During the test phase, participants are presented with a series of stimuli that vary in similarity to the CS+ along a gradient in the sensory modality of the CS. For example, a tone was used as CS+, different frequencies would be used as generalisation stimuli (similarly, if using visual stimuli then the generalisation stimuli may be similar in colour or shape). Conditioned responses to these stimuli, such as avoidance behaviours, physiological reactions, or self-reported fear, are

measured to assess the extent of generalisation. There are two typical types of stimuli used in the generalisation test (Fraunfelter et al., 2022). The first involves comparing trained stimuli to a new novel stimulus that may be a different shape. The other uses multiple generalisation stimuli that systematically differ such as colours across a dimension. Using novel generalisation stimuli that systematically differ in similarity provides a more operationalised way to study this phenomenon and allow for researchers to understand the parameters of generalisation. Whilst these are the most typical protocols, not all studies follow these designs. Some studies opt to have additional phases depending upon the specific research questions. For example, Morriss et al., (2016) incorporated an extinction generalization phase to examine how safety learning transfers to novel but similar stimuli. Other studies, such as Lissek et al. (2014), have implemented delayed recall tests days after the initial learning to investigate the stability and persistence of generalized fear responses over time. These variations in experimental design allow researchers to probe more nuanced aspects of aversive learning, such as the durability, flexibility, and specificity of fear generalisation.

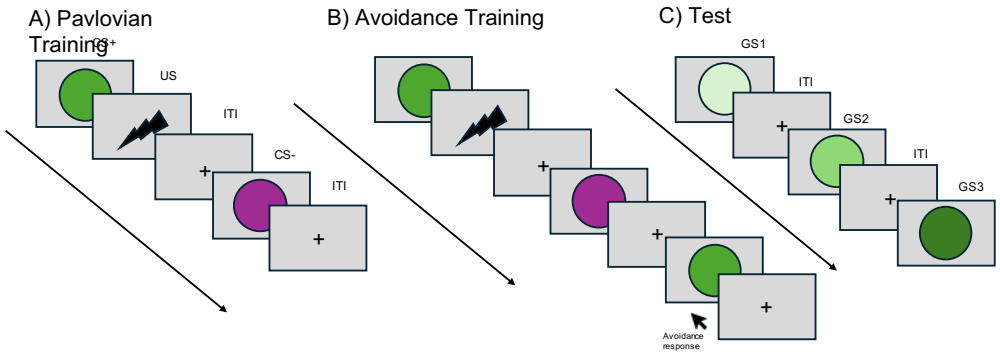

Figure 1.3
The figure depicts an example of an avoidance generalisation experiment. Panel A shows fear conditioning in which a CS+ is paired with a US (Pavlovian Training). Panel B (Avoidance Training) shows the avoidance phase in which the same stimuli are shown but the participants can make a response and avoid the US, if they fail to make this response, they will experience the US. Panel C (Test) shows the generalisation test in which similar stimuli to the CS+ are presented and avoidance responses are measured.

1.4.3 Generalisation Curves

When examining the responses during generalisation experiments researchers want to observe how much responding occurs to the CS+ and the generalisation stimuli as they become less similar to the CS+. Typically, experiments will exhibit what is referred to a generalisation curve (*see Figure 1.3*). In this, the most responding will occur at the CS+ and as the stimuli become less similar to the CS+ then the responding decreases showing a generalisation gradient. In experimental designs that use a CS- stimuli on the same dimension as the CS+ then generalisation gradient will be more linear (see Figure 1.4 B).

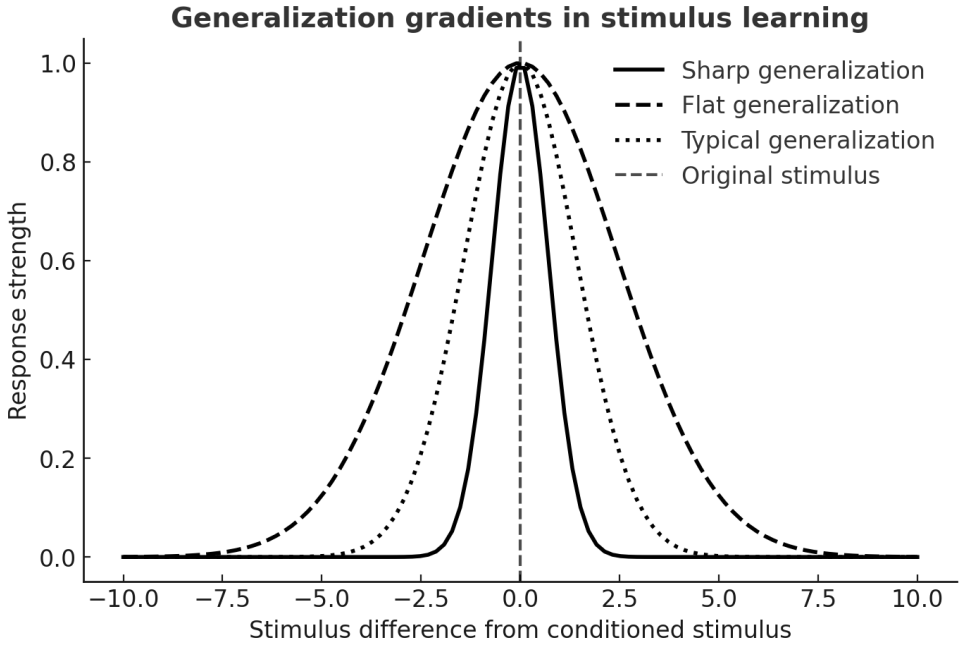

Figure 1.3
The figure depicts different generalisation gradients. The three different lines indicate different types of gradients, a broader gradient indicates more generalisation between stimuli.

A gradient that is sharp and has a clear peak (steeper) indicates that there is better discrimination between stimuli meaning there is less generalisation. Whereas a flatter or broader (shallow) gradient indicates that responding is similar across a wider range of

stimuli indicating that there is more generalisation. If the gradient is completely flat this indicates a high level of generalisation in which the participants cannot distinguish differences between any of the stimuli. Using this type of method to study generalisation allows researchers to manipulate different factors or explore individual differences, such as anxiety or age, that can influence the shape of the gradients.

1.4.4 Generalisation of fear

As previously mentioned, it is important to highlight that generalisation is also adaptive and allows us to quickly and effectively transfer previous knowledge to new novel situations and stimuli (Hermans et al., 2013). It can trigger a critical response when stimuli are similar to one that was previously associated with an aversive outcome. This process can be crucial for survival, particularly when a new stimulus resembles one previously associated with an aversive outcome. However, excessive generalisation—referred to as overgeneralisation—can be maladaptive and is considered a potential endophenotype (or intermediate marker) of anxiety disorders (Gottesman & Gould, 2003; Lissek et al., 2010). Overgeneralisation occurs when the response to stimuli is exaggerated and no longer useful (Lee et al., 2024). Research indicates that individuals with anxiety disorders exhibit higher levels of fear generalisation compared to those without anxiety (Cooper et al., 2022). Overgeneralisation may contribute to the development of certain groups, such as agoraphobia, where fear responses generalise excessively, preventing individuals from leaving their homes. This maladaptive behaviour can severely impact quality of life and highlights the importance of understanding generalisation processes in both adaptive and maladaptive contexts to help inform treatments and interventions(Lee et al., 2024).

Generalisation of fear has been widely studied in humans with the first empirical demonstration of this in 1937 (Hovland, 1937). In this experiment participants were

conditioned using a tone and an electric wrist shock, they were then tested with three additional tones. It was shown that participants exhibited fear responses, as measured by skin conductance, to the three additional tones despite them never being presented with the shock. As the tone became less similar to the tone that was conditioned, the fear responses decreased. This shows that fear can generalise to other stimuli within a healthy population. Due to the proposed relationship with anxiety, there has been a wealth of research on fear generalisation in humans (Cooper et al., 2022; Sep et al., 2019). Studies using fear conditioning and a generalisation paradigm in which participants are trained to discriminate between a CS+ and a CS- and are then tested with generalisation stimuli. They then explore group differences based on clinical diagnoses or individual differences in traits associated with anxiety such as trait anxiety.

Research using clinical samples has indicated that individuals with anxiety disorders exhibit broader generalisation gradients compared to healthy controls (Cooper et al., 2022). For instance, participants with generalised anxiety disorder (GAD) demonstrated shallow gradients, indicating a conditioned response even to stimuli dissimilar to the trained CS+ (Lissek et al., 2014). This indicates an overgeneralisation of fear to stimuli that are safe. Similarly, a study comparing healthy controls and individuals with panic disorder found that the panic disorder group had broader gradients, suggesting increased fear generalisation (Lissek et al., 2010). In another study, individuals with post-traumatic stress disorder (PTSD) showed decreased reaction times for stimuli resembling the CS+, suggesting that these stimuli elicited fear, leading to quicker responses (Lis et al., 2020). Moreover, a recent meta-analysis examined 16 studies which looked at different anxiety disorders including obsessive-compulsive disorder (OCD) and PTSD (Cooper et al., 2022). The analysis revealed that fear generalisation was significantly

elevated in individuals with anxiety disorders compared to healthy controls. The results were robust, with no moderating effects from specific disorders, methodologies, or clinical diagnoses. However, some disorders exhibited larger effect sizes, with PTSD and GAD showing the strongest associations. This is consistent with the characteristics of these disorders—GAD involves broad generalisation to anxiety-inducing stimuli, while PTSD often includes generalisation to trauma-related stimuli. Collectively, these studies suggest that individuals with anxiety disorders generalise fear more extensively than healthy individuals, potentially contributing to the development and maintenance of these disorders.

Additionally, research has explored individual differences linked to anxiety such as the role of trait anxiety, a personality characteristic representing a predisposition to experience anxiety irrespective of situational triggers. While trait anxiety is not inherently pathological, higher levels can predict the development of anxiety disorders (Van Dam et al., 2013). Studying trait anxiety can help identify individuals at higher risk for such groups. A meta-analysis of 18 studies revealed that higher levels of trait anxiety are significantly associated with increased fear generalisation (Sep et al., 2019). Although the effect size was smaller than that observed in clinical anxiety disorders (Cooper et al., 2022), the findings suggest a relationship between fear generalisation and anxious traits. Moreover, research has explored other traits that are related to anxiety such as ambiguity. Wong and Lovibond (2018) investigated how trait anxiety effects generalisation of fear in ambiguous situations. Participants underwent typical fear conditioning and then a generalisation test and it was found that those with high trait anxiety exhibited overgeneralisation of fear responses but only when they could not identify rules (heightened ambiguity). Together, these results suggest the following relationship: as anxiety levels increase, so does the

extent of fear generalisation. It is noted that these findings are from made from correlational data and whilst this can highlight key relationships, perhaps a next step in this literature would be to manipulate anxiety levels to see the direct effects on avoidance behaviour.

1.4.5 Generalisation of avoidance

The previous section focused primarily on fear because much of the existing literature has been centred on this aspect, while significantly less attention has been paid to generalisation in avoidance behaviours. Given that avoidance is a hallmark of anxiety disorders, exploring this phenomenon is an important line of research. An account of avoidance generalisation suggests that people initially develop fear to a stimulus, therefore they avoid situations or places where this stimulus occurs. This results in less fear being experienced, which then leads to the avoidance being reinforced. This ultimately results in the avoidance of an increasingly broader range of stimuli. It is also noted that there has been research which has shown that there can generalisation to other responses and contexts.

Although the existing literature is small there has been evidence that avoidance behaviour does generalise to other stimuli. For example, research has demonstrated that avoidance behaviours, including those that are instructional or socially transmitted, can generalise (Cameron et al., 2015). They classically trained participants with a CS+ (paired with a shock) and CS-, following this participant were split into two groups with one group being instructed how they can avoid the shock, and the other group watched a video showing a visual demonstration of how to avoid a shock. The participants were then presented with generalisation stimuli that were similar to the CS+. They found that both groups showed generalisation of avoidance behaviour across fear expectancy, avoidance

behaviour and physiological arousal but there was no difference between the two groups. Moreover an experiment assessed fear and avoidance using a continuum of semantic stimuli (Boyle et al., 2016). They used a task that involved fear conditioning, avoidance training and a generalisation test. They used semantic stimuli such as 'broth' and 'assist' as the CS+ and CS- and in the test they word such as 'soup' and 'help'. They found that fear (skin conductance responses) and avoidance behaviour generalised to semantically related stimuli but not to unrelated words.

Moreover, there has been some research into the generalisation of responses. One study used a task that utilises a robotic arm, which participants have to manoeuvre to a target to avoid a shock (Meulders et al., 2016). There were possible pathways to follow which vary in terms of effort and contingency to avoid, for example high effort and will always avoid the shock or low effort and will only avoid the shock 25% of the time. They found that the responses did generalise to similar arm movement trajectory responses. There has been little research into the generalisation of avoidance to different contexts however, it has been shown in an experiment using the robotic arm task that avoidance behaviour may be context dependent (Meulders et al., 2020). Avoidance behaviour that was learned in one coloured context (black or white) generalised to other stimuli (shades of grey) but responding decreased as the context became less similar to the trained context which could suggest that avoidance behaviour is context dependent (*see Chapter 7 for more on context generalisation*).

Current anxiety treatments primarily target fear extinction but often neglect avoidance behaviours. Consequently, patients may no longer fear a stimulus yet continue to avoid it. This has been evidenced within the laboratory in rats (Mineka, 1979) and in humans (Vervliet & Indekeu, 2015) preventing them from learning that the feared outcome

may no longer be associated with the stimulus. This avoidance can lead to relapse and the return of fear. If avoidance generalises similarly to fear, it could exacerbate this process, making the study of avoidance generalisation crucial for understanding anxiety disorders.

Although limited, research on the generalisation of avoidance in humans has yielded important findings. Individual differences in personality have been examined in combination with avoidance generalisation (Van Meurs et al., 2014). This study used a novel 'farming game' to investigate this. In this paradigm, participants could choose between a short, shock-paired path or a longer, shock-free path while planting seeds. Shapes appearing along the paths signalled whether a shock would occur (e.g., a circle indicated shock, while a triangle indicated no shock). During the test, participants were tested with varying different sizes of the shapes to test for generalisation. Taking the short path will allow more seeds to be planted which will increase the points therefore the authors determined taking the longer path when the generalisation stimuli was presented was a maladaptive avoidance response (i.e., avoidance of the shock-paired short path). The study found that higher levels of fear towards generalised stimuli correlated with greater avoidance behaviour, with avoidance decreasing as stimuli became less similar to the CS+. Interestingly, no association was found between trait anxiety (measured via the State-Trait Anxiety Inventory, STAI) and avoidance levels, which is at odds with expectations based on existing literature that more anxiety would lead to more avoidance (Salters-Pedneault et al., 2004). While this absence of a relationship is notable, the study still demonstrates that avoidance behaviour can generalise and that this process is linked to fear generalisation. Further research exploring both fear and avoidance generalisation has shown that while fear generalises broadly, costly avoidance may dissociate from fear and generalise to a lesser extent (Glogan et al., 2022). This suggests that fear and

avoidance may involve distinct yet interacting mechanisms. Furthermore, a similar study using shapes as the stimuli and also used fMRI data to assess brain regions involved in generalisation (Norbury et al., 2018). They found that avoidance behaviour did generalise and that it was related to both perceptual similarity and value-based learning, engaging brain regions such as the sensory cortex, anterior insula, amygdala, and ventromedial prefrontal cortex. Additionally, the study found that individuals with higher self-reported anxiety showed greater generalisation of avoidance, suggesting a link between overgeneralised avoidance learning and anxiety disorders.

A limitation of existing studies is that they often use stimuli which only one side of the generalisation gradient. For example, if the CS+ is a large circle and the CS- a small circle, the tested stimuli typically fall between these two sizes, leaving unexplored what happens with stimuli larger than the CS+. This approach may not capture the full picture, as participants might adopt a "linear" rule (e.g., larger is better), which could influence task sensitivity to overgeneralisation (Lee et al., 2018). A more comprehensive investigation could involve testing a full gradient where the CS+ is positioned in the middle of the continuum. Examining full gradients may increase sensitivity and enhance our understanding of avoidance behaviour and its relation to anxiety. Future research could investigate whether these effects can be predicted based on anxiety levels, providing deeper insights into avoidance mechanisms and their role in anxiety disorders.

1.5 Generalisation, Avoidance and Anxiety

Despite significant advancements in understanding fear generalisation, much less is known about the interplay between avoidance generalisation and the relationship with anxiety in humans. Avoidance is a core feature of anxiety disorders, yet it has received less research attention in comparison to fear. Avoidance behaviours are crucial to study

because they can perpetuate anxiety through reinforcement cycles, where avoiding a feared stimulus reduces fear temporarily but prevents the individual from learning that the stimulus is not necessarily associated with threat (Lovibond et al., 2009). This can lead to the generalisation of avoidance to other, similar stimuli, potentially broadening the impact of anxiety on daily functioning (Arnaudova et al., 2017). Additionally, research on anxiety often focuses on fear extinction, neglecting the role of avoidance, which is critical for understanding treatment relapse. Studying avoidance generalisation and the relationship with anxiety is essential for understanding the mechanisms by which avoidance develops, generalises, and contributes to the persistence of anxiety disorders. To date, only one study has investigated individual differences, such as trait anxiety and tolerance to uncertainty, in relation to avoidance generalisation. In this study, participants were trained with three stimuli (coloured lamps): a CS− and two CS+ stimuli, one avoidable and the other unavoidable (San Martín et al., 2020). During the test phase, generalisation stimuli were introduced, consisting of colours that fell between the CS+ and CS−. The results showed that anxiety traits, including distress tolerance and intolerance of uncertainty, were associated with higher levels of avoidance toward the generalisation stimuli. This study provides unique empirical evidence supporting a relationship between avoidance, anxiety, and generalisation.

By integrating these areas of research, we can better understand how anxiety disorders evolve and identify trans-diagnostic features, such as overgeneralisation, that may underpin multiple forms of anxiety. Investigating these phenomena in humans could pave the way for more comprehensive and effective treatments that address both fear and avoidance, potentially reducing the risk of relapse and improving long-term outcomes for individuals with anxiety disorders (Hofmann & Hay, 2018; Treanor & Barry, 2017).

1.6 Different events that participate in instrumental avoidance

Whilst this introduction has briefly explored the overarching themes of the thesis, each chapter will tackle different research questions regarding these themes. Therefore, the introductions of each of the subsequent chapters will cover the specific literature regarding these research questions. Broadly, this thesis can be divided into three key lines of research questions which are determined by the types of events being investigated, these are warning signals, safety signals and the context. Exploring avoidance behaviour with different experimental paradigms will help to understanding the underlying mechanisms for its development and maintenance.

Warning signals are stimuli that predict the occurrence of an aversive or negative event. They are important cues in the environment that allow organisms to prepare or avoid potential dangers through Pavlovian conditioning. An example of this would be if someone had been bitten by a dog in the past, the sound of a dog barking may serve as a warning signal and cause the individual to avoid walking near where the sound is originating. In anxiety disorders such as PTSD, the study of warning signals is integral as the condition involves individuals perceiving certain cues as warning signals for traumatic events, even when they are no longer predictive (Ehlers et al., 2002). In the context of avoidance this could result in individuals avoiding a broader range of stimuli perceived as threatening. Understanding how warning signals can result in generalised avoidance can help in treatments for anxiety, such as exposure therapy, by modifying the response to perceived threats (Kodzaga et al., 2023).

Safety signals are stimuli which explicitly indicate the absence of an aversive event (Hefner et al., 2016). Safety signals can inhibit fear or anxiety responses that would

otherwise occur in the presence of a warning signal or a conditioned fear stimulus. This is also known as conditioned inhibition. An example of this would be someone with OCD checking that the door is locked by pulling the handle a certain number of times, the exteroceptive feedback form this action can function as a safety signal . It has been shown a range of stimuli can become safety signals including people, places and behaviours. For instance, carrying a good luck charm or having a trusted individual present during a threatening event, or carrying anxiety medication around with you can serve as safety signals. Whilst safety signals can reduce anxiety, they can also hinder treatment due to protecting behaviours from extinction (used in CBT). It has been shown that safety signals can reinforce behaviour in rats (Fernando et al., 2014) in that even when both levers result in no aversive outcome the rats prefer the one that produced a safety signal. Whilst this has been evidenced in rats there have been no evidence in humans replicating these findings. Therefore, understanding safety signals and whether behaviour reinforced by them generalises is crucial to aim to reduce the dependency of these during therapy.

The term context has many definitions but overall can be defined as the environmental, situational, or background conditions in which learning occurs (Holland & Bouton, 1999). This context can influence learning by acting as a cue in which it can enhance or suppress learned behaviour, but they can also act as modulators that facilitate the retrieval of specific associations (Urcelay & Miller, 2014). There are many different aspects of context including the physical features of the environment such as the location, lighting or background noise. There can also be the temporal context which refers to the time learning occurred (Bouton, 1993). The internal context refers to the internals states or individuals such as their emotional (mood), physiological (stress) or substance induced states (Overton, 1991). There is also the social context which refers to

the presence of others during learning. An example of how context can influence behaviour would be patients undergoing CBT treatment in a therapist's office, they may learn to manage their symptoms however when they leave the therapists office, they are no longer able to do this indicating that the office has become a learning context (Bouton & Swartzentruber, 1991). Understanding the role of the context could help to optimise treatment interventions for those with anxiety.

1.7 Aims of thesis

The overarching aim of this thesis is to expand our current understanding of avoidance behaviour and generalisation spanning across safety signals, warning signals and contexts. In addition, I want to assess whether these forms on avoidance generalisation interact with anxiety levels in healthy participants. Specifically, this thesis aims to address gaps in the literature by exploring how various factors, both experimental and individual differences, influence the generalisation of avoidance. This thesis has three key questions it aims to investigate:

1. Does avoidance behaviour generalise?
2. Is there a relationship between anxiety and avoidance behaviour?
3. Is there a relationship between avoidance, generalisation and anxiety?

Collectively, we hope to better understand the mechanisms underlying generalisation of avoidance in humans, contributing to the wider field in developing preventative and therapeutic strategies for anxiety disorders. This thesis is separated to the three following sections: warning signals, safety signals and context.

1.7.1 Generalisation of Warning Signals, Chapters 2-4

1.7.1.1 Contiguity Experiments 1-5, Chapter 2

The purpose of these experiments is to examine the generalisation of warning signals using a novel trace procedure in the hope to increase sensitivity of investigating individual differences. It has been shown that those with anxiety generalise fear to other stimuli more than healthy individuals (Lissek et al., 2014). For example, a phobia of a specific dog breed may generalise to all dogs. Although the idea has intuitive appeal, recent tests with large healthy samples have not found evidence of overgeneralisation (Stegmann et al., 2019). This has led to the suggestion that overgeneralisation particularly occurs in those with anxiety when there is stimulus-outcome ambiguity (Wong & Lovibond, 2021). Basic experiments in nonhuman animals have revealed that overgeneralisation (non-discriminated avoidance) occurs when there is a gap (i.e., trace) between the stimuli and the outcomes(Kamin, 1954) - in other words, because the temporal gap creates ambiguity between the stimuli and outcomes, subjects displayed non-discriminated avoidance. There have been no demonstrations of this phenomenon in humans therefore highlighting that combining trace procedures with overgeneralisation and avoidance behaviour is of high research interest. If this phenomenon is found in humans, it is critical to identify the specific circumstances in order to improve existing treatments. It has been shown that ambiguity modulates anxiety and the generalisation of fear (Wong & Lovibond, 2018) however, studies have not assessed whether ambiguity introduced by trace procedures in humans results in overgeneralisation of avoidance. This chapter aims to investigate generalisation of avoidance performance in humans, using a novel trace procedure approach. Firstly, a new online task that includes uncertainty by adding a trace group and delay group, which was a control group, was designed and

piloted *(Chapter 2: Experiment 1 & 2)*. This was then further assessed using a between subjects' task online to allow direct comparison between the two groups *(Chapter 2: Experiments 3 & 4).* Finally, investigating the trace and delay groups within subjects within the laboratory to assess the relationship with anxiety *(Chapter 2: Experiment 5)*.

1.7.1.2 Effects of Stress on the generalisation of avoidance, Chapter 3, Experiments 1-2

These experiments set out to investigate the effects of stress on the generalisation of avoidance behaviour. We wanted to assess if differences in stress result in differences in generalisation of avoidance behaviour. It has been suggested that there is a link between stress and anxiety both in the aetiology and the maintenance of anxiety disorders. There has been little research investigating the relationship between stress and anxiety on avoidance behaviour despite the clinical applications to disorders such as post-traumatic stress disorder. We wanted to investigate this so we utilised the delay condition of the previous chapter (Chapter 2; *see above*). We wanted to investigate this both using self-reports and by manipulating stress levels. Firstly, we assessed whether self-reported perceived stress had a relationship with avoidance behaviour and its generalisation *(Chapter 3: Experiment 1).* Secondly, we causally manipulated stress with a social stressor mood induction to assess whether this influenced generalisation of avoidance behaviour *(Chapter 3: Experiment 2)*.

1.7.1.3 Ontogeny of the generalisation of avoidance, Chapter 4

The onset of anxiety disorders has become younger over recent years; particularly since Covid-19, with an increase in the prevalence of anxiety disorders being diagnosed in children. Much of the existing literature on anxiety comes from adolescent and adult samples therefore little is known about the ontogeny of anxiety. In particular avoidance, is particular understudied with only a few experiments comparing generalisation in children

to adults. In this experiment we wanted to investigate how the generalisation of avoidance behaviour changes with developmental age, and if levels of anxiety (reported by caregivers) modulate this *(Chapter 4).* Research on generalisation in children is limited and in studying it in conjunction with anxiety levels this could provide some pre-screening/susceptibility measure that could then help with prophylactic interventions.

1.7.2 Safety Signals and their generalisation, Chapters 5 and 6

1.7.2.1 Safety Signals Review

The aims of this review were to identify and explain the current literature on relief with a focus on instrumental conditioning. This review assessed the current findings in the animal literature with a focus on the work involving safety signals and the human literature which utilises both self-reports of relief (Vervliet et al., 2017) and behavioural measures (Angelakis & Austin, 2015). It also considers the theoretical framework of relief such as Two factor theory (Mowrer, 1951); Relaxation theory (Denny, 1971) and Opponent Processing Theory (Solomon, 1980). Finally, it considers individual differences within the human literature and the applications of the work into relief and safety signals such as enhancements to treatments.

1.7.2.2 Safety Signals Experiments 1-5

The first aim of this line of experiments was to demonstrate for the first time in humans the reinforcing properties of safety signals. This has been documented within rats (Fernando et al., 2014) but never shown with humans. However, there has been work in humans on relief which is thought to be a possible reason why safety signals become reinforcing. There is an emerging body of work in humans which has shown that individuals experience more pleasant feelings of relief when they have avoided an aversive

outcome(Vervliet et al., 2017). However, this research relies on self-reports which do allows us insight into the emotional experiences' participants but do not allow us to assess the reinforcing properties of safety signals, if a safety signal provides a positive feeling of relief, then it should also reinforce avoidance behaviour, therefore in this chapter we investigated this. The reinforcing properties were tested with a range of controls, including generalisation. Firstly, I compared the reinforcing properties of a safety signal vs nothing *(Chapter 6: Experiment 1)*. Secondly, in an attempt to investigate generalisation of safety signals, I assessed the safety signal vs a similar signal *(Chapter 6: Experiment 2)* and a dissimilar signal *(Chapter 6: Experiments 3 and 4)*. Furthermore, to assess the reinforcing properties transferred to a new response, the response was changed during the test phase to assess the transfer *(Chapter 6: Experiment 5)*. The different controls and safety signals allowed us to observe generalisation across experiments to similar but not dissimilar safety signals.

1.7.3 Generalisation of Context, Experiment 1, Chapter 7

1.7.3.1 Context Experiments 1

Finally, the aim of this experiment was to examine the generalisation of avoidance across contexts. It can be argued that contexts play a fundamental role in cognition, yet the literature is unclear as to whether avoidance behaviour generalises across contexts (Meulders et al., 2020, 2024). This experiment is the first step within the human literature in determining whether this depends on similarity, which is a property of generalisation tests. Therefore, this experiment manipulated the background colour to investigate whether this had an effect on avoidance behaviour.

1.8 Thesis Approach

1.8.1 Avoidance Task

This body of work whilst having different streams of projects and assessing different aspects such as warning signals, safety signals and the context it has a central avoidance task. Each experiment (*except Chapter 4 as we needed a task that was suitable for children*) utilises the same task as we wanted to develop a task that could be used to investigate multiple aspects of avoidance behaviour. In order to develop this task a number of decisions had to be made so that the main aspects and phases of the task could remain consistent across different streams of research. The basics of the task are that the participants are presented different stimuli (coloured squares, fractals or Gabor patches) some of which are paired with an aversive outcome (an aversive image in online experiments and a loud noise in laboratory experiments) and some are not. The participants can avoid the aversive outcome by pressing the space bar, for this to be successful it needs to be 1 second before the aversive outcome is due to be presented. There is variability in when the aversive outcome can occur, it will either be seconds 4, 5 or 6 of a trial and as the aversive outcome always results in termination of the CS then this means the CS can either be 3,4 or 5 seconds in length. This added variability encourages participants to press the space bar more than once for a better chance at successful avoidance. Participants are told that they may need to press the space bar more than once to avoid but are not given any information about the variability of the aversive outcome.

The overall structure of the tasks is similar in that all versions of the task have a pretraining phase an avoidance training phase and then a test phase. The pretraining and avoidance stages are similar, but they use different stimuli as the CS. Participants have to

reach a criterion of responding more to the CS+ compared to the CS- for two consecutive blocks. The reason for this is that this thesis conducted a large amount of these experiments online. Therefore, we wanted to ensure that participants were engaged with a task and understood the tasks instructions.

None of the experiments within this thesis have a pavlovian stage and this was a decision made on the basis of wanting to increase uncertainty. As there was a pretraining phase in which the participants gained experience in the task (same as avoidance training) we were able to omit this section. This also addresses the argument that differences in anxiety cannot be observed without incorporating some ambiguity (Wong & Lovibond, 2021). Furthermore, whilst out of the scope of this thesis the intention is to use the data to conduct computational modelling and in order for this to be conducted there needs to be learning present during the avoidance training. With a pavlovian phase this would have eradicated this as participants would already know the CS and US pairing so on the first avoidance trial there would already be differences between the CS+ and the CS-.

Furthermore, on the notion of uncertainty we decided to make the aversive outcomes variable (as stated above), in doing this it adds ambiguity into when the aversive outcome will occur. Furthermore, we wanted to use a task similar to Flores et al. (2018) in order to get a measure of avoidance that was more than a binary button press. Therefore, we opted to use a task that encourages the participants to make more than one response; in using a variable aversive outcome it allows this as participants best strategy is to press the button more than once for successful avoidance. This allows us to look at the number of responses made per trial, and we can see if this changes as trials increases or with different stimuli. This way of measuring avoidance may be more sensitive to assessing differences in individual differences.

All of the generalisation test phases within this thesis are completed on extinction, i.e. the aversive outcome (loud noise or IAPS image) is no longer presented. This is due to the primary goal of a generalisation test is to assess how a conditioned response, such as fear or avoidance, extends from one stimulus (CS) to similar stimuli (generalisation stimuli). By omitting the unconditioned stimulus (US) during the test phase, researchers can observe how the learned behaviour, like avoidance, transfers to new stimuli without being reinforced by the aversive outcome. If participants continue to avoid similar stimuli in the absence of the US, it suggests that the avoidance behaviour no longer relies on reinforcement from the aversive stimulus itself.

Furthermore, whilst there is a growing literature on the cost of avoidance behaviour (Meulders et al., 2016; Pittig & Scherbaum, 2020) this thesis did not use a costly task. The other research in the field does not use costly avoidance tasks (Krypotos et al., 2018) and because many of the experiments conducted in this thesis have not been conducted in humans before we wanted to keep the task as simple as possible. However, in Chapter 8 it is highlighted that this would be a future direction based on the results of this thesis.

Moreover, we used the same stimuli across experiments in different ways. The object of interest (warning signal, safety signal or the context) was always a stimulus from the blue-green continuum. This was selected as it has been used in a range of generalisation experiments (Alcalá et al., 2024; Lee et al., 2021). As there are 21 colours across the continuum, which have been selected to be equal differences apart, it allowed us to assess generalisation in a standardised way and to test a large number of stimuli. Within each of the experiments there are variations of the task the phenomena of interest but the overall the core task remains the same.

1.8.2 Data Analysis

As with the methodological design, several key decisions were made regarding the data analysis approach in this thesis. While different streams of experiments required distinct analyses, many elements were consistent across studies. For the generalisation tests, three primary types of analysis were employed. First, we utilised ANOVAs, which are the standard analytical approach for generalisation data. In these analyses, we reported quadratic functions, as we expected the data to exhibit a generalisation curve. Second, in Chapters 2 and 3, we applied a Gaussian-augmented model (Lee et al., 2021), which enables the assessment of each side of the gradient independently. This model was chosen because its parameters (detailed in Chapter 2) are thought to be less susceptible to Type II errors. Third, in Chapters 3 and 7, we implemented a generalisation slope analysis. This was done to examine age-related effects in Chapter 3, and in Chapter 7, because the use of linearly spaced generalisation stimuli rendered the data incompatible with Gaussian modelling.

Additionally, we employed median splits to categorise participants into high and low trait anxiety groups. This decision facilitated the use of trait anxiety as a between-subjects factor, allowing for clearer and more interpretable group comparisons within the ANOVA framework. While median splits may reduce sensitivity compared to continuous analyses, they are widely used in the literature field (Lawrance et al., 2022 ; Wong & Pittig, 2023) - including, Fisher & Urcelay, 2024) and were deemed appropriate given the exploratory nature of our trait-

based comparisons. Importantly, this approach was applied consistently across all analyses to ensure methodological coherence and comparability of results throughout the thesis.

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Chapter 2

Trace procedures broaden avoidance generalisation gradients

Abstract

Generalisation of fear is a candidate endophenotype however, the generalisation of avoidance is less understood. The limited research shows that avoidance behaviour does not always follow the patterns of fear. Furthermore, current paradigms may not be sensitive for investigating the individual differences of anxiety. Therefore, this series of experiments we developed an avoidance generalisation test in which we could compare delay and trace procedures and investigate the generalisation of avoidance behaviour and anxiety. Experiment 1a and 1b were pilot studies of the avoidance generalisation task to test delay (US immediately after CS termination) and trace (US approximately 6s after CS termination) groups. Experiments 2 and 3 were online between subjects' experiments comparing delay and trace procedures and their effect on generalisation of avoidance behaviour. Experiment 4 was a within-subject laboratory experiment in which participants completed both trace and delay conditions. It was found consistently that generalisation gradients were broader in the trace groups compared to the delay. Furthermore, experiment 4 suggested that it was the delay group which was most sensitive to detect differences between high and low trait anxiety. Overall, this study indicates that avoidance behaviour generalises across a continuum which may be of clinical relevance when designing treatments for anxiety disorders.

2.1 Introduction

Anxiety disorders are the most prevalent mental health disorder worldwide, affecting 61.5 million people in Europe alone (Wittchen et al., 2011). Research has predominantly focused on fear which is present within all anxiety disorders (Fraunfelter et al., 2022). A potential factor for the persistence of fear within anxiety is stimulus generalisation. This can be defined as excessive fear towards stimuli that are similar to the initial threat stimuli either conceptually or perceptually (Arnaudova et al., 2017). On a continuum of stimuli that differ along a dimension (i.e colour) conditioned responses fluctuate as a degree of similarity with the CS (Guttman & Kalish, 1956). Generalisation is

an adaptive function which allows us to quickly transfer past knowledge to new novel situations and stimuli (Hermans et al., 2013), triggering a response when stimuli are similar to one that was previously associated with an aversive outcome. For aversive outcomes, it is beneficial to have a broader generalisation response, as it is more costly to incorrectly assume a threatening cue is safe, than a safe stimulus as threatening (Laufer et al., 2016). This has been referred to as a "better safe than sorry" strategy (Lommen et al., 2010). However, in the case of anxiety disorders it has been proposed that this is maladaptive and people overgeneralise fear (Boyle et al., 2016). Overgeneralisation can be defined as excessively responding to stimuli that are similar to the original fearful stimulus (Lissek et al., 2010). Within the fear literature the overgeneralisation effect has been observed consistently in both healthy samples with high trait anxiety (Sep et al., 2019) and clinical samples with people with anxiety disorders (Cooper et al., 2022). Therefore, it has been proposed that overgeneralisation is a putative endophenotype (or intermediate marker) of anxiety.

Research investigating human avoidance behaviour is limited and research into generalisation is even more scare. Research is conflicting, Boyle and colleagues (2016) used a semantic stimuli continuum in which they found that avoidance responses did generalise to other similar stimuli but these responses did not correlate with physiological measurements of fear (SCR). However, research using a novel farming simulator game, in which participants had to harvest crops by moving between a shed and a garden to plant seeds and earn points, investigated fear and avoidance measures (Van Meurs et al., 2014). Shapes were superimposed onto the screen; one was paired with an electrical shock (CS+) and the other was not (CS-). These were small and large circles. Participants could avoid the electric shock by taking the longer path which had a cost in that the participant

was not able to harvest as many crops. Generalisation stimuli (GS) were also presented (different sized circles). Results indicated that the GS and CS+ evoked the longest reaction time indicating a conflict between avoiding and getting a higher task score. Moreover, they observed the shapes of the generalisation gradients of fear potentiated startle responses to the stimuli (Pavlovian) and the amount of avoidance (instrumental). It was found that broader skin conductance gradients (a measurement of fear) were accompanied by broader avoidance gradients however, they found no effects of anxiety on either generalisation curves. Further research has also found that with perceptual stimuli avoidance behaviour seems to generalise, in healthy participants, to stimuli similar to the trained CS+ (Arnaudova et al., 2017) and this is linked to traits linked to anxiety (neuroticism) (Lommen et al., 2010). Overall, the evidence in humans seems to suggest that avoidance behaviour can generalise to similar stimuli however, it is unclear whether there are links with anxiety levels so further research is needed.

There are a number of factors which can influence the shape of a generalisation; one such factor is contiguity which refers to the temporal separation between conditioned stimulus (CS) and unconditioned stimulus (US) (Mackintosh, 1974). A way in which contiguity can be manipulated is using trace conditioning procedures; that is by inserting a temporal gap between the CS and US. Research in animals has shown that trace procedures can introduce ambiguity in the relationship between the two events. In a study by Ellison (1964) they trained dogs to discriminate between two different tones one was paired with food and the other was not. They had 2 different trace groups that had a temporal gap of 8 and 16 seconds. There were also two delay groups that were presented the tones for 8 or 16 seconds. When measuring the saliva flow, they found that during acquisition there were no differences in the two 8 second groups however, the 16 second

trace group showed the least amount of discrimination. This indicates that introducing a temporal gap can introduce ambiguity which then leads to difficulties in discrimination. Honey and Hall (1992) observed in rats that the use of a trace procedure attenuated learning of a CS+/CS- discrimination, consistent with the idea that trace procedures broaden generalisation gradients. Moreover, when restrained rats were trained with delay and trace groups it was found that when measuring the conditioned heart rate responses that the longer trace intervals led to weaker and less reliable heart rates (Marchand & Kamper, 2000). Overall, these suggest that introducing a trace can led to more generalisation to other stimuli (such as the CS-).

In humans there is limited research into the effects of trace conditioning on generalisation gradients. A recent preprint (Alcala et al., 2025) investigated trace conditioning in a predictive learning task. Participants were trained with coloured squares one of these (aqua) was the CS+ and then a green and blue stimulus were the CS-. During a generalisation test other colours across the blue and green continuum were presented. They found that the trace group had a broader generalisation gradient compared to the delay groups. However, they also observed that this was more prominent on green side of the colour continuum. Overall, this predictive learning task shows that trace can influence generalisation in humans.

Decreasing contiguity can be understood as introducing “ambiguity” regarding the status of a relationship between two events. Previous research has revealed that ambiguity modulates both anxiety and the generalisation of fear (Wong & Lovibond, 2020) however, studies have not assessed this in detail, in particular using active avoidance procedures. As said, ambiguity can result from situations in which the CS-US contingency is manipulated, or the CS-US temporal relationship (i.e., trace) is manipulated. In Kamin’s

(1954) experiment, physiological manifestations were observed in dogs trained with trace procedures. It was reported that the longer the CS-US interval, the more likely the animals were to display behaviours such as vomiting, whining, and bouncing. These behaviours are similar to the physiological symptoms of anxiety (American Psychiatric Association, 2013). This suggests that incorporating trace procedures may provide a more sensitive protocol for studying anxiety. There has only been one documented piece of research investigating the use of trace conditioning on human avoidance (Miller et al., 1970). In this experiment, participants had to press a button in order to avoid a blast of air behind their ear (US) but they received no instructions on what the avoidance response was. They manipulated both the duration of the CS which predicted the US (2, 5, 8 seconds) and the CS-US trace interval (0, 3 or 6 seconds). The results showed that neither effect was significant, but the latency data for the avoidance response showed that the time to make the avoidance response increased as the trace intervals got longer, thus suggesting that humans are sensitive to variations in the CS-US trace interval. Because ambiguity (and uncertainty) modulates anxiety (Morriss et al., 2019; Morriss & Ellett, 2024), then adding the trace element into an avoidance paradigm may provide a more sensitive test for individual differences in anxiety and overgeneralisation.

Furthermore, research on avoidance tends to use a one press task. This only allows the researchers to assess if participants avoided or not however, a better way to study this would be to incorporate a task which involves more active avoidance. Active avoidance is behaviour that escapes or prevents an aversive stimulus whereas passive avoidance is where avoidance occurs due to not engaging in particular behaviour (Cain, 2019). An example of these in a person with a phobia of dogs would be seeing a dog on the street and the taking a different route (active avoidance) or avoiding a friend who owns a

dog's house (passive avoidance). Utilising a task that focuses on active avoidance would allow researchers to assess the number of avoidance responses made by participants. One such task is that used by (Flores et al., 2018) which involves a variable US and window of time in which participants have to make a response within 1 second of when the US will occur, this approach encourages participants to respond more so a measurement of the rate of responding can be taken. Furthermore, this also introduces an element of ambiguity, which has been studied in conjunction with avoidance behaviour (Wong & Lovibond, 2021) for the participants will be unsure which avoidance response resulted in the successful avoidance of the US.

The current study aimed to investigate the generalisation of avoidance behaviour using a novel trace paradigm. It was thought that by using this novel approach it would be more sensitive to capturing the individual differences of trait anxiety on avoidance behaviour. We adopted a similar task to Flores and colleagues (2018) combined with a trace element. Due to the uncertainty of the trace, it was hypothesised that these gradients would be broader than the delay group indication more generalisation. It was hypothesised that those with high trait anxiety would make more avoidances responses than those with low anxiety, and that these differences would be bigger in the trace group. This chapter includes a series of 4 experiments. Experiments 1a and 1b were pilot studies looking at generalisation in human avoidance with delay and trace procedures, respectively. We run these experiments because we needed to ensure that both groups were suitable to be used online to collect data. Experiments 2 and 3 were conducted online and were between subjects' experiments comparing trace and delay groups. Experiment 4 was conducted in the laboratory with a biologically relevant stimulus (loud

noise). This experiment was also within-subjects to allow for more statistical power to also explore anxiety levels in addition to the trace and delay comparisons.

2.2 Experiment 1

2.2.1 Experiment 1a

2.2.1.1 Introduction

The aim of Experiment 1 was to develop an avoidance generalisation task in humans and ensure that the task was sensitive to collect online data. It is also noted that conducting research online there is a trade-off between gaining a more diverse sample and having less control of experimental settings. A key aspect of this study is that we wanted to assess anxiety levels, and it has been found that student samples, typically used in laboratory experiments, have heightened levels of anxiety (Thorley, 2017). Previous successful avoidance work has been conducted online (Cameron et al., 2022) and because we wanted to attempt to capture a wider range of anxiety scores we opted to create an online task. Particularly, we wanted to pilot the generalisation test part of the task to ensure that we included enough generalisation stimuli to produce a continuum, but not too many that it revealed the nature of the experiment to the participants. For online data, this was particularly important as participants can become demotivated and unresponsive with longer tasks, so we wanted to ensure that we were able to collect orderly data. Furthermore, we wanted to ensure that the aversive images (selected from the International Affective Picture System) were aversive enough that participants were motivated to avoid them.

2.2.1.2 Method

2.2.1.2.1 Participants

This study was approved by the School of Psychology's ethics committee at the University of Nottingham (Reference: S1402). The sample was recruited via prolific with the following inclusion criteria: they had to speak English, have no colour vision impairments and were aged 18 – 40. There were 60 participants however 9 were excluded due to not completing the pre training, so we ended with a sample of 51 participants who fully completed the experiment. There were 27 females and 24 males with ages ranging from 20 to 40 (M = 30.11, SD = 5.67). Participants were recruited online via Prolific (www.prolific.org) and were given information about the experiment (including the use of aversive images) before signing up to the study. They then received more information about the task and filled in a consent form before starting the experiment.

2.2.1.2.2 Design

This was a within subject's design with the independent variable being the colour of the generalisation stimuli presented during test of which there were 9. The dependent variable was the number of avoidance responses during the CS presentation of each trial in the training and the test phases of the experiment. Trait anxiety scores were also used to investigate the relationship with avoidance behaviour. There were four key phases to the experiment including completing the state and trait anxiety index (STAI) scales, pre training, avoidance training, test and expectancy scales.

2.2.1.2.3 Materials

Software

This experiment was made using Psychopy version 2022.2.2 and hosted via Pavlovia (Pierce et al., 20). Psychopy is an experiment builder which use a user graphics interface. In addition, the experiment used Pavlovia.org which is

developed by the same company to hose the experiment and allow the collection of online data. Prolific (www.prolific.com) was used to recruit online participants.

State and Trait anxiety scale

Participants completed a short questionnaire to assess their anxiety levels. The was the Spielberger's State-Trait Anxiety Inventory (Spielberg & Craighead, 2010) which contains 40 questions, all of which have a 4-point Likert scale from 1 to 4 (with 1 being not at all, 2 being somewhat, 3 being moderately so and 4 being very much so). The first 20 questions ask the participants to answer the questions based on how they are feeling at this very moment. These questions assess the participants state anxiety levels. Some example questions include 'I feel calm' and 'I feel frightened'. The remaining 20 questions assess trait anxiety and participants are asked to answer the questions based on how they generally feel. Some example questions include 'I feel secure' and 'I feel satisfied with myself'.

Aversive outcome

Aversive outcome images were selected from the international affective picture system (IAPS). The images chosen were aversive but not traumatic and all images had similar arousal and aversive ratings (*see Appendix 9.1).* A selection of six different images was chosen as there are many individual differences in the types of images that individuals find aversive. At the beginning of the experiment, participants had to rank all six images from least to most aversive. The image that was selected as the second most aversive was used as the outcome image during the experiment. The images included a spider, snake, a dirty toilet, a cockroach on a pizza, a surgery and a person vomiting. Having participants rate the images allowed the task to be tailored to them, potentially resulting in better avoidance learning. The second most aversive image was

chosen for ethical considerations as we wanted to ensure that the stimulus was aversive but did not want to traumatise the participants.

Pre-Training Stimuli

There were two fractal images used during a pre-training phase for all experiments (see Figure 2.1). These images were abstract fractals of different colours (yellow and red). These fractals were chosen as they differed in colour from the stimuli used in the other phases of the experiment. During pre-training, one fractal was paired with the aversive outcome, and the other was not, and participants had to press the space bar to avoid seeing the aversive outcome. These stimuli were always presented in the centre of the screen and were 50% of the screen height.

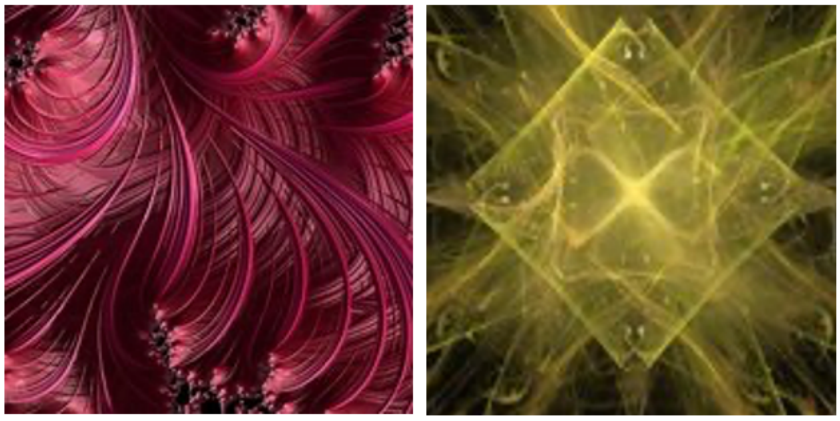

Figure 2.1
This shows the stimuli used in the Pre-Training stage, one of the fractals served as the CS+ and the other as the CS-.

CS Stimuli

In the training stage participants were shown three coloured square stimuli that acted as warning signals (*see CS-1, CS+, and CS-2 in Figure 2.2)*. These were taken from the blue-green continuum. The blue shade and the green shade served as the CSs- whilst the middle aqua shade served as the CS+. The stimuli were always presented in the centre of the screen and were shown for a maximum of 6 seconds (minimum of 3

seconds) but the presentation time varied trial to trial. The stimuli were programmed to be 50% of the screen height. The experiment opted to use two CS- stimuli to allow the assessment of a full gradient. In addition, within generalisation experiments a phenomenon called peak shift can occur when responding deviates from the CS+ and towards the stimulus that is farthest away from the CS-. Therefore, having two CS- ‘s on either side of the gradient should prevent this. Some studies have found that when using only one CS+ and one CS-, participants may adopt a simplistic rule for responding, such as associating a certain colour with safety or danger (Lovibond et al., 2020). To avoid this, we included two CS- stimuli to prevent participants from relying on a linear rule like 'the bluer (or greener) the stimulus, the safer it is,' ensuring a more robust and generalizable response pattern

Generalisation stimuli

The generalisation stimuli were also taken from the colour continuum (*see Figure 2.2*). The original colour continuum contained 21 colours from blue green however, it was decided that it is including all of these stimuli in the test would increase the chance for participants realising the objectives of the experiment. Furthermore, it would have increased the length of the experiment which we wanted to remain as short as possible to decrease the chances of participants becoming fatigued and unmotivated. Therefore 6 additional stimuli were chosen for the test phase of the experiment. The shades were all of equal distance apart on the continuum and 3 of the shades were blue and 3 were green.

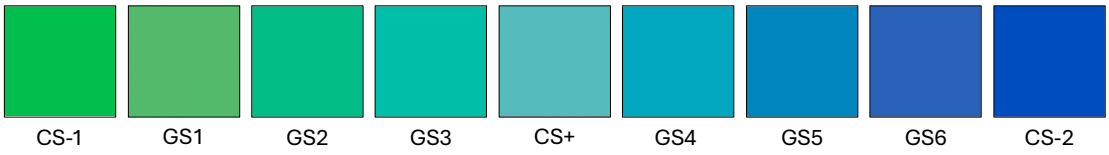

Figure 2.2
This is a figure including the generalisation stimuli. The CS+, CS-1 and CS-2 are used within the instrumental phase. The other six stimuli are the generalisation stimuli that are used within the test phase alongside the three used in the instrumental phase.

2.2.1.2.4 Procedure

After filling out a consent form and agreeing to take part, participants completed the anxiety scale (STAI). Following this, the participants ranked each of six aversive images which served as the aversive outcome. They ranked them from most to least aversive and the image selected as the second most aversive was used as the aversive outcome for the remainder of the experiment. This experiment involved four phases. These were pretraining, avoidance training, avoidance test and expectancy test.

Pretraining

The first phase was the pretraining phase. During this phase participants were presented with two fractal images. These were square images (these were 50% of the screen height and presented in the middle of the screen). The background was black throughout the whole experiment. One fractal served as the CS+ and was followed by the aversive outcome (aversive image US). The other was the CS- and was followed by nothing. Participants were instructed that they could avoid the aversive image by pressing the space bar on the keyboard. The CS's (both + and -) were variable in duration ranging from 2-5 seconds. In the CS+ trials, the US could appear during seconds 3-6 of this trial. If an avoidance response was performed one second before the US was scheduled to appear, avoidance was successful, and the trial ended. If the avoidance response was unsuccessful, then the aversive outcome was displayed for 1 second. The inter trial

interval (ITI) was variable with an average of 6 seconds. During the ITI, a white fixation cross was presented in the centre of the screen. There were two presentations of the CS+ and CSs- per block. The participants had to meet a criterion before they were able to complete the pretraining phase. For them to move on to the next phase, they had to respond more to the CS+ than the CSs- for two consecutive blocks. If participants failed the criterion, the pre-training continued for 20 blocks maximum, but once the participants met the criteria they then automatically progressed onto the next phase. If the participants did not pass the criteria, they were shown the end of the experiment screen, and the task ended, and this participants data was disregarded. Pre-training was used to make sure all participants understood the nature of the avoidance task. It also served as an attention checker to ensure that participants were actively taking part in the experiment and not just starting it and leaving it to run until the end without engaging in the task.

Avoidance Training

The second phase of the experiment was the training phase, which was similar to the pretraining phase, except that it used coloured square stimuli instead of fractals. These were presented in the centre of the screen and were programme to be 50% of the screen's height. There were 3 coloured squares presented in this phase. One of the squares was paired with the aversive image (CS+) and two were not (CS-1, CS-2). The CS+ was an aqua square taken from the mid-point of the blue-green colour spectrum *(see Figure 2.2)*. The CSs- were taken from the two ends of the blue-green continuum, therefore CS-1 was dark blue, and CS-2 was dark green. The aversive outcome could be avoided if the participants pressed the spacebar 1 second before the aversive outcome would appear. If avoidance was successful, the CS was terminated, and the aversive image was not shown. If unsuccessful the CS was terminated when the outcome was scheduled to

occur, and the aversive image (US) was shown for 1 second. The presentation of the aversive image was variable and could occur on seconds 4, 5 or 6 of the 6-sec CS+ trials. Therefore, the response windows for successful avoidance were seconds 3, 4 and 5. Each of the coloured square stimuli were shown 2 times per block in a randomised order and there were 5 blocks which equated to 10 trials of each stimulus.

Avoidance Test

The next phase was similar to the training phase however the aversive outcome was no longer shown (i.e., participants were tested on extinction). Also, in addition to the three training stimuli 6 new stimuli were presented. These stimuli were from the blue-green continuum that were the same height as the training stimuli and served as generalisation stimuli (GS). The participants received no instructions and went straight into the test phase. The stimuli were shown on the screen for 6 seconds and were the same size as the stimuli during the training phase. The ITI was variable the same as during avoidance training. Participants could press the space bar at any point during the test phase, and responses during the CSs were recorded. Each stimulus was tested once, and the order was randomised.

Expectancy Test

Participants were then asked to rate the 3 training stimuli on likely the aversive outcome was to follow each of them: 'Please rate how likely the aversive image will follow this stimulus on a scale of 1-9'. Each stimulus was presented separately with a 9-point scale with 9 being 'will certainly follow' and 1 being 'will not follow'. The order of the three stimuli was randomised. Finally, they were then presented with the aversive outcome used in the experiment and asked to' Please rate how aversive the aversive image is on a scale of 1-9' , with 1 being not aversive and 9 being extremely aversive.

2.2.1.2.5 Data Analysis

Avoidance responses on each trial were used as the main dependent measure of avoidance behaviour. We only analysed responses made when the CSs (CS+, CS-1, CS-2) were on the screen. This was the same in the test phase, only the responses made when the stimuli were on the screen were analysed. In the training phase a 3 (CS: CS+, CS-1, CS-2) X 10 (Trials) repeated-measures ANOVA was conducted. This allowed us to analyse the number of avoidance responses made per trial to the CS+ and the two CS- and examine the effects of stimulus along the 10 training trials.

In the test phase a one-way repeated-measures ANOVA was conducted with the 9 test stimuli to examine the generalisation of avoidance behaviour. Furthermore, to assess the relationship between avoidance generalisation and anxiety levels, additional exploratory ANOVAs were run. A median split was conducted with participants trait scores used to divide participants into high and low anxiety levels. Trait anxiety was chosen as this is the most widely used within the fear generalisation literature (Sep et al., 2019). Trait anxiety captures the anxiety levels participants feel in their day to day lives which is the most similar to the type of anxiety experienced by those with anxiety disorders.

If the data did not meet the assumption of the sphericity, then the Greenhouse Gessier correction was applied. The effect sizes reported for ANOVA's is the partial eta squared and for T-Tests Cohen's d was reported.

2.2.1.3 Results

2.2.1.3.1 Training

As training trials progressed, participants made more avoidance responses to the CS+ compared to CS-1 and CS-2 (*see Figure 2.3*A). A repeated-measures ANOVA revealed that there was a significant main effect of Trials, $F(6.112, 305.59) = 10.56$, $p < .001$, $\eta_p^2 =$

.174 and a main effect of CS, $F(1.48,73.92) = 65.28$, $p < .005$, $\eta_p^2 = .566$. Furthermore, there was a significant interaction between CS and Trials, $F(7.65, 382.26) = p < .001$, $\eta_p^2 = .211$. Post-hoc T-tests using the last block of training, revealed that participants responded more to the CS+ ($M = 10.1$, $SD = 6.09$) compared to the CS-1 ($M = 1.1$, $SD = 3.48$); $t(50)$ 9.36, $p < .001$, Cohens $d = 1.31$. Participants also responded more to the CS+ compared to the CS-2 ($M = 1.84$, $SD = 5.0$); $t(50) = 8.05$, $p < .001$, *Cohen's d* = 1.13. However, there was no difference in responding to the CS-1 and CS-2; $t(50) = -1.31$, $p = .097$, *Cohen's d* = -.18.

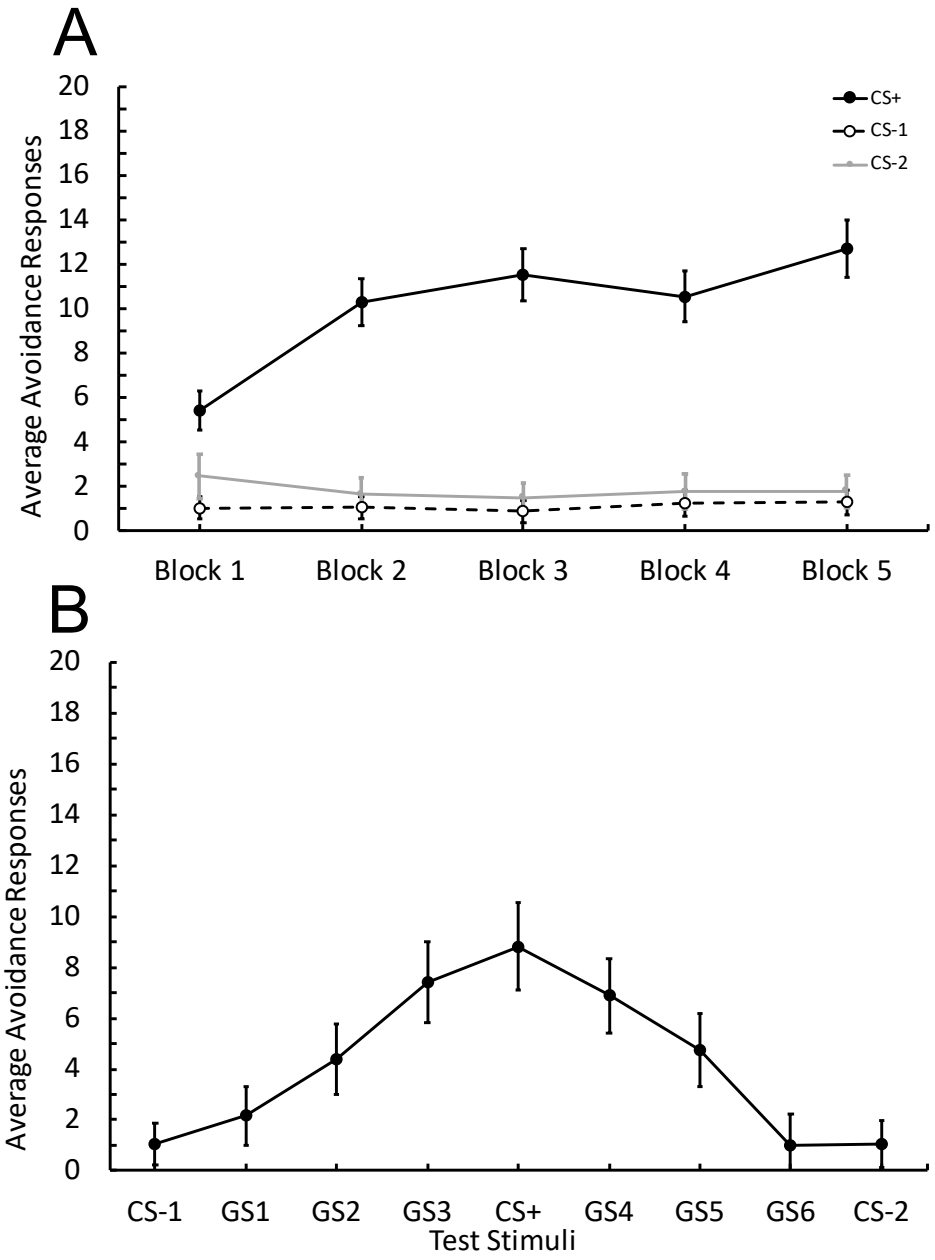

Figure 2.3

Results from Experiment 1a assessing the avoidance responses during training and test phases. *(A)* Training data depicting avoidance responses to the CS+, CS-1 and CS-2. Each block contains 2 trials. Participants made more responses to the CSs+ across blocks compared to both the CS-1 and CS-2. *(B)* Test data showing avoidance responses to the CS+, CS-1, CS-2 and the 6 generalisation stimuli (GS). Participants responded most to the CS+ and then this decreased as the stimuli became closer in similarity to the CSs-. Error bars depict standard error of the mean.

2.2.1.3.2 Test

During the test the participants responded the most to the CS+ and as the stimuli decreased in similarity to the CS+ the number of avoidance responses decreased with the fewest number of responses being made to the CS-1 and CS-2. A one-way ANOVA was used to examine whether there were differences in responding to each Stimulus (*see Figure 2.3B*). The quadratic contrasts were used as we expected the test data to follow a quadratic shape. There was an effect of Stimulus, $F(1,46.97) = 66.45$ $p < .001$, $\eta_p^2 = .571$.

2.2.1.3.3 Expectancy

The expectancy ratings given by participants were analysed using a one-way ANOVA which revealed an effect of stimulus $F(2, 81.44) = 121.317$, $p < .001$, $\eta_p^2 = .708$. Follow up paired t-tests. It was revealed that participants rated the CS+ ($M = 8.02$, $SD = 1.58$) higher than the CS-1 ($M = 2.29$, $SD = 2.41$); $t(50) = 12.33$, $p < .001$, *Cohen's d* = 1.726. Participants also rated the CS+ higher than CS-2 ($M = 2.20$, $SD = 2.26$); $t(50) = 11.93$, $p < .001$, *Cohen's d* = 1.674. However, there was no difference between ratings to the CS-1 and CS-2; $t(50) = .32$, $p = .377$.

2.2.1.3.4 Anxiety

We also assessed anxiety levels and avoidance responses in the training and test phases (see Appendix 9.2 for full analysis). We found that during training there was no effect of anxiety and participants made the same number of avoidance responses to the CS+, CS-1 and CS-2. Furthermore, during test there was also no effect of anxiety on the generalisation gradient.

2.2.1.4 Discussion

Overall, this pilot study yielded successful results in terms of development of this task. During training participants learned to discriminate the CS+ from the two CSs- which indicated that they understood the task and were motivated to actively used the avoidance response and prevent the aversive outcome from appearing on the screen. This was further supported with the expectancy data, as participants rated the CS+ higher than both CSs-. Furthermore, during the test phase participants avoidance responses differed depending on the stimulus tested. Avoidance responding peaked at the CS+ and decreased the closer the stimuli were to the CS- showing a gaussian-shaped curve. This shows a generalisation gradient in which stimuli similar to the CS+ elicit avoidance behaviour.

Furthermore, when exploring the relationship with anxiety and avoidance generalisation there was no effect of anxiety. This is most likely due to the small sample size as there were 25 in the low anxiety group and 26 in the high anxiety group. From previous research we know that the effects of trait anxiety and generalisation (fear) (Sep et al., 2019) are smaller than those seen in people with clinical diagnoses of anxiety disorders (Cooper et al., 2022) therefore these differences may not be detectable with small samples, in particular when the data is collected online. Also, as this was a pilot and there were no studies investigating avoidance generalisation with a task and stimuli like these, we were unable to do a power analysis, so the experiment could also be underpowered. Overall, this data indicates that the experiment had the desired effects and that the task was suitable to collect online data. The next step was to run a similar experiment but using a trace procedure to manipulate the contiguity between the offset of the CS+ and the appearance of the aversive outcome.

2.2.2 Experiment 1b

2.2.2.1 Introduction

Following on Experiment 1a, we wanted to develop the novel CS-US trace interval to the procedure. However, as this procedure has not been used with human avoidance tasks before, it was important to pilot the task. We wanted to ensure that with the added trace the participants would still be able to learn the task during the training phase (i.e., discriminate between CS+ and CSs). For these reasons we wanted to pilot this group before collecting data comparing the delay and trace groups.

2.2.2.2 Method

2.2.2.2.1 Participants

The exclusion criteria were the same as the previous experiment. There were 55 participants however, 10 participants did not pass the pretraining criteria therefore there were 45 participants in total. There were 22 females, 22 males and 1 nonbinary person. The ages ranged from 20-40 (M = 29.56, SD = 5.12).

2.2.2.2.2 Design

This experiment followed the same procedure as Experiment 1a. However, there was one crucial difference in the training and test phases. In the previous experiment the CS duration was variable between 2-5 seconds and the US was then programmed to occur 1 second after the CS termination with the 1 second response window for a successful avoidance response being 1 second before the US. I.e., if the CS was presented on second 3 of the trial, then the US would occur at second 4 and the successful response would need to occur on second 3. Depending on a successful avoidance response the US was either presented or not. In this experiment a 6 second trace was implemented which shifted the response window and the outcome. The CS+ presentation was still variable 2-5

seconds. There was then a fixed 6 second trace, in which the 1 second response window was the last second of the trace and then the aversive outcome was presented (or not if avoidance was successful). During the trace, nothing was presented on the screen except the background colour of the experiment (black). All other aspects of the task remained the same as Experiment 1a.

2.2.2.2.3 Data Analysis

The data was analysed in the same was as Experiment 1a and the avoidance responses were only measured when the CSs were presented on the screen. The reason for this was so that in subsequent experiments the comparisons between the groups (delay and trace) would be conducted under similar groups, in this case responses during the CSs.

2.2.2.3 Results

2.2.2.3.1. Training

As training trials progressed, participants made more avoidance responses to the CS+ compared to CS-1 and CS-2 (*see Figure 2.4A*). A Repeated Measures ANOVA showed that there was a significant main effect of Trials, $F(5.15, 226.8) = 9.08$, $p < .001$, $\eta_p^2 = .171$ and a main effect of CS, $F(1.13, 49.72) = 65.71$, $p < .001$, $\eta_p^2 = .599$. There was also a significant interaction between CS and Trials, $F(5.41, 237.82) = 8.96$ $p < .001$, $\eta_p^2 = .169$. Furthermore, Follow up t-tests revealed that participants made more avoidance responses to the CS+($M = 10.39$, $SD = 7.31$) compared to the CS-1 ($M = 1.16$, $SD = 3.00$); $t(44) = 7.99$, $p < .001$, *Cohen's d* = 1.19. Participants also made more responses to the CS+ compared to the CS-2 ($M = .80$, $SD = 1.74$); $t(44) = 8.57$, $p < .001$, *Cohen's d* = 1.28. However, there was no difference in responding between CS-1 and CS-2; $t(44) = 1.06$, $p = .147$, *Cohen's d* = .159.

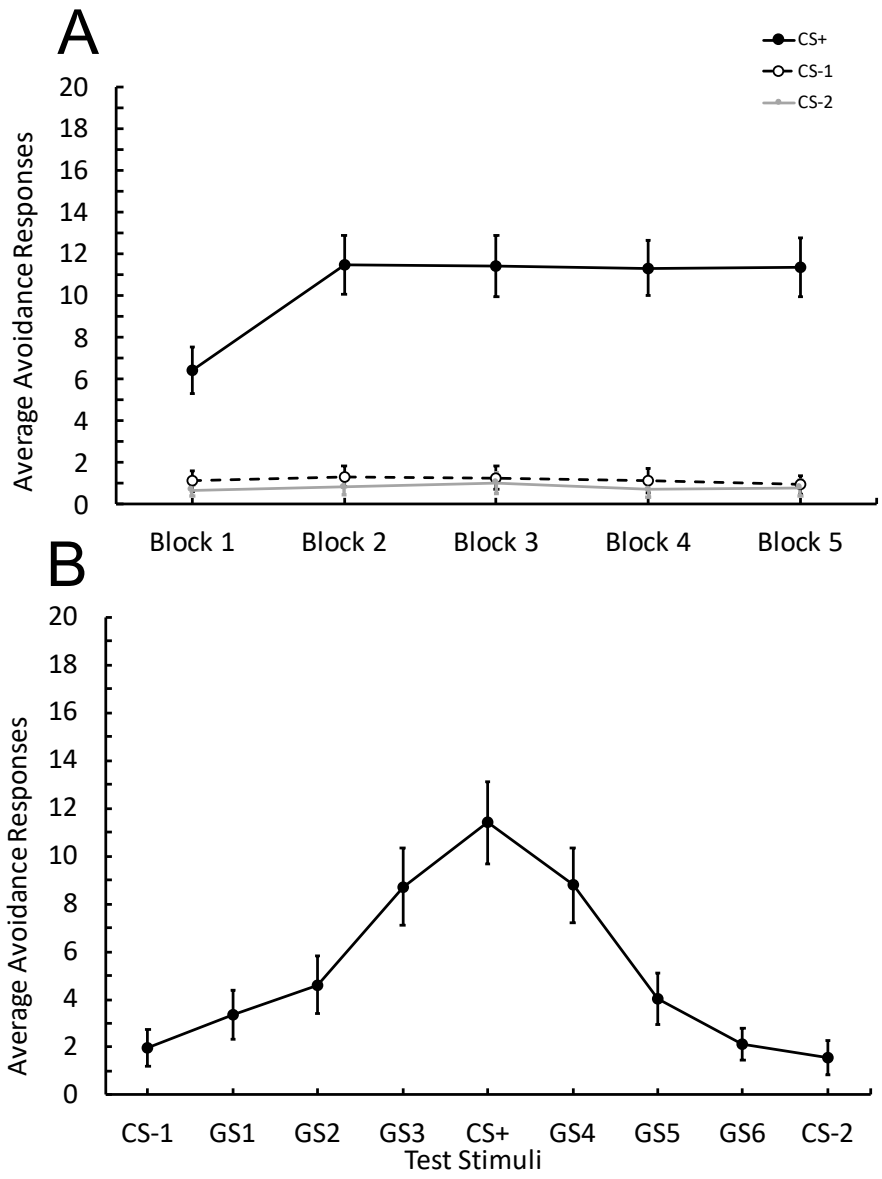

Figure 2.4
Results from Experiment 1b assessing the avoidance responses during training (with a trace procedure) and a generalisation test. *(A)* Training data depicting avoidance responses to the CS+, CS-1 and CS-2. Each block contains 2 trials. Participants made more responses to the CS+ across blocks compared to both the CS-1 and CS-2. *(B)* Test data showing avoidance responses to the CS+, CS-1, CS-2 and the 6 generalisation stimuli (GS). Participants responded most to the CS+ and then this decreased as the stimuli became closer in similarity to the CSs-. Error bars depict standard error of the mean.

2.2.2.3.2. Test

Participants responded to the generalisation stimuli differently depending on which stimulus was being tested (*see Figure 2.4B*). They responses the most to the CS+ and then responding decreased as the stimuli became less similar to the CS+. A one-way ANOVA was conducted to assess this, and the quadratic contrasts found an effect of Stimulus was found, $F(1,44) = 25.76$, $p < .001$, $\eta_p^2 = .369$.

2.2.2.3.4. Expectancy

The expectancy ratings given by participants indicated that the CS+ was rated higher than the both CS- stimuli. This was analysed using a repeated-measures one-way ANOVA $F(1.13, 49.72) = 65.705$, $p < .001$, $\eta_p^2 = .599$. Follow up t-test revealed that participants rated the CS+ ($M = 7.22$, $SD = 2.59$) higher than the CS-1 ($M = 2.82$, $SD = 2.58$); $t(44) = 7.34$, $p < .001$, *Cohen's d* = 1.095. Participants also rated the CS+ higher than CS-2 ($M = 2.84$, $SD = 2.73$); $t(44) = 6.88$, $p < .001$, *Cohen's d* = 1.025. However, there was no difference between ratings to the CS-1 and CS-2; $t(44) = -.07$, $p = .474$.

2.2.2.3.5. Anxiety

Anxiety was assessed to see if there were differences in those high and low anxiety (see Appendix for full analysis). During the training there was no effect of anxiety as those with high and low anxiety made the same number of avoidances to the CS+, CS-1 and CS-2. During the test there was also no effect of anxiety on the shape of the generalisation gradient.

2.2.2.4 Discussion

Overall, in Experiment 1b even with the trace period participants responded more to the CS+ compared to the CS-1 and CS-2 during the generalisation test, a pattern which is similar to Experiment 1a. Furthermore, no effects of anxiety were found but like

Experiment 1a this could again be due to the relatively small sample size. Importantly, now that both groups have been piloted the next step was to compare avoidances responses to the two groups. Experiments 2, 3 and 4 were aimed to compare the trace and delay groups, explore the generalisation of avoidance behaviour and the potential relationship with trait anxiety levels.

2.3 Experiment 2

2.3.1 Introduction

The aim of this experiment was to combine Experiments 1a and 1b so that the effect of the contiguity between the offset of the CS and the aversive outcome (immediate and a six second gap) could be compared. The aim of this experiment was to test if a trace between CS termination and outcome appearance results in broader generalisation (relative to a delay group). In addition, we wanted to assess whether using the trace procedure provided more sensitivity for studying generalisation of avoidance behaviour and offer a better protocol for assessing the effect of trait anxiety in the laboratory.

2.3.2 Method

2.3.2.1 Participants

This experiment was deployed on Pavlovia and participants were recruited via Prolific. The inclusion criteria set on Prolific was that participants were aged 18-40, had intact colour vision, were fluent in English and had not taken part in any previous experiments conducted within the research group. There were 70 participants (32 males, 38 Females), and their ages ranged from 18-40 (M = 28.8, SD = 7.19).

2.3.2.2 Design

This experiment had the same four phases as the previous two pilot experiments which were pre training, training, test and expectancy phases. This experiment combined

the previous experiments using a mixed design. Participants were assigned to either the Trace or Delay condition and completed that one condition. The within-subjects variable was the colour of the generalisation stimuli presented during test, of which there were 9 coloured stimuli. Participants in both groups were presented with the same stimuli during training and test, the only difference between groups was the presence of the trace (or not) during avoidance training. The dependent variable was the number of avoidance responses during the CS presentation of each trial. Identical to Experiments 1a and 1b, trait anxiety scores were also used to investigate their relationship with avoidance behaviour and generalisation.

2.3.2.3 Procedure

The procedure for this experiment was the same as Experiments 1a and 1b. It contained the exact same phases: STAI scales, pre training, avoidance training, generalisation test and expectancy scales. Furthermore, all other aspects of the task were the same in terms of the stimuli used and stimuli durations. Participants either completed the delay group or the trace group. The experiment took around 25 minutes to complete.

2.3.2.4 Data Analysis

Avoidance responses per trial were the main measure of avoidance behaviour. As the trace group is longer (because of the six second trace) we only included responses made during the period when the warning signals (CS+, CS-1, CS-2) were on the screen. This was the same in the test phase, only the responses made when the stimuli were on the screen were analysed. In the training phase a 3 (Stimulus: CS+ v. CS-1 vs. CS-2) X 10 (Trials) X 2 (Group: Trace vs. Delay) repeated-measures ANOVA was conducted. This allowed us to analyse the number of avoidance responses made per trial to the CS+ and the two CSs- for each group and examine the effects of CS, Trials and Groups.

In the test phase a 9 (Stimuli) X 2 (Group: Trace vs. Delay) mixed ANOVA was conducted to examine the generalisation of avoidance behaviour. Furthermore, in the test phase an augmented gaussian function (Lee et al., 2021) was used to model the generalisation data. The Gaussian function gives as a result three parameters that capture the generalisation curve, 1) the mean of the curve corresponds to the location of the peak, 2) the standard deviation of the curve corresponds to its Width (one SD for each side of the generalisation gradient), and 3) the height of the curve corresponds to its value at the peak location (Lee et al., 2021). As we were only interested in the generalisation, we only reported the Width + and Width -parameters. This is because due to our design with the two CS- on either side of the gradient we did not expect to see a peak shift so for simplicity we only report the Width parameters.

2.3.3 Results

2.3.3.1 Training

During training, as the trials progressed avoidance responses to the CS+ increased, whilst responding to the CS-1 and CS-2 remained low (*see Figure 2.5A*). A mixed ANOVA 3 (CS, CS+ vs. CS-1 vs. CS-2) x Trials (10) x 2 (Group: Trace and Delay) there was revealed by a main effect of CS, $F(1.13, 77.12) = 83.21$, $p < .001$, $\eta_p^2 = .544$ and trials $F(4.82, 327.25) = 3.02$, $p < .001$, $\eta_p^2 = .042$. Critically, during training there was no difference in avoidance behaviour between those in the Trace Group and those in the Delay Group, $F(1,68) = .01$, $p = .921$. Furthermore, there was an interaction between CS and Trials, $F(8.72, 592.8) = 7.14$, $p < .001$, $\eta_p^2 = .095$ which indicates that responding to the CS's changed during training, regardless of group. In other words, all participants were able to discriminate between the CS+ and the two CSs-. There was no interaction between

CS and Group, $F(1.13, 77.12) = .1.86$, $p = .176$, $\eta_p^2 = .003$ or between Trials and Group $F(4.82, 327.43) = .59$, $p = .704$, $\eta_p^2 = .014$. Finally, there was no triple interaction between CS, Trials and Group, $F(8.72, 592.8) = .314$, $p = .968$.

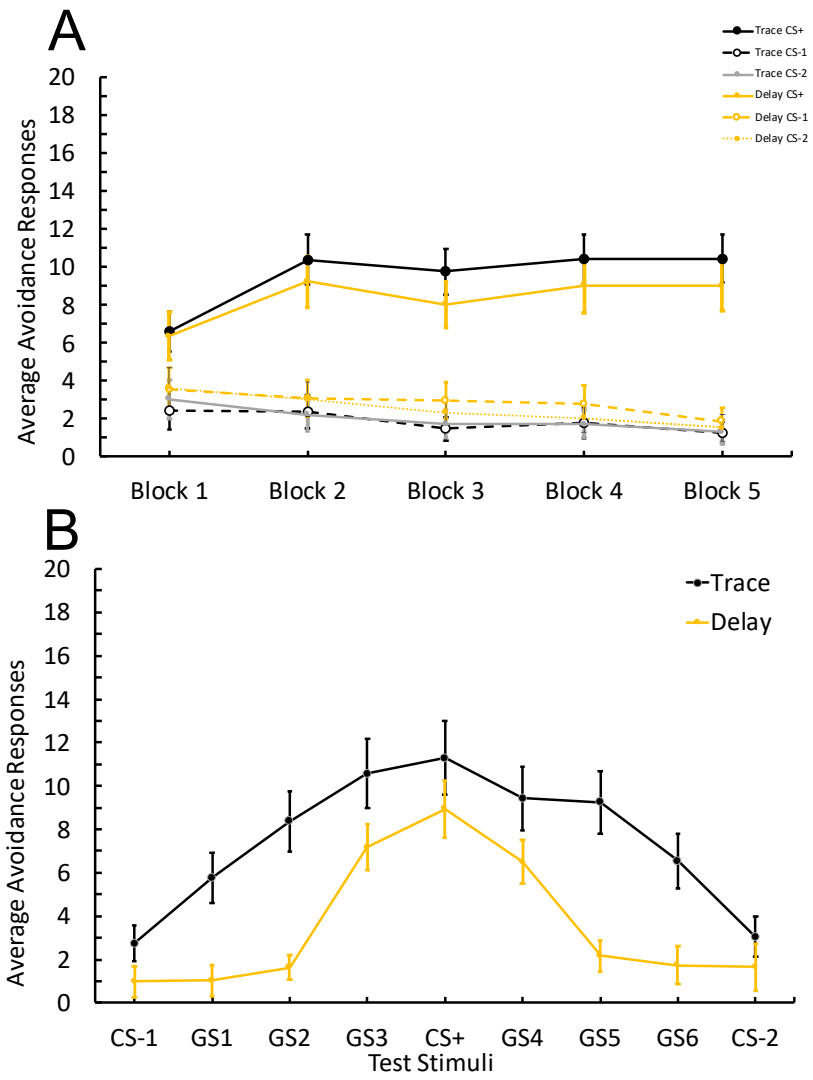

Figure 2.5
Results from Experiment 2 assessing the avoidance responses made during training and to generalisation stimuli for the delay and trace groups. *(A)* Training data depicting avoidance responses to the CS+, CS-1 and CS-2. Each block contains 2 trials. Participants made more responses to the CS+ across blocks compared to both the CS-1 and CS-2 in both the trace and delay groups. *(B)* Test data showing avoidance responses to the CS+, CS-1, CS-2 and the 6 generalisation stimuli. Participants responded most to the CS+ and then this decreased as the stimuli became closer in similarity to the CSs-. Critically, the trace gradient was broader than the delay gradient. Error bars depict standard error of the mean.

2.3.3.2 Test

Those in the trace group made more responses compared to the delay group however both groups showed the highest number of responses at the CS+ with responding decreasing as the stimuli became less similar. It also shows that the delay group there is a sharper decrease in responses compared to the trace group (*see Figure 2.5B*). A 2(Group, Trace vs. Delay) X 9(Stimuli), revealed a main effect of group, $F(1,68) = 9.78$, $p = .003$, $\eta_p^2 = .126$. In both groups responding was highest at the CS+ and lowest at the both CSs- creating a generalisation gradient was shown by a main effect of generalisation stimuli, $F(1,68) = 50.643$, $p < .001$, $\eta_p^2 = .427$. There was no interaction between generalisation stimuli and group, $F(1,68) = .943$, $p = .335$, $\eta_p^2 = .050$.

2.3.3.3 Model

We used the augmented gaussian model (Lee et al., 2021) to assess whether there were group differences. The model provides the four parameters (mean, height, Width- and Width+) however as we are interested in generalisation only the Width parameters were explored. Visually, the data suggests that in terms of the Width – and Width + - which there is an overlap in the distribution of posterior densities, but the trace group seems broader (*see Figure 2.6*).

The model calculates a *p*(direction) value for each parameter which indicates the proportion of the posterior that falls in the most probable direction, with values ranging between 0.5 and 1 (Lee et al., 2021). A value of .5 indicating no differences between the groups whereas a value closer to 1 indicates a higher likelihood there are group differences. The Width - had a p direction of .597 and the Width + had a p direction of .631. This indicates there is a low likelihood of group differences in the Width + and Width – parameters.

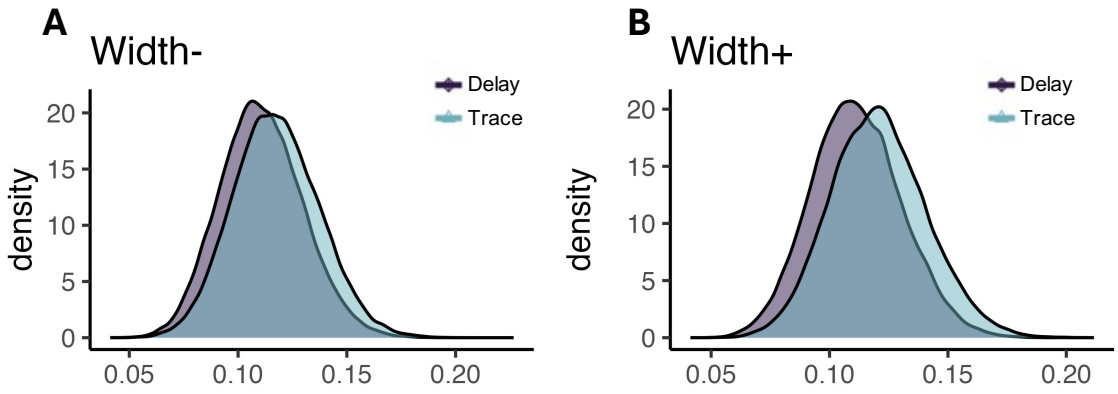

Figure 2.6
The posterior distribution estimates from the augmented Gaussian function, for the trace and delay groups, for the mean (a), Width - (b), Width +

In order to test this a 2 (Width: Width + vs. Width -) x 2 (Group: Trace vs. Delay) mixed ANOVA was conducted to assess if there were differences in the breath of generalisation. The analysis revealed that those in the trace group had higher the distribution of posterior densities compared to the delay group (see Figure 2.7) ; $F(1,68) = 13.54$, $p < .001$, $\eta_p^2 = .006$. Furthermore, there was no effect of Width; $F(1,68) = .37$, $p = .547$, suggesting no differences in terms of generalisation from aqua to green or blue colours. Finally, there was no interaction between Width and Group; $F(1,68) = .44$, $p = .510$.

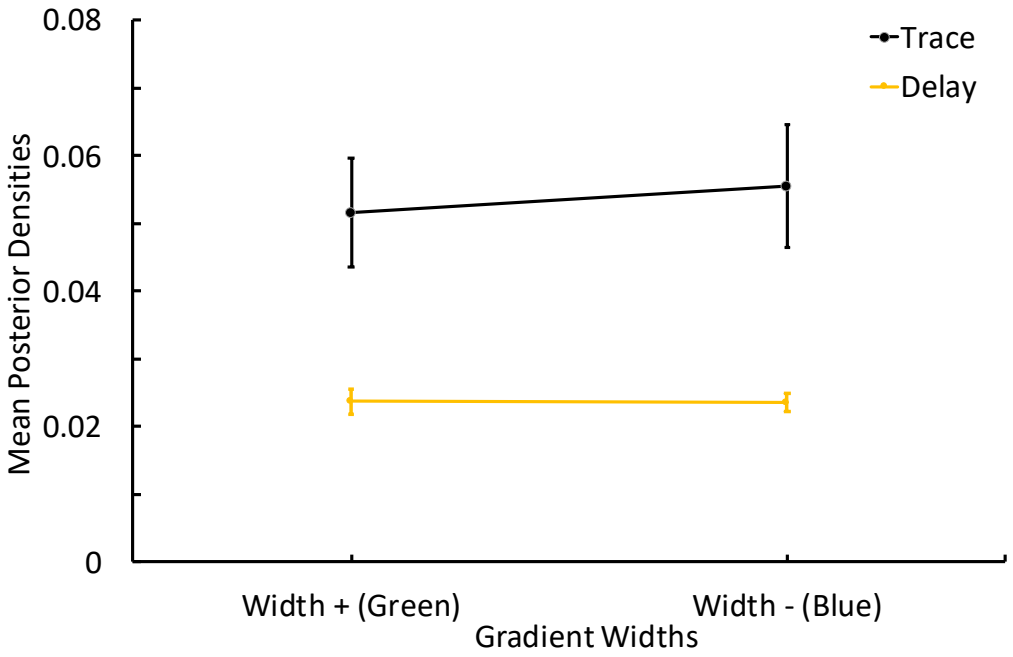

Figure 2.7
This depicts the mean distributions of posterior densities of each side of the gradient for the trace and delay groups.

2.3.3.4 Expectancy

Participants in the Trace and the Delay Groups did not differ in their ratings to the 3 CS's as shown by a mixed ANOVA with 3 (CS: CS+ vs, CS-1vs. CS-2) X 2 (Group: Trace vs. Delay) as factors. There was a main effect of CS, $F(1.6,108.82) = 117.1$, $p < .001$, $\eta_p^2 = .633$. However, there was no main effect of Group, $F(1,68) = 1.79$, $p = .186$, and there was no interaction between Groups and CS, $F(1.6,108.82) = 3.16$, $p = .058$. The main effect of CS was further analysed using paired t-tests. This was revealed that participants rated the CS+ ($M = 7.87$, $SD = 1.454$) higher than the CS-1 ($M = 3.37$, $SD = 2.78$); $t(69) = 10.53$, $p < .001$, *Cohen's d* = 1.259. Participants also rated the CS+ higher than CS-2 ($M = 2.99$, $SD = 2.45$); $t(69) = 13.11$, $p < .001$, *Cohen's d* = 1.567. However, there was no difference between ratings to the CS-1 and CS-2; $t(69) = 1.47$, $p = .072$.

2.3.3.5 Anxiety

As in previous experiments, we assessed the effect of anxiety levels on avoidance responses during the training and test phases for the Delay and Trace Groups (*see appendix for full analysis*). During training there were no effects of anxiety for those in the trace or delay groups. Furthermore, in the test there were also no effects of anxiety on the trace or delay generalisation gradients.

2.3.4 Discussion

Overall, this experiment compared two groups in which contiguity between a warning signal and an aversive outcome was manipulated. During training, there were no differences between the Trace and Delay Groups, participants responded to the stimuli in a similar pattern with more avoidance responses to the CS+ compared to the CS-1 and CS-2. This indicates that all participants learnt which stimulus predicted the aversive outcome and therefore learnt the task. Moreover, there were no differences between the trace and delay groups however, those in the trace group did tend to make more avoidance responses overall when looking at the same response window in both the trace and delay conditions. This increase in responding is likely due to the uncertainty of when the aversive stimulus will be presented, resulting in participants pressing more vigorously throughout the CS+ trial in a 'better safe than sorry strategy" (Lommen et al., 2010).

Critically, during the test phase, there was a difference between the groups in avoidance responses to the generalisation stimuli. Those in the Trace Group made more responses during the generalisation test than the Delay Group. Furthermore, those in the Delay Group had a gradient that peaked at the CS+ with similar responding to the next stimuli (either side of the gradient). Responding then sharply decreases and there is a similar amount of responding to the remaining generalisation stimuli (GS1, GS2, GS5 and

GS6). However, in the Trace Group whilst responding also peaked at the CS+ responding to the generalisation stimuli also remained high but slowly decreases the less similar the stimuli is to the CS+. Therefore, it can be concluded that those in the Trace Group had a broader generalisation gradient than those in the Delay Group which was hypothesised. It seems the differences in contiguity had an effect on the shape of the generalisation curves. This could be due to the contiguity leading to differences in associative strength between the CS and US. In the trace group the associative strength of the CS could be weaker due to the temporal interval whereas in the delay group the associative strength between CS and US is stronger (Costa & Boakes, 2011). Experiments 3 and 4 aimed to replicate these findings online and in the laboratory to assess the reliability of this finding.

2.4 Experiment 3

2.4.1 Introduction

The results of Experiment 2 were in line with our hypotheses therefore we wanted to replicate these findings in Experiment 3. This was due to the data being collected online and prior to Experiment 2 a power analysis had not been conducted as there was no data to base this on as this is a novel procedure. Therefore, a replication was needed to ensure sufficient power. This experiment was pre-registered as a replication at: https://osf.io/yu8ez.

2.4.2 Method

2.4.2.1 Participants

The rationale for the sample size in Experiment 3 is based on Experiment 2. Within the psychology research field, it is standard to achieve a power of .80 (Cohen, 1965). Thus, we determined that the interaction of interest between group and stimuli in the test phase was $F(3.56, 242.08) = 3.57$, $p = .01$, $\eta_p^2 = .05$, 95% CI [0.003, 0.101] with an observed

power of .84. Therefore, for this replication we used the same number of participants (70) as Experiment 2 was sufficiently powered. This experiment was deployed on Pavlovia and participants were recruited via Prolific. The inclusion criteria set on Prolific was the same as Experiment 2. There were 70 participants (23 males, 46 Females, 1 Non-Binary). The ages ranged from 18-40 (M = 29.24, SD = 5.22).

2.4.2.2 Procedure

The experiment was an exact replication of the Experiment 2.

2.4.2.3 Data analysis

The data analysis was also the same as Experiment 2.

2.4.3 Results

2.4.3.1 Training data

Like Experiment 2 as trials increased participants in both groups responded more to the CS+ than the CS-1 and CS-2 (*see Figure 2.8A*). A 3 (CS: CS+ vs. CS-1 vs. CS-2) X Trials (10) x 2 (Group: Trace and Delay) Repeated Measures ANOVA found that participants were able to discriminate between the CS+ and the two CS-'s as revealed by a main effect of CS, $F(1.07, 72.81) = 82.85$, $p < .001$, $\eta_p^2 = .549$. Moreover, there was also an effect in Trials $F(6.27, 426.49) = 20.46$, $p < .001$, $\eta_p^2 = .231$. Critically, there was no difference in avoidance behaviour between those in the Trace Group and those in the Delay Group, $F(1,68) = .848$, $p = .36$, $\eta_p^2 = .012$. There was no interaction between CS and Group, $F(115.71, 499.56) = .23$, $p = .648$, $\eta_p^2 = .003$ or between Trials and Group $F(6.27, 426.49) = .97$, $p = .449$, $\eta_p^2 = .014$. However, there was an interaction between CS and Trials, $F(8.17, 555.41) = 17.41$, $p < .001$, $\eta_p^2 = .204$. There was no triple interaction between CS, Trials and Group, $F(8.17, 555.41) = .95$, $p = .478$, $\eta_p^2 = .014$.

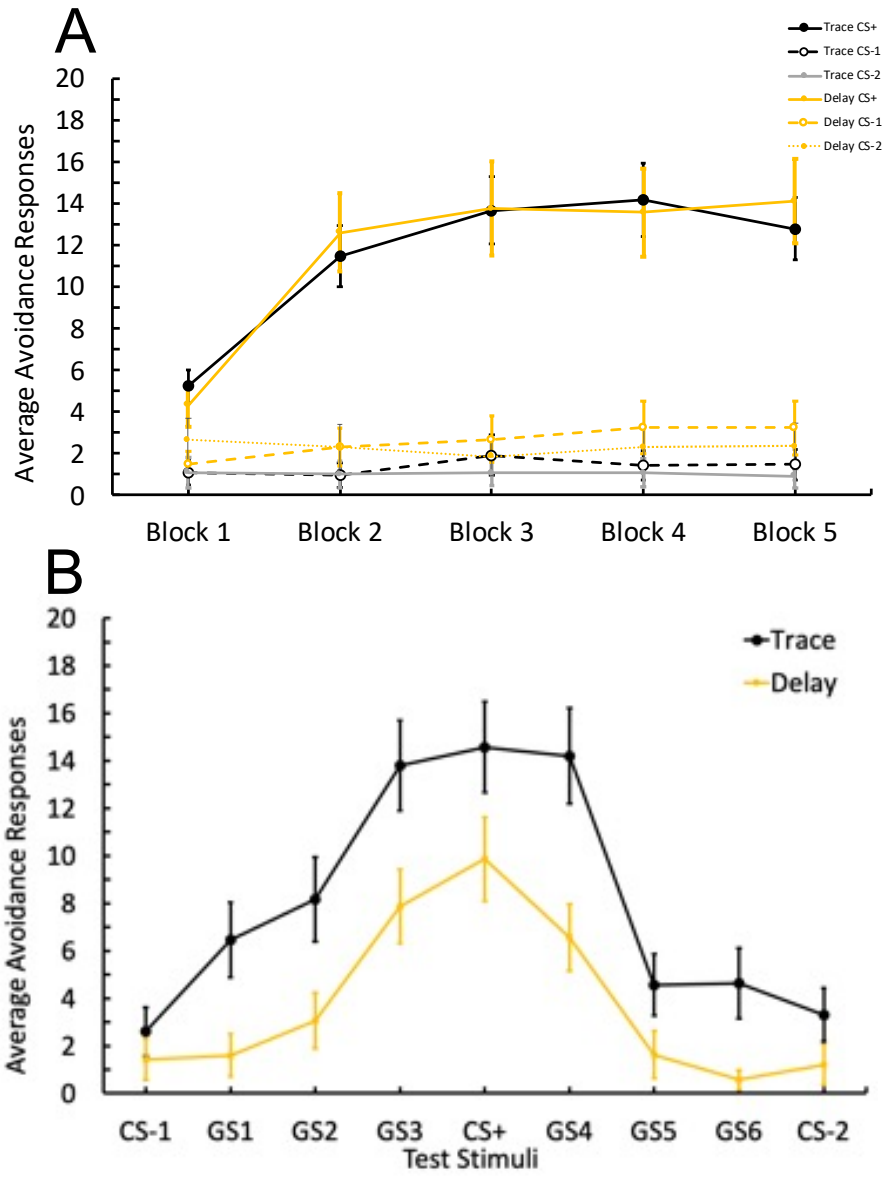

Figure 2.8

Results from Experiment 3 assessing the avoidance responses made to generalisation stimuli for the delay and trace groups. *(A)* Training data depicting avoidance responses to the CS+, CS-1 and CS-2. Each block contains 2 trials. Participants made more responses to the CSs+ across blocks compared to both the CS-1 and CS-2 in both the trace and delay group. *(B)* Test data showing avoidance responses to the CS+, CS-1, CS-2 and the 6 generalisation stimuli. Participants responded most to the CS+ and then this decreased as

the stimuli became closer in similarity to the CSs-. Critically, the trace gradient is slightly broader than the delay gradient. Error bars depict standard error of the mean.

2.4.3.2 Test Data

Those who were in the trace group made more avoidance responses compared to those in the delay group (*see Figure 2.8B*) as revealed by as revealed by a 2(Group: Trace and Delay) X 9(Stimuli) which showed a main effect of Group, $F(1,68) = 9.49$, $p = .003$, , $\eta_p^2 = .122$. Participants responded different to the generalisation stimuli there was a main effect of Stimulus, $F(1,68) = 61.05$, $p < .001$, $\eta_p^2 = .473$.There was no interaction between CS and Group, $F(1,68) = 3.26$, $p = .075$, $\eta_p^2 = .046$.

2.4.3.3 Model

In line with previous Experiments the augmented gaussian model (Lee et al., 2021) was used. We were able to compare the trace and delay groups within the model like we did in Experiment 3 (*see Figure 2.9*). Visually, the data suggests that in terms of the Width – and Width + there is an overlap in the distribution of posterior densities, but trace group seems slightly broader, similar to Experiment 2. The model calculates a *p*(direction) value for each parameter which indicates the proportion of the posterior that falls in the most probable direction, with values ranging between 0.5 and 1 (Lee et al., 2021). A value of .5 indicating no differences between the groups whereas a value closer to 1 indicates a higher likelihood there are group differences. The Width - had a p direction of .698 and the Width + had a p direction of .655. This indicates there is a low likelihood of group differences in the Width + and Width – parameters.

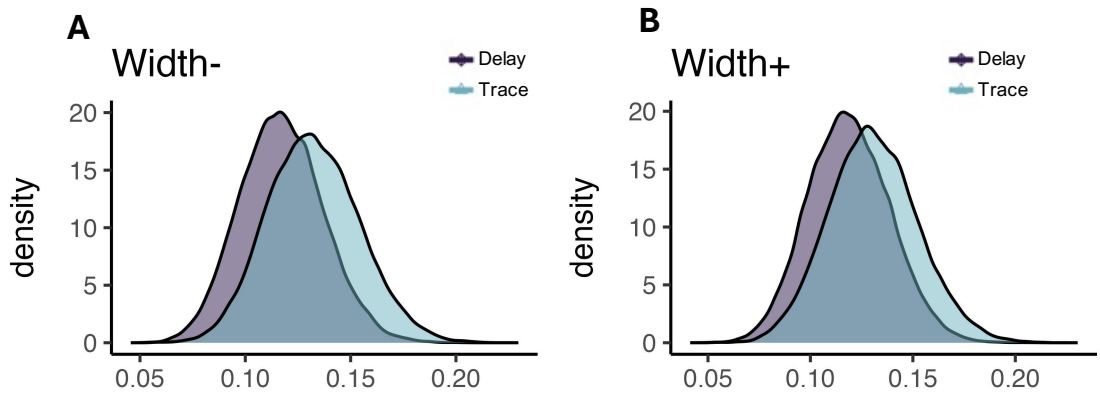

Figure 2.9
The posterior distribution estimates from the augmented Gaussian function, for the trace and delay groups, for the (b), Width – (A), and Width + (B).

In order to test this a 2(Width: Width + and Width -) x 2(Group; Trace and Delay) Repeated Measures ANOVA was conducted to assess if there were differences in avoidance responses (*see Figure 2.10*). It revealed that those in the Trace Group had similar distribution of posterior densities to the Delay Group 9 (*see Figure 2.10*) ; $F(1,68) = 2.510$, $p = .118$, $\eta_p^2 = .036$. There was no effect of Width; $F(1,68) = .001$, $p = .979$ and there was no interaction between Width and Group; $F(1,68) = .71$, $p = .403$.

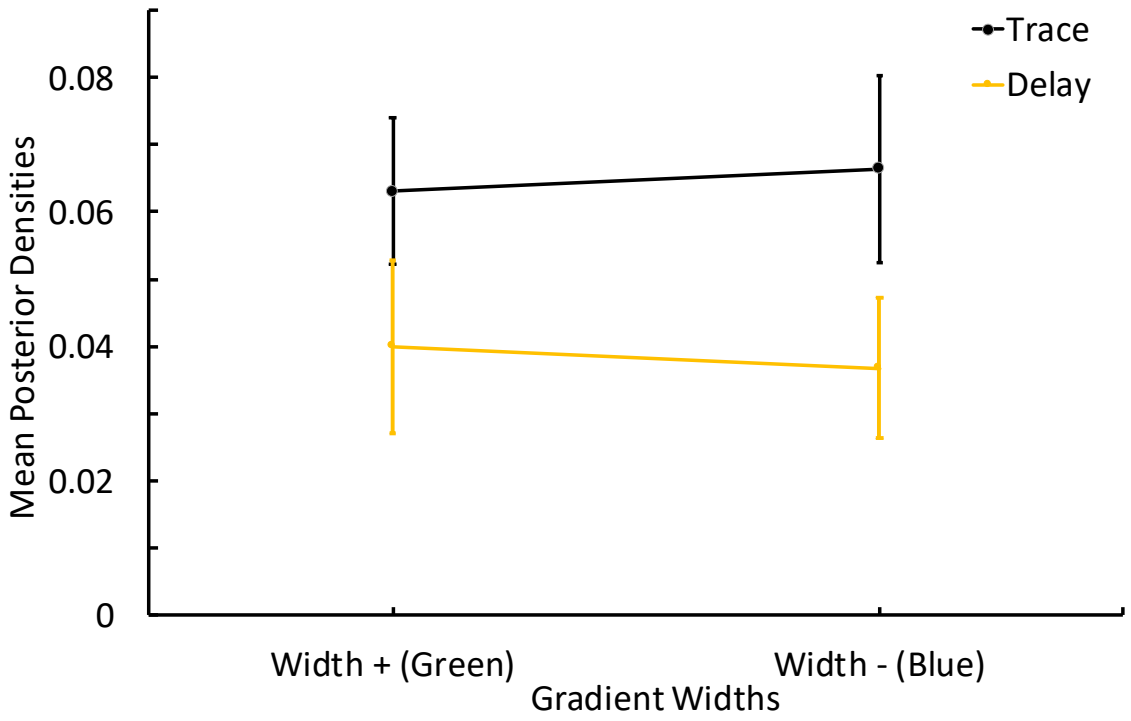

Figure 2.10
This depicts the mean distributions of posterior densities of each side of the gradient for the trace and delay groups in Experiment 3.

2.4.3.4 Expectancy

Participants in the Trace and Delay Groups did not differ in their ratings to the 3 CS's as shown by a 3 (CS: CS+ vs. CS-1 vs. CS-2) X 2 (Group: Trace vs. Delay) mixed ANOVA. There was a main effect of CS, $F(1.44,97.89) = 196.39$, $p < .001$, $\eta_p^2 = .743$. There was no main effect of Group, $F(1,68) = 1.49$, $p = .277$ and there was no interaction between Group and CS, $F(1.44,196.388) = 1.41$, $p = .247$. The main effect of CS was further analysed using paired t-tests. These revealed that participants rated the CS+ ($M = 8.19$, $SD = 1.61$) higher than the CS-1 ($M = 2.51$, $SD = 2.28$); $t(69) = 15.37$, $p < .001$, $d = 1.837$. Participants also rated the CS+ higher than CS-2 ($M = 2.37$, $SD = 2.35$); $t(69) = 14.58$, $p < .001$, $d = 1.742$. However, there was no difference between ratings to the CS-1 and CS-2; $t(69) = .69$, $p = .246$.

2.4.3.5 Anxiety

We also assessed whether anxiety levels had an effect on avoidance responses during training and test phases for the delay and trace groups (*see appendix for full analysis*). Similar to Experiment 2, during training there were no effects of anxiety for those in the trace or delay groups. Furthermore, in the test there were also no main effects of anxiety on the trace or delay generalisation gradients.

2.4.4 Discussion

Overall, the findings from Experiment 3 followed similar pattern to those in Experiment 2. In the training phase participants, in both the Trace and Delay Groups, learnt the task and responded more to the CS+ compared to the CS-1 and CS-2. Critically during test, there was an effect of group in that those in the Trace Group made more response than those in the Delay Group. In hindsight, this should have been considered before the replication was preregistered, however adopting a criterion during learning which excludes participants who did not discriminate between cues is justified when the test is assessing generalisation gradients. A possible reason for this is that there is a lot of variation with avoidance responding between participants, in particular when data is collected online, which could make it difficult to replicate.

Because of this unsuccessful replication in Experiment 4 we wanted to see if the findings from Experiments 2 and 3 could be replicated within the laboratory using a biologically relevant aversive outcome (loud noise). Because experiments in the laboratory are more time-consuming, we adopted a within subject's design so we could assess whether avoidance generalisation varies as a function of contiguity (Delay vs. Trace). Furthermore, we assessed whether anxiety levels effect avoidance behaviour in training and the generalisation test.

2.5 Experiment 4

2.5.1 Introduction

The two previous experiments revealed that, overall, trace conditioning seems to result in broader generalisation gradients. However, Experiment 3 which was pre-registered only detected an effect of group when a criterion was used to exclude participants which did not learn the discrimination during training. In addition, the experiments were collected online, with the use of a mild aversive outcome. Also, the previous experiments were between subjects therefore requiring a large number of participants. Experiment 4 was aimed at replicating the previous findings but using a within-subjects design that also allows anxiety levels to be assessed and to see how they affect both Delay and Trace Groups. It is hypothesised that those with higher anxiety levels will produce broader gradients (Cooper et al., 2022; Sep et al., 2019). Furthermore, it is speculated that individual differences will be more evident in the trace group, due to the ambiguity that is introduced by the temporal gap. It has been shown that those with anxiety have a lower tolerance for uncertainty (Morriss & Ellett, 2024) therefore by adding in the trace it introduces this ambiguity which may be more sensitive for capturing the differences between those with high and low anxiety. This experiment was pre-registered based on Experiments 2 and 3 at: https://osf.io/sykrb.

2.5.2 Method

2.5.2.1 Participants

We based the sample size on the Experiments 2 and 3. Whilst we had the power estimates form Experiments 2 and 3, they could not be used to calculate power as the design was changed from between subjects to within subjects. These two experiments had 70 participants and it has been suggested that within subjects' experiments require

half the number of participants (Maxwell & Delaney, 2003). Therefore, it was decided that a minimum of 35 would be needed. However, as this was a rule of thumb it was decided to increase this to 40 participants in total to ensure there was sufficient power. There were 9 males and 31 females. The ages ranged from 18 to 28 (M = 19.93, SD = 2.42).

2.5.2.2 Design

This experiment was similar to the previous experiments but unlike the previous experiments this was a within-subjects design. The experiment had the same pretraining phases as previous experiments with the same learning criterion. The experiment also had training and tests phases which were the same as the ones used in Experiments 2 and 3, except that all participants experienced both conditions. Participants completed either the Trace or Delay training and test first (counterbalanced) and then completed the other. After the second phase, participants completed expectancy ratings when presented with the training stimuli from both conditions. The Trace and Delay relate to when the aversive stimulus was scheduled to appear. In the Delay Group this is immediately after the termination of the CS and in the Trace Group this is 6 seconds after the termination of the CS. The second within-subjects factor is the generalisation stimuli during the test phase. Anxiety levels were also explored using the trait anxiety scores to split participants into high and low anxiety levels.

2.5.2.3 Materials

CS Stimuli

Similar to previous experiments, in the training stage participants were shown three coloured square stimuli that acted as warning signals (CS+, CS-1, CS-2). Because each participant completed the task with Delay and Trace groups, there were two sets of stimuli; these were either on the blue-green continuum (as in previous experiments) or the

black-white continuum (*see Figure 11*). On the blue-green continuum the darkest blue shade and the darkest green shade served as the CSs- whilst the middle aqua shade served as the CS+, similar to previous experiments. On the black-white continuum, black and white served as the CSs- and the middle grey shade served as the CS+. The squares were always presented in the centre of the screen and were shown for a maximum of 6 seconds (minimum of 3 seconds) but the presentation time varied from trial to trial, similar to previous experiments. To distinguish the two from each other and prevent carry over effects between groups we had two different backgrounds (pink and orange checkboards). These were counterbalanced for each group.

Generalisation stimuli

The generalisation stimuli were also taken from the colour continuums (*see Figure 2.11)*. Six additional stimuli were taken from each side of the continuums; 3 blue shades (or black shades) and 3 green shades (or white shades) and were presented during the generalisation test. Each shade was an equal distance from each other within each set.

Aversive Outcome

The aversive outcome in Experiment 4 (in the laboratory) was a loud aversive noise. The noise was one that mimicked a metal pole being scraped against slate and had previously been used in other avoidance research (Neumann & Waters, 2006) and was found to be similarly aversive as a shock. We received ethical approval to use this aversive sound (reference: S1482R) was delivered via headphones which were calibrated to ensure the noise was 95db. Participants were aware before taking part in the experiment that an aversive sound would be used and that if they found it too loud, they could request for the volume to be reduced, however only one of the participants requested this.

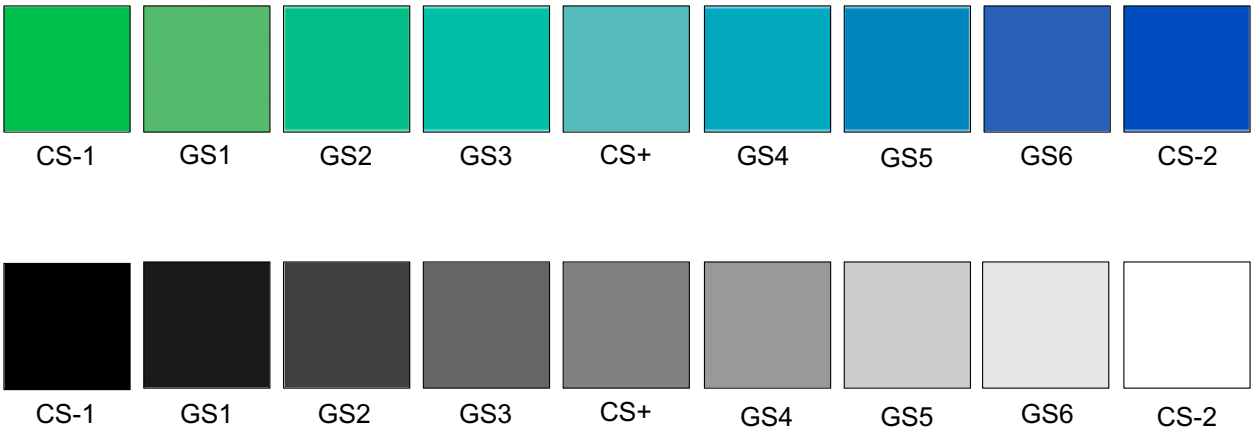

Figure 2.11
This figure depicts the stimuli used in Experiment 4. There are two sets of stimuli a black to white set and a green to blue set. One set was used for the trace group and one was used for the trace group (these were counterbalanced). Each set had two CS- and a CS+ which were used in the instrumental avoidance phases. The other six stimuli in each set were used as generalisation stimuli during the test phase.

2.5.2.4. Procedure

The pre training and STAI questionnaire was the same as the four previous experiments. The training and test phases were also the same. The only difference was that the design was now within-subjects, with participants completing both the delay and trace conditions (the order of conditions was counterbalanced). Participants then completed the expectancy scale at the end of the experiment.

2.5.2.5 Data Analysis

The only difference was that the design was now within-subjects, with participants completing both the delay and trace conditions (the order of conditions was counterbalanced).

2.5.3 Results

2.5.3.1 Training

Like previous Experiments as trials increased in both groups participants responded more to the CS+ than the CS-1 and CS-2 (*see Figure 2.12A*). A 2 (Condition:

Delay vs. Trace) X 3 (CS: CS+ vs. CS-1 vs. CS-2) X 10 (Trials) within-subjects ANOVA revealed a main effect of CS, $F(1.01, 39.38) = 6.95$, $p < .001$, $\eta_p^2 = .610$. Furthermore, there was no effect of Condition, $F(1, 39) = .161$, $p = .691$, $\eta_p^2 = .004$ but there was an effect of Trials, $F(3.66, 142.85) = 5.73$, $p < .001$, $\eta_p^2 = .128$. Furthermore, the Delay condition responded more to the CS+ at the end of the training phase compared to the Trace Condition but also respond less to both CS-'s compared to the delay group. this was shown by an interaction between CS and Condition, $F(1.87, 73.08) = 3.44$, $p = .04$, $\eta_p^2 = .081$ and an interaction between CS and Trials, $F(4.83, 188.53) = 20.08$, $p < .001$, $\eta_p^2 = .34$. There was no interaction between Condition and Trials, $F(5.33, 207.89) = 1.81$, $p = .108$, $\eta_p^2 = .044$. Finally, there was no triple interaction between CS, Condition and Trials, $F(5.88, 229.19) = .73$ $p = .621$, $\eta_p^2 = .018$.

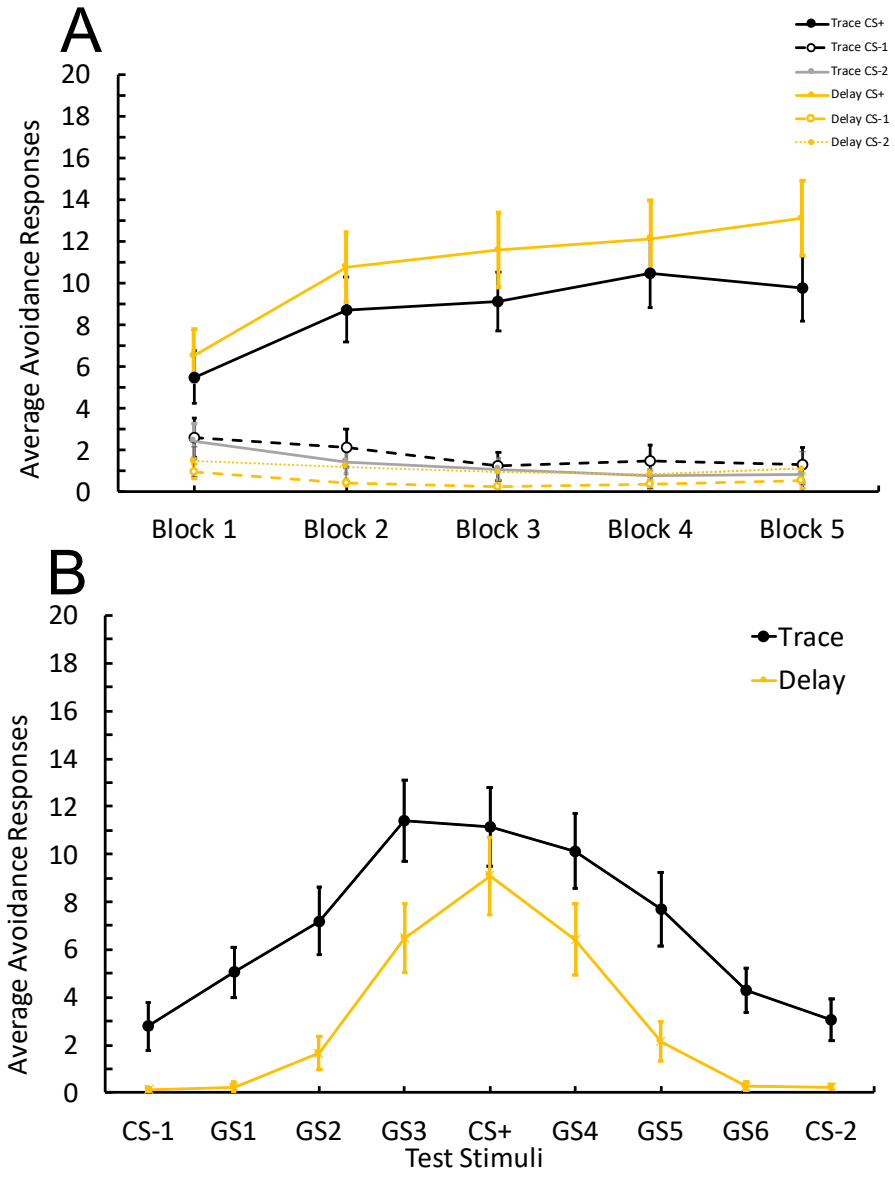

Figure 2.12

Results from Experiment 4 assessing the avoidance responses made during training and to generalisation stimuli during the test, for the Delay and Trace Conditions. *(A)* Training data depicting avoidance responses to the CS+, CS-1 and CS-2. Each block contains 2 trials. Participants made more responses to the CSs+ across blocks compared to both the CS-1 and CS-2 in both the Trace and Delay Conditions. *(B)* Test data showing avoidance responses to the CS+, CS-1, CS-2 and the 6 generalisation stimuli. Participants responded most to the CS+ and then this decreased as the stimuli became closer in similarity to the CSs-. Critically, the trace gradient is broader than the delay gradient. Error bars depict standard error of the mean.

2.5.3.2 Test

Critically, in the test phases the participants made more responses in the Trace Condition compared to the Delay Condition (*see Figure 2.12B*). A 2 (Group: Trace vs. Delay) x 9 (Stimulus) Repeated Measures ANOVA revealed a main effect of Condition, $F(1,39) = 19.03$, $p < .001$, $\eta_p^2 = .328$. There was also a main effect of Stimulus, $F(1,39) = 31.68$, $p < .001$, $\eta_p^2 = .448$. However, there was no interaction between Condition and Stimulus, $F(1,39) = .625$, $p = .434$, $\eta_p^2 = .016$.

2.5.3.3 Model

In line with previous Experiments the augmented gaussian model (Lee et al., 2021) was used. We were able to compare the Trace and Delay Groups within the model, like we did in previous experiments (*see Figure 2.13*). Visually, the data suggests that in terms of the Width – and Width + there is an overlap in the distribution of posterior densities, but trace group seems broader, similar to previous experiments. The model calculates a p(direction) value for each parameter which indicates the proportion of the posterior that falls in the most probable direction, with values ranging between 0.5 and 1 (Lee et al., 2021). A value of .5 indicating no differences between the groups whereas a value closer to 1 indicates a higher likelihood there are group differences. The Width - had a p direction of .717 and the Width + had a p direction of .781. This indicates there is a medium likelihood of group differences in the Width + and Width – parameters.

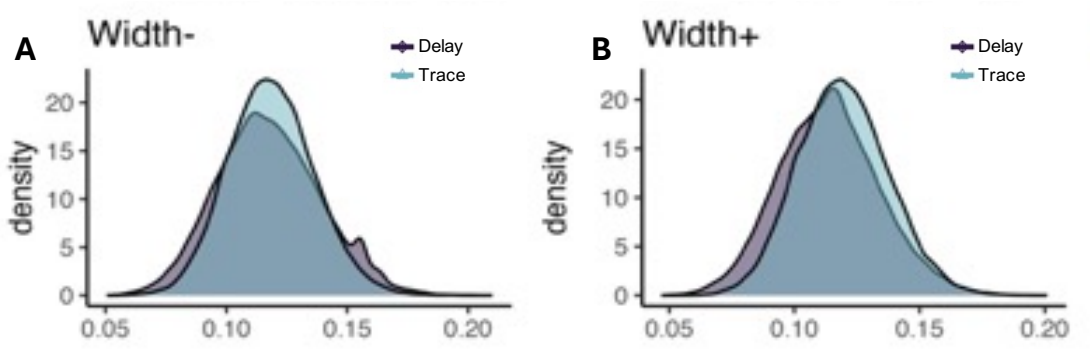

Figure 2.13
The posterior distribution estimates from the augmented Gaussian function, for the trace and delay groups, for the mean (a), height (b), Width – (c), and Width + (d).

In order to test this a 2 (Width: + vs. -) x 2 (Group: Trace vs. Delay) repeated-measures ANOVA was conducted to assess if there were differences in generalisation. The analysis revealed that those in the trace group had higher the distribution of posterior densities compared to the delay group, as shown by a main effect of Group; $F(1,39) = 7.01$, $p = .012$, $\eta_p^2 = .152$ (*see Figure 2.14*). . Furthermore, there was no effect of Widths, $F(1,39) = .67$, $p = .417$, and there was a marginal interaction between Group and Width; $F(1,39) = 3.51$, $p = .068$, $\eta_p^2 = .083$.

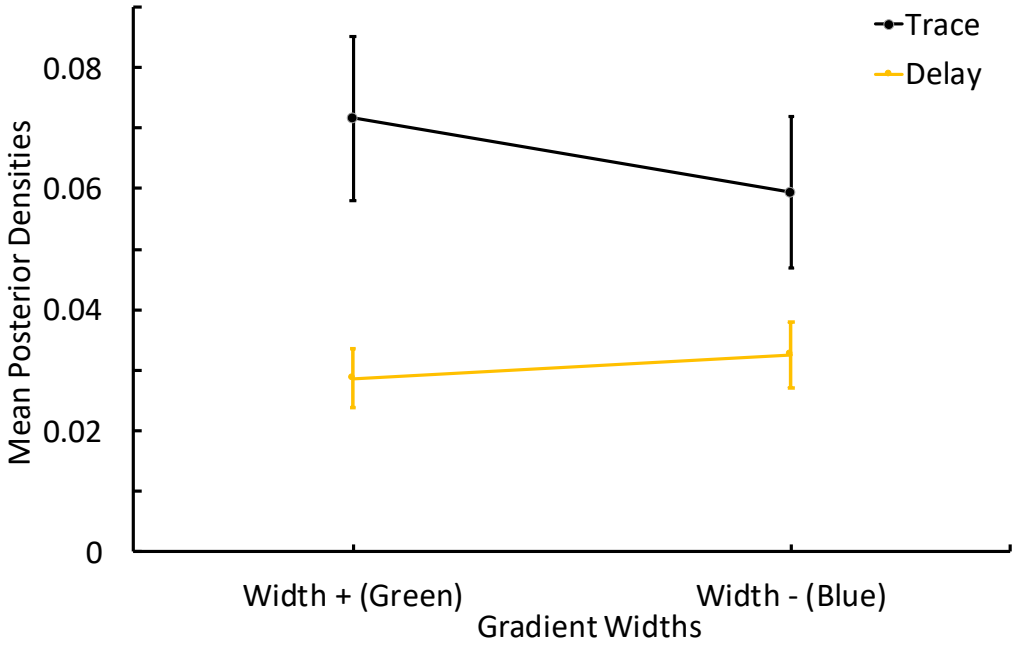

Figure 2.14
This depicts the mean distributions of posterior densities of each side of the gradient for the trace and delay groups in Experiment 3.

2.5.3.4. Expectancy

A 2(Condition: Trace vs. Delay) X 3 (CS: CS+, CS-1, CS-2) ANOVA revealed those in the trace and delay conditions made the same expectancy rating as shown by no main effect of condition, $F(1,39)$ <.001, $p = 1.00$. However, participants did rate the stimuli differently as shown by a main effect as CS, $F(1.4, 54.485) = 173.77$, $\eta_p^2 = .817$. There was no interaction between CS and condition, $F(1.88, 73.32) = .61$, $p = .539$, $\eta_p^2 = .015$. Post Hoc paired T- Tests showed that in the delay condition participants rated the CS+ (M = 8.10, SD = 1.63) higher than the CS-1 (M = 1.85, SD = 1.59), $t(39) = 15.04$, p <.001, *Cohen's d = 2.38*. Participants also rated the CS+ higher than the CS-2 (M = 2.28, SD = 2.22), $t(39)$ = 11.1, p <.001, *Cohen's d = 1.75*. However, there was no difference between ratings for the CS-1 and CS-2, $t(39) = -1.06$, $p = .148$, *Cohen's d* = -.167. Furthermore, in the trace condition participants rated the CS+ (M = 7.8, SD = 2.16) higher than the CS-1 (M = 2.18,

SD = 1.93), *t*(39) = 10.41, *p* <.001, *Cohen's d* = 1.646. Participants also rated the CS+ higher than the CS-2 (*M* = 2.25, *SD* = 1.95), *t*(39) = 11.28, *p* <.001, *Cohen's d = 1.78*. However, there was no difference between ratings for the CS-1 and CS-2, *t*(39) = -.22, *p* = .415, *Cohen's d* = -.034.

2.5.3.5 Anxiety

We assessed the effects of anxiety levels on avoidance responses during the training and test phases for the Delay and Trace groups. Critically, there were no differences between the Trace and Delay Groups in either phase (*full analyses in Appendix*).

2.5.4 Discussion

Overall, the results from Experiment 4 show that during training, participants made more avoidance responses to the CS+ compared to the CS-1 and CS-2 and the responding to the CS+ increased as trials progressed. In addition, there were no difference between Trace and Delay Groups during training. During the generalisation test, there was bell-shaped generalisation curve in which responding peaked at the CS+ and then decreased as the stimuli became less similar to the CS+. Critically, there was a difference between the delay and trace groups when using the augmented gaussian model (Lee et al., 2021) to analyse the data. That is, the trace group had broader generalisation curves compared to the delay group indicating higher number of responses to the generalisation stimuli. This experiment shows - within the same participants – that there are differences in the shape of the generalisation gradients when the contiguity between the CS and aversive outcome are manipulated in an avoidance task. When there is a temporal gap between the CS and the aversive outcome (weak contiguity) participants show a broader generalisation gradient.

Whilst no statistical effects of anxiety levels were observed within this experiment the visual data seemed to indicate some trends between the two groups. When visually comparing the curves for high and low anxiety levels for each group it is the Delay Group which has clearer differences in the shape of the gradient. Whereas in the Trace Group the two gradients have more overlap in the number of avoidance responses. This is the opposite to what we hypothesised in which it was thought that the ambiguity that was introduced by the trace would provide a more sensitive measure for studying individual differences. However, there are some limitations to the way in which anxiety was studied in these experiments (*see General Discussion*) and as there are no statistical evidence, little can be concluded about avoidance behaviour and anxiety.

2.6 General Discussion

This series of experiments assessed the effects of contiguity on the generalisation of avoidance behaviour in humans. Overall, we observed that overall manipulating the contiguity between the CS and the aversive outcome (immediate or after a six second trace) effected the gradient shape in that when there was a temporal gap (trace) the gradient was broader compared to when aversive outcome immediately followed the CS (delay). Experiments 1a and 1b piloted this novel avoidance generalisation task using delay and trace procedures. They indicated that, even with a CS-Outcome trace, participants were able to discriminate between the CS+ and CSs- during training. Experiments 2 and 3 were conducted online and used between-subjects design to compare delay and trace groups, and found there were differences between groups, in that there was more generalisation (broader gradient) in the trace relative to the delay group. In Experiment 4 we took this protocol into the laboratory and used a within-subjects design in order to assess the effects of both contiguity and anxiety levels. The experiment

revealed that there were differences between the gradients which were similar to Experiments 2 and 3. It should be noted that in Experiment 3, despite the pattern looking similar to Experiments 2 and 4, the results were only significant when we applied an additional training criterion. To our knowledge this is the first time a trace procedure has been used to investigate the generalisation of avoidance behaviour in humans.

Moreover, whilst there was an overall tendency for those in the high anxiety group to make more avoidance responses, there were no differences between those with high and low levels of trait within the trace and delay groups. This finding was consistent across all the experiments which is similar to other experiments conducted within our laboratory using an adaptation of a similar task (Fisher & Urcelay, 2024). This could indicate that the specific parameters of the experiment are not sensitive enough to capture individual differences in anxiety. Even when using the data for experiments 1-3 with 236 participants, there are still no effects of anxiety levels on the shapes of the curves, therefore suggesting that it is not due to small sample size. Furthermore, a correlational analysis with all of the data found no relationship between trait anxiety and the Width + and Width – parameters of the Bayesian model. In the fear conditioning literature, it has been found that the effects seen with trait anxiety (Sep et al., 2019) are smaller than those observed in people with diagnoses of anxiety disorders (Cooper et al., 2022), so it could be possible that our sample was in general not anxious enough to provide such sensitivity. However, when visually examining the data from Experiment 4, the differences between high and low anxiety appeared to be more noticeable in the Delay Condition. This could indicate that the ambiguity introduced with the trace causes those with low anxiety to increase their responding so that it is more similar to those in the high anxiety group. However, without

the statistical support it is difficult to draw any definitive conclusions therefore more research is needed.

Overall, the findings of this experiment series are consistent with previous research into the generalisation of avoidance behaviour. Previous research into perceptual stimuli found that those with high neuroticism avoided more to stimuli that was similar to the CS+ (Lommen et al., 2010). However, they were not able to get a clear gradient as they used a 1 press avoidance task so only investigated the number of times participants avoided each stimulus. Interestingly the results were only apparently when participants have 5 seconds to avoid as opposed to 1 second. Moreover, research by Van Meurs and colleagues (2014) also showed that avoidance behaviour can generalise, and that participants had longer reaction times to deciding whether to avoid with the stimuli closer to the CS+. Similarly, they also failed to observe any differences in avoidance behaviour and trait anxiety, but they did find differences for aspects of the distress endurance scale. Therefore, this along with Lommen et al., (2010) could suggest that potentially there are other traits – which themselves are related with anxiety, which are more related to avoidance behaviour than trait anxiety itself, although this conclusion should be taken with caution. This could highlight that other traits should be investigated, further research with contiguity could include scales of intolerance to uncertainty (Birrell et al., 2011) and tolerance to distress (Simons & Gaher, 2005) as well as anxiety scales.

The findings of this experimental series can be interpreted with a modification of the framework proposed by Pearce (1987), in which events are encoded as configurations, meaning that the individual elements of a stimulus are not processed in isolation but as part of a holistic representation. At test, responding is assumed to depend on the similarity between the configural representation formed during training and the one

activated at test. The more similar the test configuration is to the original, the stronger the conditioned response. In the context of trace conditioning, if the temporal gap between the CS and US alters the perceived configuration or disrupts its integrity, then generalisation from training to test may be reduced, leading to weaker responding. These results can further be explained by Riccio's notion of forgetting stimulus attributes (Riccio et al., 1994). It emphasises that forgetting occurs due to not having access to the stimulus attributes such as the context, environmental cues, which serve as retrieval cues, the degradation of these attributes over time, can lead to retrieval failure. In the context of trace conditioning, where a temporal gap exists between the conditioned stimulus (CS) and the unconditioned stimulus (US), Riccio's theory offers an explanation for why longer trace intervals lead to weaker conditioned responses. During the trace interval, the memory of the CS must be actively maintained, including its associated attributes, to form a successful CS–US association. If key stimulus attributes degrade or fail to be encoded robustly, then the organism may struggle to retrieve the memory of the CS when the US is presented, weakening the conditioned response. This supported by animal literature which indicates that longer traces result in weaker learning between the CS and US (Ellison, 1964).

Further research following on from this current set of experiments is needed to understand whether aspects of sensitivity to contiguity manipulations can shed light on generalisation in anxiety disorders. For example, we only investigated two different contiguity levels (0 vs 6 seconds) therefore it would be interesting to explore whether longer traces show more overgeneralisation in comparison with the delay group. An intriguing finding in these experiments is that, during training, we did not observe a significant effect of contiguity in avoidance performance. This is likely the result of human

participants being able to bridge large periods in the absence of stimulation, a notion that has been leveraged before (Lieberman et al., 2008). In addition, contiguity manipulations could be conducted with clinical populations, which have been shown to have larger effects when investigating fear generalisation (Cooper et al., 2022). To address the questions regarding anxiety a potential line of research could be to manipulate anxiety levels to investigate whether this would result in changes to the generalisation gradients particularly with the delay group as this seems to be more sensitive for investigating differences in anxiety. Another potential line of research could investigate whether the contiguity of the response window and the aversive outcome has effects on the shape of the gradient. In this experiment even though there was a temporal gap between the CS and the aversive outcome the response window always remained 1 second before the scheduled US. Therefore, it could be interesting to see if varying this temporal gap can broaden or sharpen the generalisation curve.

In summary, we observed that avoidance behaviour can generalise to other stimuli in human participants, and that the contiguity between the CS and the aversive outcome can affect the shape of the generalisation curve. Generalisation has been highlighted as a possible reason for the maintenance of anxiety disorders (Lissek et al., 2008). Furthermore, there has been a resurgence in research into avoidance behaviour (LeDoux et al., 2017) hence trying different parameters to explore the best protocols for studying anxiety and avoidance behaviour is needed. Whilst the findings regarding anxiety were not as expected these experiments are still a firsts step into investigating contiguity (ambiguity) and the effects on avoidance behaviour.

2.7 References

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Chapter 3

The effects of stress on the generalisation of avoidance behaviour

Abstract

Vulnerability to stressors has been suggested to be a predictor for anxiety disorders and could play a role in treatment relapse. Avoidance is core symptom of anxiety disorders, but little is known about the effects of stress on the acquisition and generalisation of avoidance behaviour. Across two experiments we set out to investigate the effect of stress on avoidance in terms of perceived stress (Experiment 1) and experimentally induced stress (Experiment 2). Participants completed the same avoidance task in which a CS predicted an aversive outcome (aversive image/loud noise) and two CSs did not predict the outcome. Participants could avoid this aversive outcome by pressing the space bar within 1 second of when this aversive outcome was scheduled to happen. During the tests, participants were shown different CSs which varied in similarity to the CSs shown previously. Both experiments revealed successful acquisition and generalisation of avoidance behaviour. The results across both experiments revealed that there were no effects of stress on the acquisition or generalisation of avoidance behaviour. Whilst participants exhibited generalisation curves with the most responding occurring g at the CS+ there overall were no differences between groups.

3.1 Introduction

Anxiety disorders are highly prevalent across the world (World Health Organization, 2022), and this cluster of disorders can be categorised by excessive fear to threatening stimuli and situations, and persistent avoidance to these. Avoidance in those with anxiety disorders is excessive, meaning individuals not only avoid fearful and threatening stimuli and situations but also safe stimuli and situations (Haddad et al., 2012). Thus, avoidance in people with anxiety reflects a “better safe than sorry” strategy (Lommen et al., 2010). Previously it was believed that fear was the driver of avoidance and that by extinguishing fear (through exposure therapy in the clinical world) then avoidance would also decrease. However, empirical research has found this is not the case and that

avoidance can persist when fear levels are low or minimal (Mineka, 1979; Vervliet & Indekeu, 2015). Moreover, clinical studies highlight the large relapse rates after exposure therapy (Levy et al., 2021) suggesting that targeting fear alone is not effective. The literature on avoidance is limited but there has been a resurgence in research due to these clinical implications (Krypotos et al, 2015; Labrenz et al., 2022)

There have been several factors which have been considered to have a relationship with persistent (maladaptive) avoidance, and one such factor is stress. Stress and anxiety have been intuitively linked within the literature and can be difficult to distinguish as they have some overlapping features (Endler & Parker, 1990). Stress can be defined as a physiological or behavioural response produced because of perceiving something aversive as uncontrollable or unpredictable (Koolhaas et al., 2011). In line with this definition, a link between the number of stressful events individuals experience and anxiety levels has been established (McLaughlin & Hatzenbuehler, 2009) and also with a diagnosis of an anxiety disorder (Green et al., 2010). Thus, this correlational data strongly suggests a relationship between stress and anxiety. Moreover, in conditions such as PTSD, there is an identifiable, stressful triggering event which leads to the development of this disorder (White et al., 2015).

It has been suggested that stress plays a significant role in relapse for individuals undergoing Cognitive Behavioural Therapy (CBT) or other forms of treatment for anxiety. In addiction models, stress has long been recognised as a major contributor to relapse, with numerous studies supporting this link (Sinha, 2007). For example, Sinha (2001) reviewed litertuare which suggested that stress-induced changes in the brain's reward system are closely associated with relapse in addiction. Similarly, in the context of anxiety, research has indicated that stress is a predictor of relapse in individuals who have undergone CBT

(Lorimer et al., 2021). Moreover, in a survey study it was found that stress exposure significantly predicted the occurrence of anxiety symptoms (Kessler, 1994). This highlights that there is a relationship between anxiety and stress, and understanding this may help to understand the underlying mechanisms of anxiety and suggest that managing stress could be a critical factor in preventing relapse in anxiety disorders, much like in addiction models. Further research is needed to fully explore this connection and its implications for treatment.

Animal Research

Within the rodent literature the findings on the effects of stress on fear and avoidance behaviours are conflicting, and this presumably stems from a number of reasons (López-Moraga et al., 2022). There are a wide variety of different stress protocols used within the literature and some of these yield different results. Firstly there is a distinction between acute and chronic stress, an acute stressor can be defined as the stressor being presented once whereas chronic can be defined as it being presented more than once – on numerous occasions (López-Moraga et al., 2022). Moreover, in terms of the stressor, most use shocks in which the rats are given unpredictable foot or tail shocks for an extended period of time. Different procedures use different intensities, durations and sessions lengths (López-Moraga et al., 2022). Another way of eliciting stress is the cold swim task, which involves the placing the rats in cold water for a period of time. There is also the restraint stress procedure, which involves rats being placed in a cylindrical tube for a period of time (this can be used as both an acute and chronic stressor Gamaro et al., 1999). In terms of research into generalisation and stress, there have been few studies investigating this within avoidance however there has been work on fear generalisation. A study with mice investigated how stress influenced the generalisation of negative

memories (Ren et al., 2022). They exposed mice to acute stress and then tested their fear responses to both the original conditioned stimulus and similar but novel stimuli. They found that stress increased generalised fear responses to the novel stimuli in comparison to controls, which suggests that stress can broaden fear generalisation

As well as there being different methods for inducing stress, there are also many different avoidance tasks used within the rodent literature. When reviewing the literature on acute and chronic stress and active avoidance studies a majority use the shuttle box or lever press task. The shuttle box task involves the rats being placed in a box that has two chambers and there is grid floor which can be electrified (Weiss & Glazer, 1975). The rats are trained with a CS (light or tone) and will receive a foot shock unless they cross into the other chamber. The lever tasks involve rats being trained to press a lever to avoid an aversive outcome (shock), a number of different measures can be collected such as frequency of presses and latency.

A number of studies have used a mixture of the stressors and the avoidance protocols to test the effects of stress on avoidance behaviour; yielding mixed findings. One of the first experiments in rodents was conducted by Seligman and colleagues using the lever press task and they found that the rats, that underwent the stress manipulation (shock exposure), pressed the lever less compared to the controls, indicating less avoidance overall (Seligman et al., 1975). Moreover, this has been replicated with a combination of other methods (as outlined above) which showed that the stressed rats (via shock exposure and cold swim) exhibited less or reduced avoidance behaviour compared to controls (Lehmann et al., 1999; Weiss & Glazer, 1975). However, there are also other reports that suggest that stress has no effect on avoidance behaviour. For example, using a lever-press avoidance task and shock exposure stressor, there were no

differences between the stressed rodents and the controls in the acquisition of lever-press avoidance behaviour (Brennan et al., 2005). Finally, there is also evidence that suggests that stress can potentiate avoidance behaviour and a subsequent experiment by Brennan and colleagues found that using 30 second shocks (instead of 1 second shocks) resulted in increased lever pressing in the stressed subjects (Brennan et al., 2005). This indicates that potentially different parameters can elicit different results when inducing stress. This has also been found in other studies using the shuttle box and shock exposure stressors (Koba et al., 2001; Wakizono et al., 2007). Overall, the literature on the effects of stress on avoidance behaviour in nonhuman animals is conflicting. Whilst it useful to have many measurements and manipulations, potentially in the future the research should adopt an operationalised design as all studies using different mixtures of avoidance and stress protocols making it difficult to reach general conclusions.

Human Research

Within the human literature there are also a number of different techniques to induce stress including the Cold Pressor Test, Maastricht Acute Stress Test and Trier Social Stressor Task (Allen et al., 2014). The Cold Pressor Test involves participants placing their hand in a bath of cold water and instructing them to keep it submerged for as long as they can, there is also a modified social version of the task which involves either a person watching the participant or the participant being told they are being recorded and someone in another room is watching (Schwabe & Schächinger, 2018). The Maastricht Acute Stress Test involves the cold pressor task but also involves the participants having to engage in difficult mental arithmetic (e.g. counting back from 2043 in steps of 17) (Smeets et al., 2012). Moreover, in the Trier Social Stress Task participants are given a few minutes to prepare a before delivering the speech in front of a panel, this is then followed

by a challenging mental arithmetic task (Allen et al., 2014). These stress procedures have been used to investigate the effects of stress on human behaviour including fear generalisation.

There has been a multitude of studies investigating generalisation in humans due to the links with anxiety. It has been shown that in those with high trait anxiety (Sep et al., 2019) and in individuals diagnosed with anxiety disorders (Cooper et al., 2022), fear generalisation is broader than on low trait anxiety or neurotypical controls. This evidence suggests that anxiety is associated with broader fear generalisation and could factor into the maintenance of anxiety disorders. Moreover, clinical work has highlighted that there is a link between stress and generalisation in anxiety disorders and that stress may exacerbate symptoms such as fear (Ibrahim et al., 2024). Stress is also a symptom of many anxiety disorders and in some cases the catalyst (Lemmens et al., 2021). Some research has investigated stress as a factor because of the implications for PTSD. This psychiatric disorder involves generalisation of responses which were elicited by a traumatic events to similar stimuli (triggers) (Lis et al., 2020) and involves stressors. Research has shown that those with PTSD show increased anxiety when exposed to unpredictable stressors compared to those with generalised anxiety disorder (Grillon et al., 2009).

The research is limited but studies on the generalisation of fear and the effect of stress have found a range of results. A recent study investigated the effects of acute stress and propranolol on fear generalisation. Participants completed the Socially Evaluated Cold Pressor Test before undergoing fear conditioning and a generalisation test. They found that stress had no effect on the gradients compared to participants in the control group in terms of both skin conductance responses and fear ratings (Kausche et al., 2021).

Another study has shown that stress can potentiate fear generalisation, in that those who were exposed to a stressor generalised more than those who did not (Dunsmoor et al., 2017). Participants underwent fear conditioning and then either took part in the cold pressor task or a control task and were then presented with the fear generalisation test. Furthermore, participants did this either immediately after training or 24 hours later. They found that stress induced immediately after training has no effect on generalisation when tested soon after the stress manipulation, but in those who had a 24-hour delay between training and stress had increased generalisation of skin conductance responses and shock expectancy indicating heightened generalised fear. Much like the research in rodents it appears there may be specific parameters in which stress can affect generalisation behaviour, and thus that is why it has been proposed that stress may be a factor that can impact overgeneralisation of fear. Whilst this highlights that stress may not have an effect on the generalisation of avoidance, it is has been found that fear and avoidance do not always follow the same patterns (Vervliet & Indekeu, 2015).

Stress and Avoidance

Moreover, the literature on the effects of stress on avoidance generalisation are also limited due to a lack of research into avoidance behaviour. However, since the resurgence into avoidance research, because of the links with anxiety disorders, newer studies have investigated this phenomenon. The literature, similar to that in rodents, has mixed findings One study has found across two experiments that participants exposed to acute stress exerted more physical effort to avoid potential threats (e.g., electric shocks) but showed no change in effort for monetary rewards (Pavlíčková et al., 2024). Moreover one study investigated the effects of stress on both fear and avoidance generalisation (Lemmens et al., 2021). On day one they used three geometric shapes and paired one with

a shock, whilst the other two were not. On day two, they were trained with an avoidance responses (pressing space bar) and were instructed that when a message popped up on screen, they could avoid the aversive outcome. They were then either exposed to the Maastricht Acute Stress Test (MAST) or a control and were then tested with a range of generalisation stimuli (shapes that were in between the CS+ and the CSs-). They found that stress increased shock expectancy to stimuli that were similar to the CS+. Furthermore, whilst they observed generalisation gradients for both fear (measured via skin conductance responses) and avoidance responses, there were no effects of acute stress on either measure. These limited studies highlight that there are mixed findings in the literature and due to the limited research, it is difficult to determine whether stress does have an effect on generalisation of avoidance behaviour, and that is the goal of the current study.

When reviewing the human and animal literature it is unclear the effect of stress on generalisation of avoidance behaviour. Much of the research on generalisation in humans has been conducted measuring expectancy and fear but rarely avoidance. Because fear and avoidance behaviour are similar and related, but do not always align (Mineka, 1979; Vervliet & Indekeu, 2015), we wanted to directly assess the effects of stress on the generalisation of avoidance behaviour. Given the direct relationship between stress and psychiatry disorders (Pêgo et al., 2009), our goal was to understand the effect of stress (perceived or experienced) on the generalisation of avoidance behaviour. The aim of the current study is to build on the work by Lemmens and colleagues (Lemmens et al., 2021) to investigate the effects of stress on the generalisation of avoidance behaviour. In Experiment 1, we will investigate perceived stress via a questionnaire to observe whether there are differences between those with high and low stress levels based on self-reports.

Furthermore, in Experiment 2 we will manipulate participants stress levels using a social stressor protocol to see if this has an effect on avoidance behaviour and its generalisation. Whilst the literature is mixed, we hypothesise that stress will have an effect on avoidance behaviour in that participant in the High Stress Levels Groups will make more avoidance responses compared to those in the Low Stress Levels Groups. Furthermore, we hypothesised that the High Stress Levels Group would generalise avoidance responses more than the Low Stress Level Group.

3.2 Experiment 1

3.2.1 Introduction

The first experiment investigated the effect of perceived stress on the acquisition and generalisation of avoidance behaviour elicited by trained and generalised signals. In this experiment conducted online, we used the Perceived Stress Scale to determine stress levels (Cohen et al., 1983). This instrument includes scales that take into account both the stress of a situation and also how the participant perceives this. This instrument was chosen because we wanted to assess the individual differences regarding stress, so using a scale that also considers participants perceptions of stress will enable us to target this construct. This scale also allowed us to collect the data online as there have been no studies using online stress manipulations. The 10 item- scale was selected as it been shown to have better validity and reliability than the other versions of the scale (Lee, 2012).

Moreover, as this study was conducted online, we opted to use a self-report as there has been little research using stress manipulations online. We also wanted to use this experiment to help inform us whether there are individual differences in trait stress levels and determine if this would need to be taken into account when we manipulated

stress in Experiment 2. We used the same generalisation task developed in previous experiments (*see Chapter 2*). The findings from Chapter 2, in which we investigated the effect of contiguity on the generalisation of avoidance behaviour, indicated that there were no differences between the delay and trace groups when exploring the relationship between anxiety and generalisation. If any in Experiment 4 there was evidence at a descriptive level that the delay group seemed to be more sensitive to differences between high and low anxiety participants than the trace group. Therefore, in these two experiments, we opted to use only the delay group.

3.2.2 Methods

3.2.2.1 Participants

Participants were recruited via Prolific with the following inclusion criteria: a) had to speak English, b) have no colour vision impairment, c) were aged between 18 and 40, and d) had not taken part in other experiments from the laboratory. Seventy-five participants were recruited, however 9 could not pass the pre-training phase and did not progress with the rest of the experiment. Along with this, one participant did not fully complete the task. In total therefore, there were 65 participants (32 male, 32 female and 1 agender) the ages ranged from 19 -40 (M = 30.2, SD = 5.92). As with the previous online experiments, participants were compensated for their time in accordance with the Prolific guidelines. This study was approved by the University of Nottingham's Ethics committee (reference code: S1267)

3.2.2.2 Design

Participants completed the Perceived Stress Scale (PSS; Cohen et al., 1983) before completing the avoidance generalisation task. The avoidance task had four phases. The first was a pretraining phase which allowed the participants to understand the task

and allow the researchers to exclude any participants who did not learn the basic contingencies of the task during this phase. The second phase was the training phase in which participants were presented one CS+ and two CS- stimuli and were able to avoid the aversive stimulus + by pressing the space bar on the computer keyboard. The third phase was the test phase during which participants were shown several stimuli in order to test for generalisation. Following the avoidance generalisation test, the participants completed phase four in which they answered some expectancy questions about the training stimuli, and a rating about the aversive stimulus.

This was a mixed design with the independent variable being the colour of the generalisation stimuli presented during test of which there were 9. The dependent variable was the number of avoidance responses during the CS presentation of each trial. Perceived stress scores were also used (between subjects) to investigate the relationship with avoidance behaviour.

3.2.2.3 Materials

Perceived Stress Scale

Participants completed the Perceived stress scale (Cohen et al., 1983). This scale measures the level to which the various aspects of life are perceived as unpredictable, uncontrollable and overloading in the last month. In this scale, participants rate each statement on a 5-point Likert scale (0=never, 1=almost never, 2= sometimes, 3=fairly often, 4=very often) depending upon how often they have felt or thought in a certain way in the last month.

3.2.2.4 Procedure

The avoidance task was the same as used in Chapter 2, *Experiment 1*. The task has a pretraining, training, test and expectancy phases. We used the blue- green colour

continuum with the middle Aqua colour as the CS+ and a dark blue and dark green as the CS-1 and CS-2.

3.2.2.5 Data analysis

In this experiment we collected the number of avoidance responses per trial and use this as the dependent variable. For the stress variable, we took the total score on the perceived stress scale and then conducted a median split to divide the participants into high and low stress groups. The median was 20 and the groups were then split based on this which left 30 in the high perceived stress group (M = 25.1, SD = 4.4) and 35 in the low perceived stress group (M = 13.9, SD = 4.5).

During training a 3 (Stimulus: CS+ vs CS-1 vs CS-2) X 10 (trials) X 2 (Stress: High stress, Low stress) repeated-measures ANOVA was conducted. This enabled us to investigate the effect of stress on training as well as if the number of avoidance responses to different stimuli change over trials. Follow up t-tests were conducted to assess the differences between the high and low stress groups for each of the stimuli.

During Test a 2 (Stress: High stress, Low stress) X 9 (Stimuli) mixed ANOVA was conducted to assess the effect of stress on avoidance responses to generalisation stimuli. As the test data is expected to follow a gaussian shape the quadratic effects were reported. Furthermore, in the test phase an augmented gaussian function (Lee et al., 2021) was used to model the generalisation of avoidance responses

3.2.3 Results

3.2.3.1 Training

During training, all participants made similar responses to the three stimuli early on, but by the end of training they made more avoidance responses to the CS+ compared to the CS-1 and CS-2 (*see Figure 3.1*). A 3 (CS: CS+ vs. CS-1 vs. CS-2) x 2 (Group: High

Stress vs. Low Stress) x 10 (Trials) mixed ANOVA revealed a marginal effect of CS, $F($1.049, 66.073) = 3.443, p = .066, η_p^2 = .052 and an effect of Trials, $F($4.757, 299.676) = 5.201, p < .001, η_p^2 = .076, and an interaction between CS and Trials, $F($9.932, 625.739) = 4.245, p <.001, η_p^2 =.063. This suggested that across participants, there were more responses to the CS+ compared to the CSs-, in particular at the end of training. There was no effect of Group on avoidance responses, $F($1,63) = .022, p = .882, η_p^2 = .000 which suggests that that both Groups made a similar number of responses to each CS. There was no interaction between Group and CS, $F($1.049, 66.073) = .013, p = .917, η_p^2 = .000 and no interaction between Group and Trials, $F($4.757, 299.676) = .836, p = .52, η_p^2 = .013. There was no triple interaction between CS, Group and Trials, $F($9.932, 625.739) = 1.239, p = .263, η_p^2 =.019. Follow up t-tests were conducted to assess the main effect of stimulus. They revealed that there was a difference between the CS+ (M = 6.38, SD = 2.42) and CS-1 (M = 3.49, SD = 2.5); t(64) = 6.084, p <.001, Cohen's d = .755 and CS+ and CS-2 (M = 3.66, SD = 2.66); t(64) = 5.255, p <.001, Cohen's d = .652. However, there was no difference between CS-1 and CS-2; t(64) = -.939, p = .176, Cohen's d = -.116 .

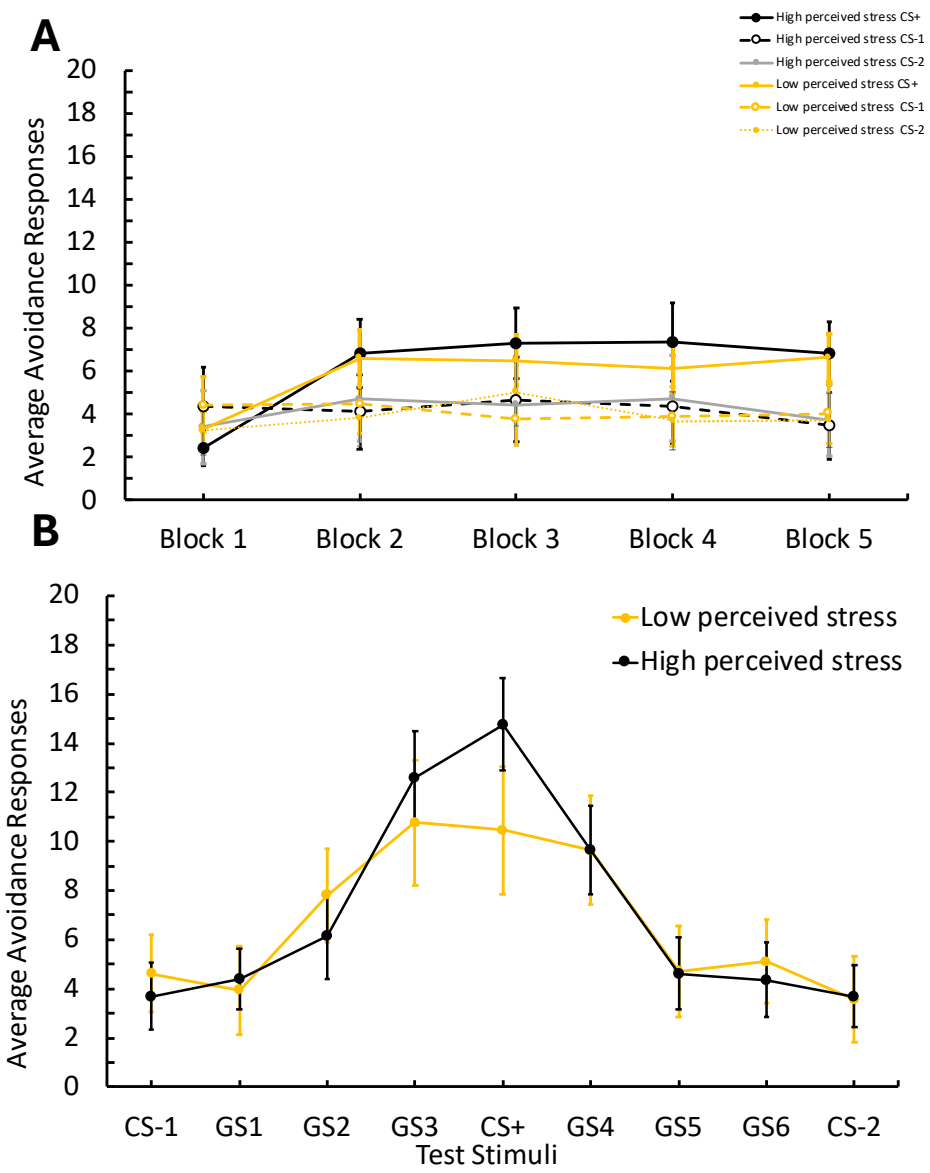

Figure 3.1
The figures show average avoidance responses for the training stimuli for the high and low perceived stress groups during training and test. Panel A shows the training data for both the groups for the CS+, CS-1 and CS-2. The data has been placed into blocks of two trials. Panel B shows the training data for both groups and the 9 test stimuli which include the CS+, CS-1 and CS-2 as well as 6 generalisation stimuli GS.

3.2.3.2 Test

Critically, during the test phase avoidance responses peaked at the CS+ and decreased as the stimuli became less similar to the CS+ creating a curved gradient (*see Figure 3.1b*). A 2 (Group: High Stress and Low Stress) x 9 (Stimuli) mixed ANOVA revealed a

main effect of Stimulus, $F(2.519, 158.679) = 16.42$, $p < .001$, $\eta_p^2 = .207$. This indicates that participants responded differently to the test stimuli. There was no effect of Group on the number of avoidance responses, $F(1,63) = .036$, $p = .851$, $\eta_p^2 = .001$. Critically, there was no interaction between Group and Stimulus, $F(2.519, 158.679) = 1.041$, $p = .368$, $\eta_p^2 = .016$.

3.2.3.3 Model

Visual inspection of the gradients reveals that, aside from height, there seems to be a lot of overlap between the high and low perceived stress groups for the Width + and Width – (See Figure 3.2). This suggests that the responses to the generalisation stimuli were similar in both groups, in other words there was no effect of perceived stress on generalisation.

The *p*(direction) value indicates the proportion of the posterior that falls in the most probable (either positive or negative) direction, with values ranging between 0.5 and 1 (Lee et al., 2021). A value of .5 indicating that half of the posterior estimates are negative and the other positive suggesting no differences between the groups whereas a value closer to 1 indicates a higher likelihood there is a group difference. The Width - had a p direction of .554 and the Width + had a p direction of .628. This indicates there is a low likelihood of group differences in the Width + and Width – parameters.

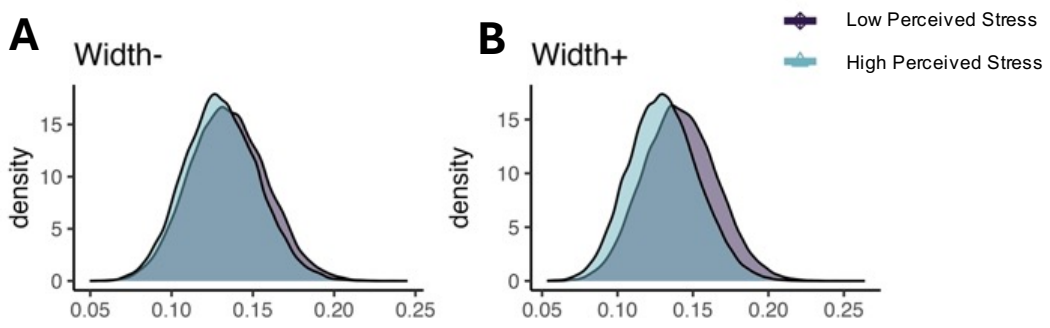

Figure 3.2
The posterior distributions, for the high and low perceived stress groups, Width – (A), and Width + (B).

Participants made similar avoidance responses to each of the widths and there were visually no differences between those with high and low perceived stress. In order to test this a 2(Width: Width+ vs Width-) x 2(Group: Low Stress vs. High Stress) repeated measures ANOVA was conducted to assess if there were differences in avoidance responses. There was no effect of Width, $F(1,63) = .503$, $p = .481$, ηp2 = .008. There was also no main effect of Stress, $F(1,63) = .345$, $p = .559$, ηp2 = .005. Furthermore, there was no interaction between stress and widths, $F(1.63) = .466$, $p = .466$, ηp2 = .007.

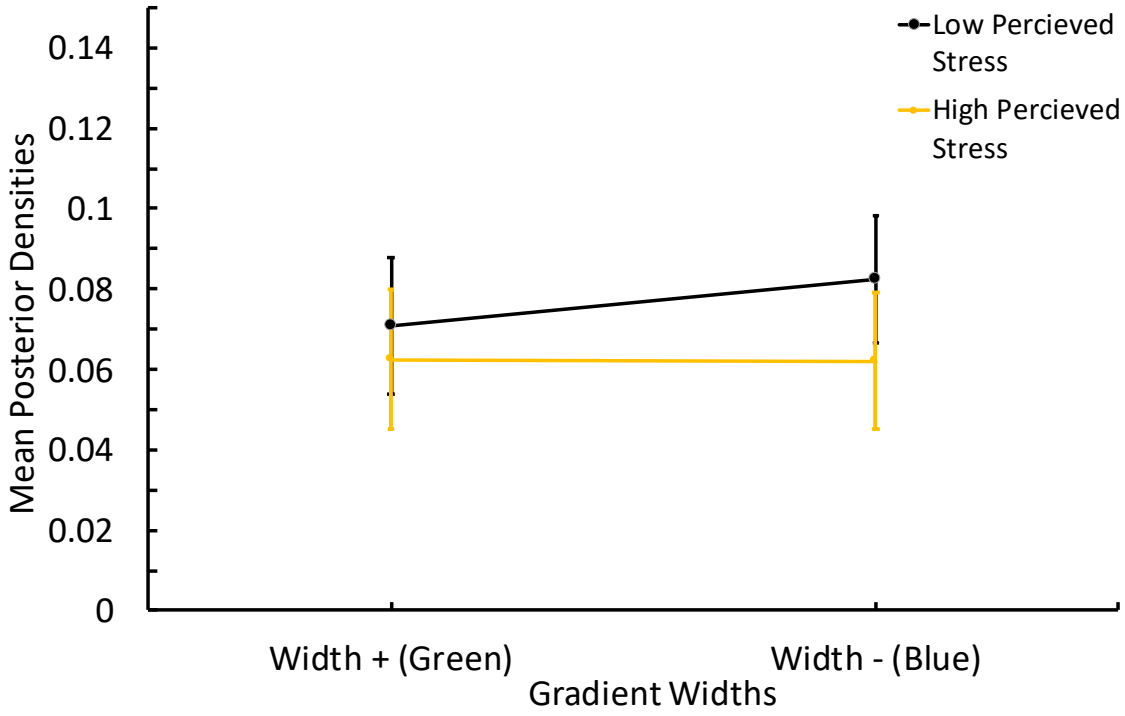

Figure 3.3
This depicts the mean distributions of posterior densities of each side of the gradient for the low and high perceived stress groups.

3.2.3.4 Expectancy

There was no effect of stress on expectancy ratings for the training stimuli. A 3 (CS: CS+ vs. CS-1 vs. CS-2) an effect of CS, $F(1.188,74.821) = 29.294$, $p < .001$, $\eta_p^2 = .317$.

Follow up paired t-tests showed that participants rated the CS+(*M* = 6.38, *SD* = 2.415) higher than the CS1- (*M* = 3,49, *SD* = 2.495), *t*(64) = 6.084, *p* < .001, *Cohen's d* = .755. Participants also rated the CS+ higher than CS-2 (*M* = 3.66, *SD* = 2.659), *t*(64) = 5.255, *p* < .001, *Cohen's d* = .652. However, there were no differences in ratings between CS-1 and CS-2, *t*(64) = -.939, *p* = .176, *Cohen's d* = -.116.

An independent samples t-test was conducted to compare US Aversiveness scores between the two groups. The results showed no statistically significant difference between the low perceived stress group (*M* = 7.26, *SD* = 2.41) and the high perceived stress group (*M* =6.83, *SD* = 2.41); *t*(63) = 0.71, *p* = .482, suggesting that US Aversiveness did not significantly differ between groups.

3.2.4 Discussion

Overall, participants were able to discriminate between the CS+ and CS-1 and CS-2 as the training trials progressed, and they made more avoidance responses to the CS+ at the end of training. However, there were no differences in the number of responses in those with high levels and low levels of perceived stress. Critically, during the test phase, participants' avoidance responses peaked at the CS+ and then decreased as the stimuli became less similar to the CS+ and more similar to the CS-1 and CS-2 creating a bell-shaped gradient.

There could several possible explanations for not finding any effects of perceived stress on the generalisation of avoidance behaviour. Firstly, this could be due to the way in which we determined allocation to the two groups. Whilst median splits have been used within this field (Lawrance et al., 2022 ; Wong & Pittig, 2023) - including, Fisher & Urcelay, 2024) they may not have the required sensitivity for finding differences in psychological

phenomena on avoidance such as psychological perceived stress. However, Lee's model requires different groups to assess differences between them, hence the data needs to be divided into groups such as high and low perceived stress. But visual inspection of the gradients does not suggest any appreciable differences between the groups.

Furthermore, the use of scales could be argued to be subjective and whilst the overall validity of the perceived stress scale is high, it may not be the best and most suitable way of assessing stress and avoidance. Also, as seen in other chapters (*Chapter 5*) within this thesis there is a lot of variability in responses on the task. This is present both within a task and also across experiments, for example in Chapter 5 Experiment 2 showed no differences in training despite using the same training phase as all other experiments within Chapter 5. Moreover, this online task uses images as the aversive outcome, as opposed to a loud noise during the avoidance task. Whilst these images are aversive and have been taken from the IAPS (Lang et al., 2020) it could be that participants turned away from the screen when they were presented, an issue with online data collection is that there is no way of ensuring or knowing how the participants participate in the task.

Therefore, to address these issues and attempt to study the links between avoidance and stress we aimed to manipulate participants stress levels within the laboratory to see if this had an effect on avoidance responses and generalisation.

3.3 Experiment 2

3.3.1 Introduction

The previous experiment did not detect differences during avoidance acquisition, nor in the gradients for those with high and low perceived stress scores therefore we wanted to assess whether manipulating stress in the laboratory would increase sensitivity for the observation of effect of stress on the generalisation of avoidance behaviour. We

decided to use a social stressor manipulation which is similar to some aspects of the TSST (Sayette et al., 2001), that has been previously developed at the University of Nottingham. This stressor involves informing participants at the start of the experimental session that they will need to prepare a speech about the aspects of their bodies they like and dislike, which will later be recorded and analysed by a clinical psychologist. After these instructions, participants are given 3 minutes to prepare the presentation. However, they are then told at the end of the experiment that they do not have to complete the speech. Control participants are invited to read a National Geographic article during the 3 minutes of preparation before the experiment takes place. A reason for using this manipulation is that it has more ecological validity as this kind of stress is faced in day-to-day life in terms of having to have difficult conversations or giving public speeches. This could be similar to social anxiety or public speaking phobias which makes it more relevant to the study of anxiety compared to other manipulations such as the cold pressor task (which involves exposure to a painful situation). Furthermore, when manipulating stress in the laboratory, we wanted to also measure the physiological effects such as changes in the skin conductance response. We wanted to ensure that the stress manipulation was successful so also collected SCR to assess pre and post manipulation differences. However, due to time constrains the SCR have not been analysed yet.

3.3.2 Methods

3.3.2.1 Participants

Participants were recruited from the University of Nottingham's School of Psychology and were first year undergraduates. They completed the experiment in exchange for credits which were a requirement of their degree course. There were 40 participants with 20 in each group. The ages ranged from 18 to 30 years old (M = 19.8, SD =

3.13) and there were 38 females and 2 males. This experiment was approved by the University of Nottingham's Ethics committee (reference code: S1627).

3.3.2.2 Design

This was a between subject's design in that participant either took part in the Stress condition or the Control condition. The avoidance task used was the same as Experiment 1 with the same phases: Pre-training, training, generalisation test and expectancy ratings. One aspect of the task that was different was the aversive outcome. In this experiment we used an aversive noise (1 second) which sounded like metal on concrete which has been used within other experiments within the field and validated by Neumann and collaborators (Neumann & Waters, 2006)

3.3.2.3 Materials

Stress Mood Induction

An adaptation of a speech stressor task (Sayette et al., 2001) was used to elicit a transient state of anxiousness in each participant. In this mood induction, participants are told that they will give a speech about their bodies which will be recorded and later evaluated by a clinical psychologist. The experimental room had a camera setup that was turned on (but not recording), and photography lights were also set up and turned on, all this to mimic a recording environment. The exact instructions participants were given were:

After doing the computer task, you will be asked to give a speech about what you like and dislike about your body and physical appearance. You will need to sit in the chair behind you, so we can have the white wall to be the background, look at and talk to this camera (a camera was set about two meters away from the seat). I will turn on this photography light before I leave the room, please do not turn it off. In the speech, you will need to talk about what you like and dislike about your body for at least 3 minutes. Please

try to be as open and as honest as possible. A therapist will rate the videotaped speech later. The therapist will rate your openness by analysing how often and in what ways you were defensive. Some common defences include:

Denial: Sometimes people may deny something because the truth is hard to accept. Facing reality can be too painful and stressful. For example, when children break things, they often cover their eyes with their hands. Sometimes people refuse to believe that loved ones are passed away.

Suppression: When experiencing some pain, people consciously try not to think about it. This reduces the psychological contact with the injury. For example, after a mother lost her child in a car accident, she would quickly change the topic when people mention something about driving. She may also quickly turn the page when she read some news about the car accident in the newspaper.

Rationalization: To give an unacceptable emotion, or action some seemingly rational explanation. This is the most common defence people use to cover up their pain or failures in order to maintain peace of mind. For example, if your friend is mean to you, you may rationalise it as them having a bad day rather than letting yourself be hurt by their words.

Humour: Sometimes people use humorous language or behaviour to cope with stressful situations, express aggression or desires. For example, jokes about sex, death, and attack are the most popular.

These are some examples. In your speech later, we hope you can be as open and honest as possible. Now, if you are ok with it, please sign this consent form to agree to be videoed.' You will now have 3 minutes to think about your speech.'

Informed consent for the video recording was sought at this stage, after participants have read the task instructions. At the end of the session, the participants were debriefed about the true purpose of the study and given the assurance that nothing was video recorded within the experiment, and they only had to fill out the video recording consent form as part of the stress manipulation.

Following the experimental task and after the debrief, the participants in the Stress condition underwent a positive mood induction to restore their mood after the stress manipulation. This involved them watching 3 short videos (combined = 3 minutes in length) taken from (Kogan et al., 2018) who used these videos along with several others to induce a positive mood amongst veterinary students.

Control Mood Induction

The camera and photography lights were turned off in this group. A neutral reading task (passage taken from the National Geographic) was used to elicit/maintain a neutral mood state, providing a neutral Control Group. In this task participants were asked to read a passage provided on paper in front of them for 3 minutes. Once the 3 minutes were finished, they started the experimental computer avoidance task. At the end of the session, the participant will be debriefed about the true purpose of the study.

Skin Conductance

Electrodermal activity was measured using Biopac (Model M160) and recorded using AcqKnowledge (version) at a sampling rate of 2 Hz. The electrodes were attached to the left hand (index and ring finger) and participant were asked to keep their hand still for the duration of the experiment. It was decided to use the left hand as the task involved pressing the space bar which was not dominant hand specific.

3.3.2.4 Procedure

The procedure is similar to *Experiment 1* with the addition of the stress manipulation and that it was run in the laboratory instead of online. Participants were given an information sheet and signed a consent form. They were informed that the experiment would involve an aversive stimulus. The electrodes were then placed on the participants left hand and they were asked to keep their hand on the table for the duration of the experiment. A two-minute baseline of skin conductance was then taken, during this period nothing was presented to the participants. After this baseline participants then filled out the STAI at their own pace. After this the screen informed them that the experimenter had further instructions for the next part of the study. Participants were given the instructions for the mood induction; they were either in the Control Group or Stress Group. After the instructions the computer screen displayed a 3-minute timer so participants were aware of how long they had to either prepare their speech (Stress Group) or read the magazine article (Control Group). Following the mood induction, the pre training instructions were displayed on the screen and the experimenter informed them that all the remaining instructions would be on the screen but if they had any questions, they could ask the experimenter. Then they were asked to put the headphones on and begin the task. The task then moved through the pre training, training, test, expectancy and then the state anxiety scale again before ending. The whole experimenter took approximately 25 minutes to complete. After the task had finished, the participants in the stress group were informed that they would not have to complete the speech. The electrodes were removed, and all participants were then debriefed fully and those in the stress group underwent a positive mood induction (watched a 3-minute videos). They were

then thanked for their participation and asked not to reveal the true nature of the experiment to other people.

3.3.2.5 Data Analysis

The data analysis was the same as Experiment 1 in this chapter, except participants were split by the mood induction they underwent (Stress or Control). Furthermore, we also had participants fill out pre and post State anxiety scales taken from the Spielberg's State and Trait Anxiety Scale (Spielberger, 2010) in order to assess whether the stress manipulation was successful.

3.3.3 Results

3.3.3.1 Training

During training, participants made more responses to the CS+ compared to both the CS1- and CS2- as trials progressed and the Stress and Control groups made similar responses (Figure 3.3.A). A 2 (Group: Stress vs. Control) X 3 (CS: CS+ vs. CS-1 vs. CS-2) x 10 (Trials) repeated-measures ANOVA was conducted and revealed a main effect of CS, $F(1.46, 55.49) = 57.46$, $p < .001$, $\eta^2_p = .602$, indicating that avoidance responses differed significantly for the CSs. There was a significant main effect of Trials, $F(2.73, 103.88) = 17.02$, $p < .001$, $\eta^2_p = .309$, indicating that avoidance responses changed over the course of the Trials. Critically, there was no significant main effect of Group on avoidance responses, $F(1, 38) = 0.79$, $p = .379$, $\eta^2_p = .020$, indicating that those in the Stress and Control Groups made similar avoidance responses.

Moreover, the interaction between CS and Group was not significant, $F(1.46, 55.49) = 0.005$, $p = .981$, $\eta^2_p < .001$, suggesting that the effect of CS on avoidance responses did not differ by group. The interaction between Trials and Group was also not significant, $F(2.73, 103.88) = 1.22$, $p = .304$, $\eta^2_p = .031$, suggesting that changes in

avoidance responses across trials did not differ by Group. Additionally, there was a significant interaction between CS and Trials, $F(5.12, 194.40) = 18.14$, $p < .001$, $\eta^2_p = .323$, indicating that the effect of CS on avoidance responses varied over trials. However, the three-way interaction between CS, Trials, and Group was not significant, $F(5.12, 194.40) = 0.31$, $p = .910$, $\eta^2_p = .008$.

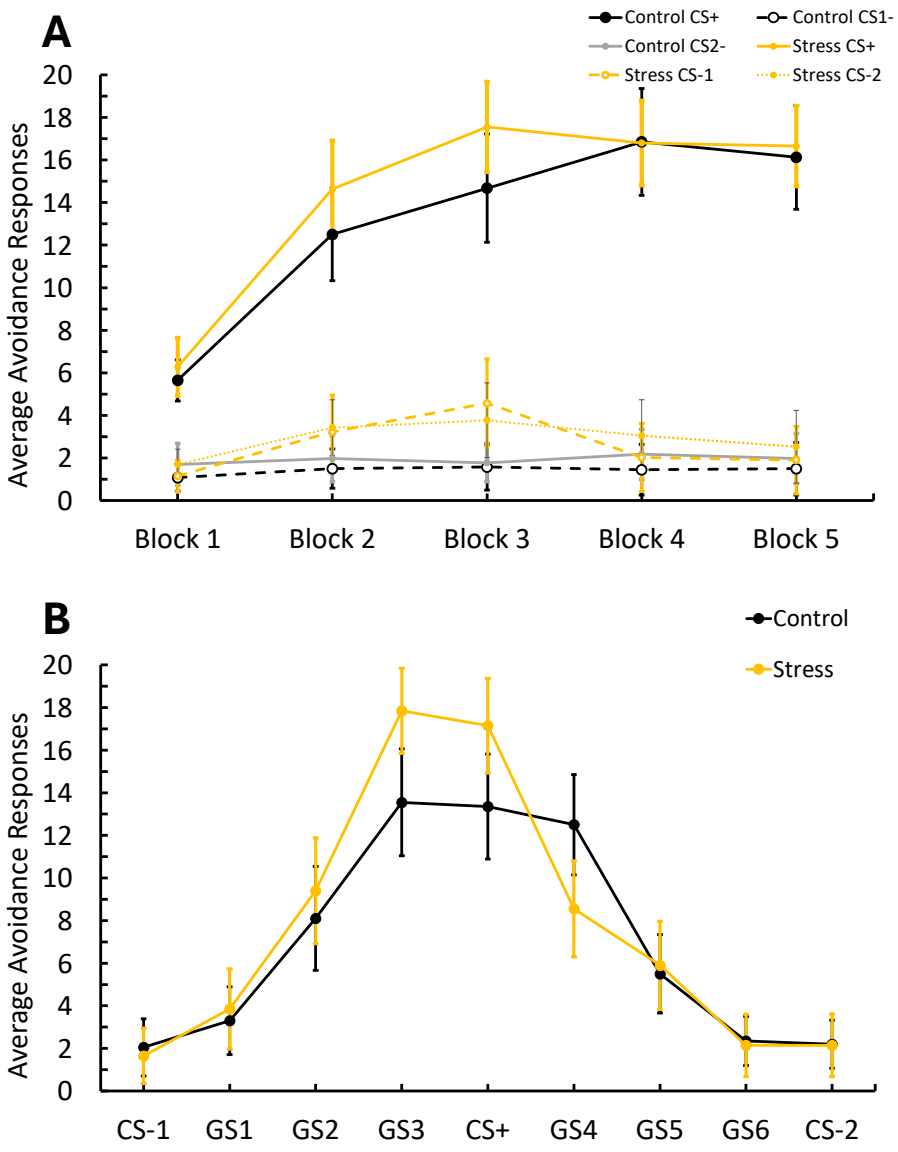

Figure 3.4
The average avoidance responses for the training stimuli for the Stress and Control Groups. Panel A shows the training data for both groups for the CS+, CS-1 and CS-2. The data has been placed into blocks of two trials. Panel B shows the testing data for both groups and the 9 test stimuli which include the CS+, CS-1 and CS-2 as well as 6 generalisation stimuli (GS).

3.3.3.2 Test Data

Overall, the data shows that participants' avoidance responses decreased as the stimuli became less similar to the CS+ (see Figure 3.3B). A 2 (Group: Stress vs. Controls) X

9 (Stimulus) mixed ANOVA was conducted, and a significant main effect of Stimulus was found, $F(3.40, 129.24) = 31.22$, $p < .001$, $\eta^2 = .255$, indicating that avoidance responses varied significantly across stimuli. However, the interaction between Stimulus and Group was not significant, $F(3.40, 129.24) = 1.70$, $p = .164$, $\eta^2 = .014$, suggesting that the effect of Stimulus on avoidance responses did not differ by Group. There was no significant main effect of Group on avoidance responses, $F(1, 38) = 0.11$, $p = .739$, $\eta^2 = .001$, indicating that Group did not have a significant overall effect on avoidance responses.

3.3.3.3 Model

Visually, the data suggests that there is a clear distinction in distribution of posterior densities in height. In terms of the Width – and Width + - which are critically modelling the generalisation - there is an overlap in the distribution of posterior densities. The *p*(direction) value the model calculates indicates the proportion of the posterior that falls in the most probable (either positive or negative) direction, with values ranging between 0.5 and 1 (Lee et al., 2021). A value of .5 indicating that half of the posterior estimates are negative and the other positive suggesting no differences between the groups whereas a value closer to 1 indicates a higher likelihood there is a group difference. The Width - had a p direction of .782 and the Width + had a p direction of .602. This indicates there is a low likelihood of group differences in the Width - and a slightly higher likelihood of differences with the Width – parameter.

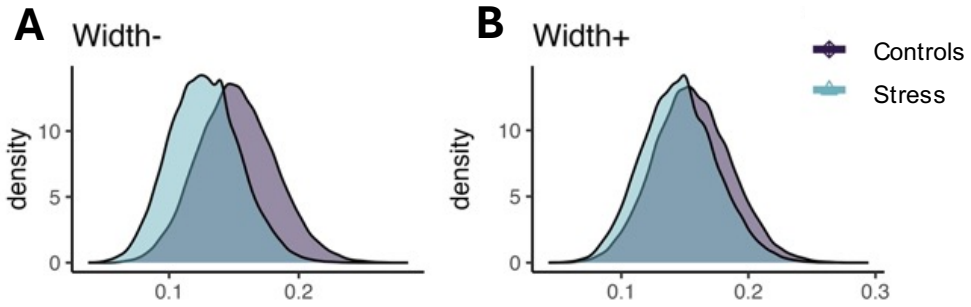

Figure 3.5
The posterior distributions, for the high and low perceived stress groups, for Width – (A), and Width + (B). The axis indicate the probability for the

In order to test this a 2(Width; Width+ and Width-) x 2 (Group: Stress vs. Control) repeated measures ANOVA was conducted to assess if there were differences in avoidance responses. There was an effect of Width, $F(1,38) = .6.042$, $p = .019$, $\eta p2 = .137$. There was also no main effect of Group, $F(1,38) = .961$, $p = .33$, $\eta p2 = .025$. Furthermore, there was no interaction between Group and Widths, $F(1.38) = 2.68$, $p = .11$, $\eta p2 = .025$.

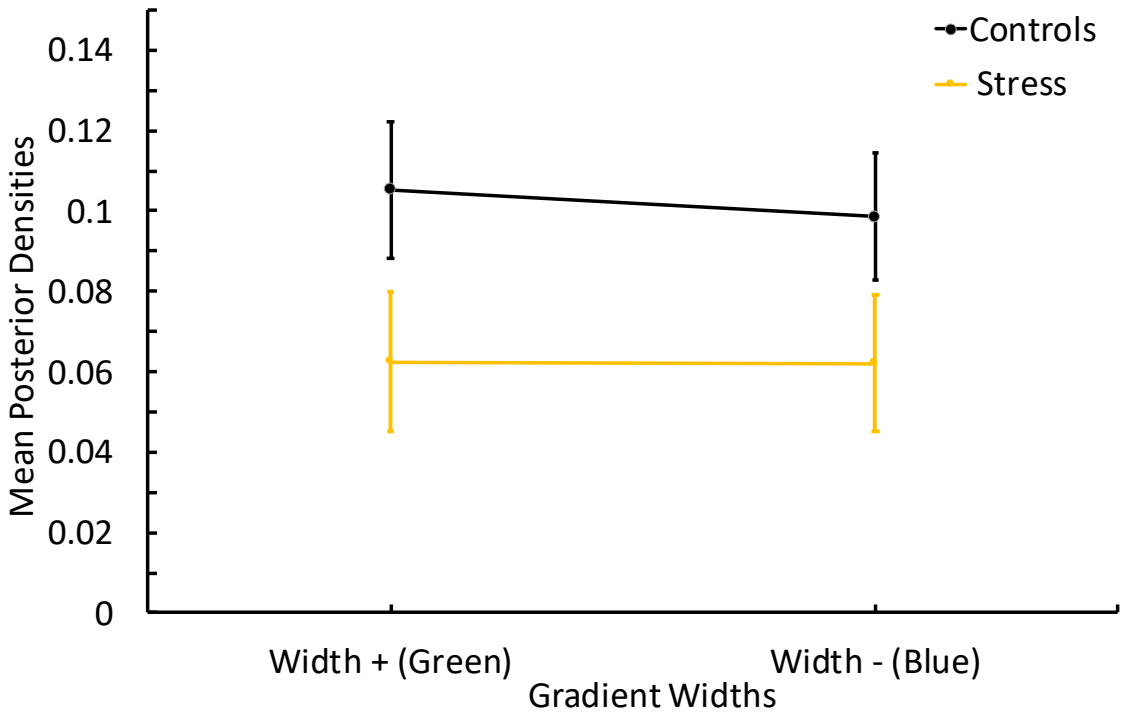

Figure 3.6 This depicts the mean distributions of posterior densities of each side of the gradient for the Stress and Control groups.

3.3.3.4 Expectancy

An ANOVA was conducted to examine differences in expectancy ratings to the three CSs that were presented during training for the Stress and Control groups. There was no significant main effect of condition, $F(1, 38) = 1.05$, $p = .312$, There was a significant main effect of CS on expectancy ratings, $F(1.91, 74.63) = 118.65$, $p < .001$, $\eta^2_p = .753$, indicating that expectancy ratings differed significantly across trained stimuli. There was no interaction between CS and Condition; $F(2, 76) = 0.90$, $p = .413$. Independent Samples t-test revealed that expectancy ratings for CS+ ($M = 7.85$, $SD = 1.27$) were significantly higher than both CS1− ($M = 2.40$, $SD = 2.33$), $t(39) = 12.84$, $p < .001$, and CS2− ($M = 2.00$, $SD = 2.00$), $t(39) = 13.79$, $p < .001$. However, the difference between CS1− and CS2− was not significant, $t(39) = 0.94$, $p = .349$.

An independent samples t-test was conducted to compare US Aversiveness scores between the Control and Stress groups. The t-test results showed no statistically significant difference between the Control group (M= 6.85, SD = 1.18) and the Stress group (M = 6.35, SD = 2.16) in ratings of the US aversiveness; $t(38) = 0.91$, $p = .369$.

3.3.3.5 Pre and Post STAI

A 2 (Time: Pre vs. Post) X 2 (Group: Stress vs. Control) repeated-measures ANOVA was conducted to examine the effect the stress manipulation on state anxiety scores**.** main effect of Time, $F(1, 38) = 14.79$, $p < .001$, $\eta^2 = .280$ however, there was no main effect of Group; $F(1, 38) = 1.46$, $p = .235$, $\eta^2 = .037$. There was also no interaction between Time and Group; $F(1, 38) = .033$, $p = .857$, $\eta^2 = .001$.

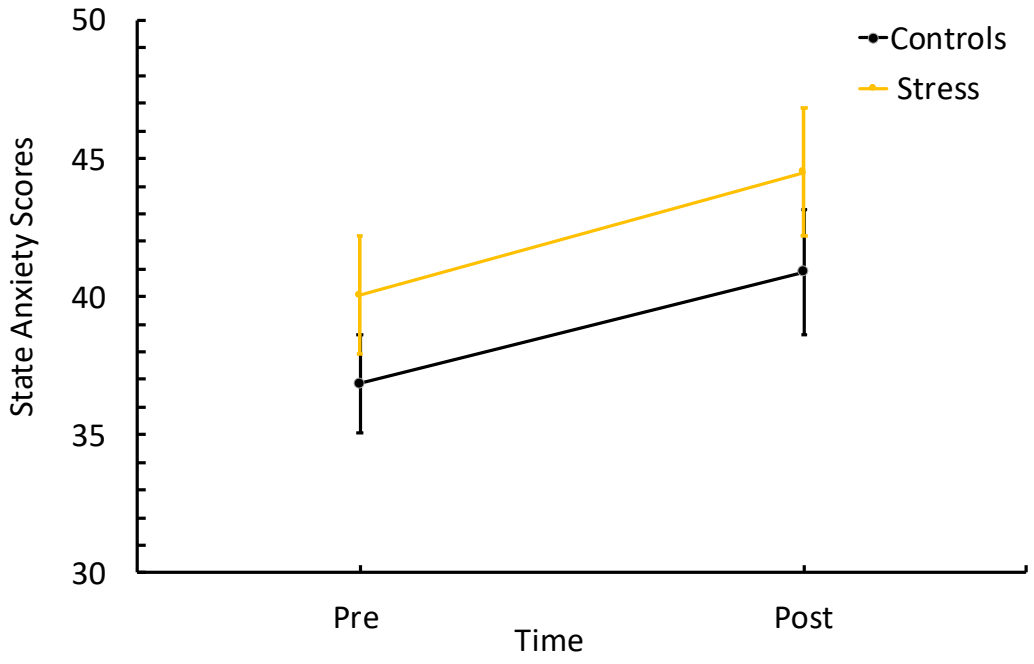

Figure 3.7
This figure shows the state anxiety scores pre and most mood induction for the stress and control groups.

3.3.4 Discussion

Overall, the results from this experiment indicate that there were no effects of induced stress on the acquisition and generalisation of avoidance behaviour. During training, both the Stress and the Control Groups responded to the CS+ more than the CS-1 and CS-2 which indicates they learnt which CS predicted the aversive outcome. During the generalisation test it was found that there were differences in avoidance responses to the test stimuli, in that responding peaked at the CS+ and as the stimuli became less like the CS+ the responding decreased. Critically, there were no differences between the Stress and Control Groups on generalisation behaviour.

There are a few possible reasons for the absence of group differences in this experiment. It is noted that whilst experiments conducted on stress have found differences when using samples of 40 participants (Schwabe & Wolf, 2010) that the sample used in this experiment is considered small and could potentially have little statistical power. Other studies within the literature use samples of around 80 participants (Schwabe & Schächinger, 2018) therefore this could be replicated after a power analysis has between conducted to ensure there is sufficient power. Moreover, from assessing the pre and post STAI measures it seems that it is possible the stress manipulation was not successful. Participants in both groups showed an increase in state anxiety levels post manipulation. A possible reason for the increase in both groups could be because participants found the avoidance computer task stress inducing. Equally, the set-up of the room in both groups was similar and whilst the video camera and photography light were turned off in the Control Group, the presence of them within the room could perhaps had an effect on the participants. Therefore, it seems that both Groups were similar on these psychometric scales so it is difficult to ensure that the

stress manipulation was successful which could account for the results within this experiment. The skin conductance responses will be assessed in the future to investigate whether there is physiological evidence that the stress manipulation was successful.

3.4 General Discussion

The aim of this experiment series was to investigate the effects of stress on the acquisition and generalisation of avoidance behaviour. Experiment 1 was conducted online and investigated the effects of self-reported perceived stress on avoidance behaviour and Experiment 2 manipulated stress levels in the laboratory to investigate the effects on avoidance behaviour. Both of these experiments used the same avoidance task and measured the number of avoidance responses. The results in both experiments showed a similar pattern of results for both acquisition and generalisation. In neither experiment there was any indication of an effect of perceived or induced stress.

Overall, both experiments revealed that during the acquisition phase, there was more responding to the CS+ than the CS-1 and CS-2 by the end of the training phase, and this was independent of stress status. This suggests that stress measured both by self-reports (Experiment 1) and by manipulation (Experiment 2) did not have an effect on the acquisition of avoidance behaviour. This aligns with previous research conducted in animals which showed that there was no effect of acute stress on the acquisition of avoidance behaviour in rats (Brennan et al., 2005). However, this finding goes against a large section of the literature in rats which shows that stress reduces avoidance responding (Lehmann et al., 1999; Seligman et al., 1975; Weiss & Glazer, 1975). Moreover, the limited research in humans found that stress had no influence on fear acquisition (Kausche et al., 2021) and also in an avoidance task it was found that there were no

differences in avoidance acquisition between those who underwent a stress manipulation and controls (Lemmens et al., 2021).

Critically, during the test phase, a generalisation gradient was observed with responding the highest at the CS+ and then decreasing as the stimuli became less similar to the CS+ (and more similar to the CSs-) across both experiments. However, in both experiments there was no effect of stress on the generalisation of avoidance. In Experiment 1, those with high perceived stress scores showed more responding to the CS+ however, there were no differences in generalisation with both groups showing similar gradients. In Experiment 2, the results were roughly similar, with the group that underwent the stress manipulation responding more to the CS+, but the overall generalisation gradient was similar to the control groups. Together, these two experiments suggest that stress has no effect on generalisation of avoidance behaviour. The findings within the literature are mixed, but the current findings align with those of Lemmens et al. (2021) who found that acute stress only resulted in differences in fear generalisation gradients, but not gradients obtained through avoidance responses. However, with little research having been conducted on the effects of stress on avoidance generalisation it is difficult to make solid conclusions, but the literature seems to lean towards there being no effects.

A limitation of these experiments is that whilst the primary focus of the study was to investigate the effects of stress on avoidance behaviour, we did not take any measurers of fear (or expectancy) during the generalisation tests. Research has suggested that whilst these measures are related, in some circumstances fear does not predict avoidance behaviour (Mineka, 1979; Vervliet & Indekeu, 2015). In addition, one report which reported data consistent with the current results also measured fear and expectancy and found a

(rather small) effect on expectancy, so it is possible that an effect would have been detected had we measured expectancy and fear measures. In other words, it would have been interesting to measure some aspect of fear alongside the avoidance measurements to explore whether stress has similar effects on fear and avoidance acquisition and generalisation. Moreover, whilst this study utilised two different methods of assessing the effect of stress on avoidance behaviour both using subjective self-reports and by manipulating stress levels, a future direction with this line of research could be to use a difference stress manipulation. Whilst the social stressor speech task (Sayette et al., 2001) has been used throughout the literature and does imitate aspect of social anxiety other methods such as the cold pressor (Schwabe & Schächinger, 2018) are more widely used. As stress can be manipulated in many different ways both acutely and chronically then it would be interesting to see if the current results could be replicated using a different procedure.

Overall, the findings from this experiment seem to indicate that stress does not have an effect on both the acquisition and generalisation of avoidance behaviour. The current literature in both rats and humans is limited and the research that has been conducted is mixed. This highlights a need for more research with the hopes that this can expand the current stress and anxiety literature on avoidance and eventually lead to the enhancement of treatments.

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Chapter 4

Ontogeny of the generalisation of avoidance behaviour

Abstract

The developmental trajectory of avoidance behaviour generalisation has received limited research attention, despite rising rates of anxiety diagnoses in young children who are often excluded from such studies. This study used an avoidance task to investigate generalisation in children aged 5–11 years. The task involved an adaption of the classic "Space Invaders" videogame, in which participants have to shoot spaceships (pressing the space bar on the keyboard) but also avoid being shot by a large spaceship using the arrow keys. The oncoming of a large spaceship (which results in loss of points) is signalled by coloured sensors at the top of the screen. Some sensors predict the outcome (CS+) and some do not (CS-). Participants can avoid the large spaceship by moving into the safe areas of the screen and hide. Following avoidance training, we then manipulated the colour of the sensor along the CS+ dimension to assess generalisation. The participants were children attending a summer outreach week and they were aged 5-11 years old. Our findings revealed that age significantly influenced generalisation gradients, with younger children (5-8) exhibiting flatter gradients compared to older children (9-11). Regression analyses indicated that age, but not anxiety, was a significant predictor of generalisation patterns. These results underscore the impact of ontogenetic changes on the generalisation of avoidance behaviour and highlight the importance of including young children in research to better understand the mechanisms underlying anxiety disorders. Studying these processes in relation to development may inform the design of early interventions and treatments targeting maladaptive avoidance behaviour.

4.1 Introduction

Avoidance is when people engage in behaviour to prevent or keep away from situations or stimuli which is perceived as threatening or aversive (LeDoux, 2017). Avoidance is a core symptom of anxiety disorders and research attention has shifted in recent years from fear research to avoidance since it has been found that fear and

avoidance although related do not always follow the same behavioural patterns (Vervliet & Indekeu, 2015). Moreover, the prevalence of anxiety disorders among young people is rising, with global estimates ranging from 2% to 41% (Cartwright-Hatton et al., 2006; Racine et al., 2021). In children, anxiety-related psychological disorders can have detrimental effects on many different aspects of life including difficulties in school (Mazzone et al., 2007) and also social interactions between peers (Ginsburg et al., 1998). Little is known in humans about the generalisation of avoidance behaviour and in particular there has been no empirical work investigating the ontogeny of avoidance behaviour. It has been shown that developmental age can have effects on other aspects of learning such as fear conditioning (Glenn et al., 2012). Through studying the ontogeny of behaviour, we can help to explore how avoidance changes as children develop cognitively and how this behaviour is maintained form childhood into adolescence and on wider scale it could be useful from a clinical perspective.

Research on development of generalisation in children is limited, though insights can be drawn from studies in the animal literature. There have been studies which involve comparing infant animals (of various ages depending on the species) to adult counterparts to assess the development of behaviour. However, the rodent literature is mixed with no clear findings in whether there are developmental differences in generalisation behaviour. Furthermore, when exploring the rodent literature, it is important to distinguish two critical types of tasks. The first is a discrimination task which typically involves training one stimulus or context paired with an aversive stimulus and another stimuli or context which is paired with nothing. Researchers then assess the behaviour with both stimuli (or contexts) to assess whether the rats can discriminate between the two. If they cannot then it is suggested that there is low discrimination which could be interpreted as

generalisation. The second type of task is a generalisation task in which rats are trained the same as a discrimination task but during a test they are presented with novel stimuli (or contexts) which differ in similarity to the CS+ and CS-. This allows research to see the generalisation to new stimuli as a function of similarity to the trained stimuli. The rodent literature uses a mixture of both of these designs.

In one study, Rohrbaugh & Riccio (1968) compared infant rats (18 days old) and adult rats (120 days old) using a fear conditioning paradigm. The rats were trained in an inhibitory avoidance task in which the black compartment of a box was paired with a shock, whereas the safe white compartment was not. They were then tested in the box with the guillotine door open and they could roam each compartment freely. They were tested for spatial avoidance of the black compartment. Critically, subjects were also tested in a similarly constructed – yet different – apparatus to assess generalisation of avoidance behaviour. The results revealed that generalisation between apparatuses increased with age; in that the adult rats spent roughly equal times in each compartment compared to the infant who displayed weaker spatial avoidance in the untrained apparatus used to test for generalisation. This finding challenged earlier assumptions that early development stages generalise fear more broadly. Moreover, Frieman et al. (1969) trained two groups of rats (19-23 days old and 90-120 days old) with a tone in one compartment of a shuttle box. They then were presented with different tones and they found that the infant rats showed steeper generalisation slopes compared to the older rats. Frieman et al., (1970) further explored this by training infant (17 day old) and adult (90+ day old) rats in a conditioned suppression preparation and varying at test the CS+ dimension (different tone frequencies). Their findings supported Rohrbaugh and Riccio's,

(1968) and Frieman et al.'s, (1969) showing that infant rats displayed steeper generalisation gradients relative to the adults, indicating less generalisation in young rats.

Moreover, other research has investigated generalisation using auditory stimuli, one study McGaughey and Thompson (1975) trained infant (20 day old) and adult (80 day old) rats in a fear conditioning preparation. Each age group was divided into two groups, one that received pairings of a tone (120hz) and a shock and the other received random presentations of the tone and shock. During the generalisation test they were presented to two tones (1000Hz and 1400Hz). The results revealed that when measuring heart rate (physiological measure of fear), the infant rats had steeper generalisation than adults meaning their heart rate decreased as the stimuli became less alike the CS+ whereas the adult rats had a raised heart rates (indicating more fear) when the stimuli was similar to the CS+.

On the other hand, some research has found the opposite results. A study habituated two groups of rats (16-17 days old and 19-20 days) old rats to a 1600Hz tone and on the 16th trial they then presented one of seven different generalisation tones (Campbell & Haroutunian, 1983). They found that when assessing heart rate responses, the younger rats showed no changes indicating that they had generalised to other stimuli. Similarly, a study investigating the effects on generalised auditory fear cues trained rats aged 18 days and rats that were 25 days with a tone they were then tested with a different tone (Rudy & Pugh, 1996). They found that the younger rats showed more generalised fear compared to the older rats. Overall, much of the rodent literature seems to indicate that infant rodents exhibit less generalisation in comparison to adults, although some findings suggest more (rather than less) generalisation early in ontogeny.

Research involving human children is even more limited than that in other animals. Whilst, as stated above, it is beneficial to study children it also poses several ethical and methodological challenges. Investigating the developmental aspects of avoidance behaviour is particularly difficult because it involves aversive stimuli. Human studies typically use shocks (Vervliet & Indekeu, 2015) which are not suitable for experiments involving young children. This tension is evidenced by infamous experiment such as the 'Little Albert' experiment (Watson & Rayner, 1920). This experiment whilst showing that fear can generalise to a range of stimuli in a child, it also revealed that aversively motivated training had lasting effects on Albert with the conditioned fear still be present weeks later, therefore rendering this type of experiments unethical. Since then, fear conditioning has become one of the widest used paradigms for studying fear (Mertens et al., 2020). However, the ethical implications of using aversive stimuli in children have pushed researchers to design more creative methodologies that balance ethical requirements with scientific goals. For example, tasks now use stimuli that are less distressing but still effective such as such as aversive images which are also used in adult studies (Fisher & Urcelay, 2024). Moreover, studies use loud noises; however, unlike the 'Little Albert' study, these noises are calibrated to ensure they are ethically acceptable, controlled in intensity, and do not cause lasting distress or harm to participants. and One study, using the fear conditioning paradigm, used faces as the stimuli with the aversive stimulus being an image of a screaming woman (Glenn et al., 2012). This allowed the researchers to assess generalisation. This revealed when focusing on fear potentiated startle responses the older children (11–13-year-olds) had similar generalisation gradients to adults whereas the younger children's (8-10 years olds) gradients were different to adults in that they were broader. This indicates that younger children tend to generalise

fear more than older children and adults. This highlights differences in generalisation between age groups indicating that age is factor of interest.

Moreover, research in fear conditioning has identified age related relationships with discrimination. Studies have directly compared adults and children on the generalisation of fear conditioning (Schiele et al., 2016). In this large sample it was revealed that children exhibited broader gradients than the adults for both skin conductance responses and US expectancy ratings. Moreover, a study using children and adolescence aged 9-18 years old with anxiety disorders and matched controls trained participants with two tones, one rewarded them with points and one resulted in a loss of points and in a generalisation phase they presented with a range of tones (El-Bar et al., 2017). They found that in the control group adolescence (12 -18 years old) showed less generalisation compared to children (9-11 years old), in the anxiety group this was reversed, and adolescences showed a flatter slope compared to children. However, it should be noted that the sample in this study was small with only 17 participants in the anxiety group and 23 in the control. Reinhard et al. (2022) conducted a fear generalisation study with 8–17-year-olds using female faces as stimuli, two neutral faces were used as the CS+ (paired with a woman's scream). In the test phase they were presented with 4 stimuli that morphed the two faces by 20% increments. They found that discrimination, based on US expectancy, improved with age and more importantly reduced overgeneralisation as age increased. This indicates as age increases generalisation decreases and gradients become sharper.

One of the current limitations in the existing ontogeny generalisation literature is that there are differences during training for the different age groups. An example of this can be found in Glenn et al. (2012) in which during training the older children (11–13-year-

olds) responded more to the CS+ and less to the CS- than the younger children (8–10-year-olds). It can be seen that at the end of the training phase the older children are able to discriminate better than the younger children therefore it is difficult to conclude whether the results during the test are due to generalisation or are due to the different learning rates in training. The results that younger children generalise more could be confounded by the fact they discriminate less during training and these then carry over into the generalisation test which limit the conclusions that can be drawn. It has been highlighted that in order to make conclusions made by developmental age then all other factors need to be controlled for including perception and motivation (Spear and Riccio, 1994). Therefore, we wanted to try to minimise the differing rates of learning during the training phase, so we introduced a practice task (with a different CS+ and CS-) which enabled all of the children to understand how to work the task. The aim of this was to reduce discrimination difference during training so that during test if differences were found this would be due to generalisation.

Another key limitation of such studies is the tendency to focus on a single age group of children, which, while useful for comparisons with adults, does not allow for conclusions about developmental changes in generalisation. To address this, future research would benefit from including a broader age range, subdividing participants into multiple age groups, or treating age as a continuous variable. This approach would enable a more nuanced understanding of how generalisation gradients shift across developmental stages.

Overall, when assessing the literature in animals and children the results seem to be mixed. Particularly within the rodent literature there is evidence for infants showing both more and less generalisation in comparison to adult rats. In humans the overall

picture seems to indicate that younger children exhibit broader generalisation gradients. However, most of these findings are from the fear research and there have been no studies conducted using an avoidance task. Therefore, one of the aims of this experiment was to adapt a task used in adults to assess the generalisation of avoidance behaviour. The task we used was a variation of the popular 'Space Invaders game'. This has been used in adults to assess contiguity and overshadowing (Alcalá et al., 2024; Herrera et al., 2022). This was an ideal task to adapt as it was similar to a video game so the children would find it interesting, and it also had a cover story that we could adapt. The task itself was also relatively simple so younger children would also be able to participate. It also enabled us to navigate the issues of studying aversiveness in children as the aversive event was a loss of points as opposed to a shock or loud noise. In turn having the participants earn points is thought to have keep them engaged in the task. The adaption of this task only required making it simpler in terms of the coloured sensors used to predict the oncoming of the aversive outcome (mothership). Furthermore, changing the points so that mothership did not cause too much of a deduction in points as to deter the children's motivation. The instructions were also adapted to include child friendly language (*see Method*).

Moreover, the human fear studies have typically focus on those aged 8 and older, leaving a significant gap in our understanding of generalisation in younger children and how it develops across different ages. Therefore, another aim of the experiment was to be able to look at the development of this behaviour in younger children there we recruited at ages ranging from 5 to 11 years old. This age span enabled us to both group children into age groups and compare them and also assess age as a continuous variable to investigate whether age can predict generalisation. Furthermore, we also wanted to investigate

anxiety in children to assess whether anxiety levels can influence generalisation. Although the research on the ontogeny of generalisation is scarce and conflicting, we expected that during training there will be no differences during training and that children of all ages will be able to discriminate between the CS+ and the CS- and therefore spend more time hiding during the CS+ presentation compared to the CS-. During the test it is hypothesised that there will be developmental differences in the amount of time spent in the safe areas of the screen indicating (avoidance behaviour). It is hypothesised that younger children will have broader generalisation gradients in terms of spending more time in the safe zone when tested with all of the generalisation stimuli. As age increases, we expect that the gradients will become steeper, and that older children will generalise less. Also we will measure anxiety scores using the S-STAI (Al-Yateem & Brenner, 2017), as mentioned in the beginning of this introduction avoidance is a hallmark of anxiety therefore we wanted to assess differences in generalisation based on anxiety. Based on this we expect that those with higher anxiety scores would exhibit broader generalisation gradients. This experiment would be the first to assess generalisation of avoidance in children and would provide a protocol of assessing avoidance generalisation which could then be used to assess other phenomena related to generalisation.

4.2 Method

4.2.1 Participants

The participants in this experiment were recruited at Summer Scientist Week event, which is an annual public engagement event conducted at the University of Nottingham and organized by the School of Psychology. Participants were collected in August of 2023 and 2024. This event is aimed at children aged 4-17 years old. When we started the experiment, we initially aimed to collect all ages however, the children we

recruited ended up being between 5 and 11 years old. We initially recruited a few 4-year-olds however, during the practice it became apparent that they did not fully understand the task and did not engage with it, so we decided to only recruit 5 and above. Whilst some 5-year-olds did not do very well on the practice, they did understand the task and the buttons they needed to press therefore they were included. Apart from these exclusions based on age, we included all participants who completed the task.

Participants had normal or corrected to normal vision. For their participation they received a token which they could later exchange to play on a game at the event. In total there were 96 participants, 41 females and 55 males. The ages ranged from 5-11 (*M* = 8.16, *SD* = 2.01). We divided the participants into different age groups for some of the analyses because . Participants were divided into 5–8 and 9–11 year-old groups to account for developmental differences in cognitive, emotional, and learning processes that could systematically influence task performance. Research indicates that younger children (5–8 years) tend to rely more on affect-driven, reflexive responses due to less mature executive functioning, whereas older children (9–11 years) exhibit greater cognitive flexibility, memory capacity, and emotion regulation abilities (Best & Miller, 2010). We included 5-8 years (*M* = 7.1, *SD* = 1.19) and there were 54 participants with 18 females and 36 males. There was also a second group 9-11 years (*M* = 10.61, *SD* = .7), there were 42 participants with 23 females and 19 males.

4.2.2 Design

There were three phases of the current experiment. A practice task, experimental task. The parents of the children also filled in questionnaires on autistic traits and anxiety. This was a mixed design experiment. The generalisation variable was assessed within subjects, in that participants were trained with a visual cue in the middle of the green-blue

dimension (aqua) and during the test phase, participants were shown different stimuli from the blue-green colour continuum. The other variable of interest was age which was measured in years with an age range of 5-11. The dependent variable is the time spent 'hiding' behind the shields.

4.2.3 Materials

Task

This task is a computer-based video game with a space invader cover story. This task is a modified version of a previously used task (Herrera et al., 2022; Molet et al., 2006; Sheynin et al., 2014). The goal of the task is to gain as many points as possible. The game has the background of a galaxy. There are four main sections of the screen, the playing area, safe area, enemy area and signal area (*see Figure 4. 1 Panel A below*).

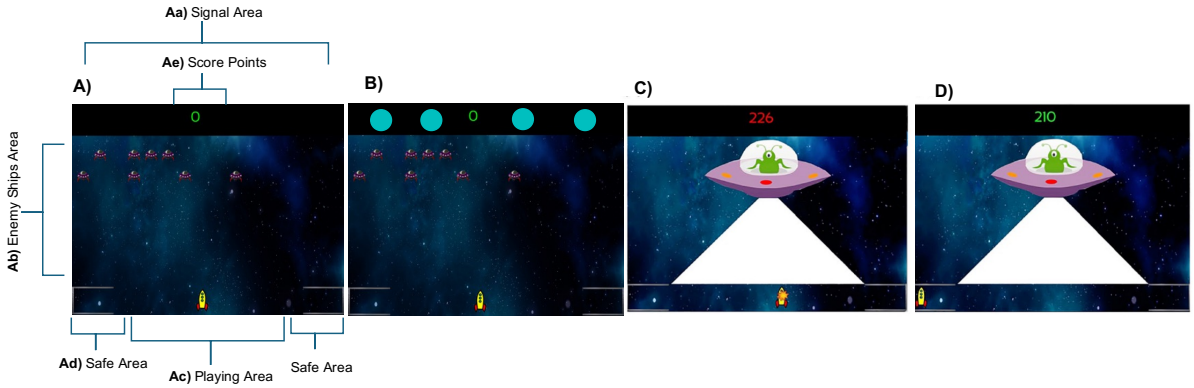

Figure 4.1

This figure contains stills from the Space Invaders task. Panel (A) shows the different areas of the screen (Aa) is the signal area I which the CS's appear to help the participants predict the oncoming of the aversive outcome (Mothership); (Ab) is the enemy area which is populated by spaceships that participants can shoot; (Ac) is the playing area and this is where the participant can move the rocket freely left to right; (Ad) marks the safe areas in which the participants can hide within the shield to avoid point loss and (Ae) is where the participants total points are shown throughout the game. Panel (B) shows the CS signals (CS+) Panel (C) shows unsuccessful avoidance where the participants has failed to avoid and hide and remains in the playing area therefore the Mothership takes away points. Panel (D) shows successful avoidance of the Mothership as the rocket is within the safe area of the screen.

The participant is in control of a rocket ship which is displayed at the bottom of the screen in the playing area. They can move this left and right with the arrow keys on the keyboard. They can also shoot (green) lasers with the spacebar, if a shot is successful, they gain points (total points are displayed at the top of the screen in the signal area). The enemy ships fire red lasers and if these hit the participant's ship then the participant loses a small number of points. In each of the bottom corners, there is a 'safe area' which are represented as lines (a shield). When in this area, the participants can avoid being hit by the enemies, but they cannot shoot and earn points. Players can move freely between the safe and the playing areas. The time needed to move from the centre of the playing area to either of the safe areas is approximately one second. The signal area is located at the top of the screen with the points counter in the centre. On either side of this, the signals can be presented. Signals are circular shapes (sensors) which can be of differing colours. The sensor depicts whether a large spaceship is going to appear or not. The participants' task is to learn which colours predict the large spaceship and which do not, as they play the game. The training and test signals used in this experiment are shown in Figure 4.2.

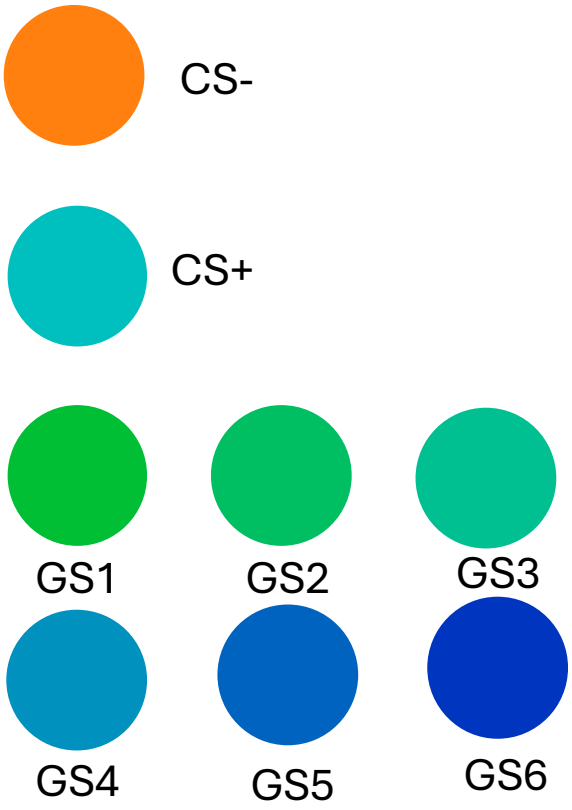

Figure 4.2
The figure shows the colours of the stimuli used in this experiment. During training, the CS+ was an aqua colour, and the CS- was orange. During the test phase, six different generalisation stimuli were presented, (GS1-GS6) as well as the CS+.

The enemy ships appear in different horizontal lines, descending from the top of the screen down to the player's line forming the enemy's area. Enemies move sideways and when they reach either edge of the screen, they descend towards the player line. When one enemy ship reaches the players area it simply disappears from the screen. The red enemy's lasers descend in a vertical line through the screen until reaching the participant's spaceship or the bottom edge of the screen and then disappear. When the enemies fire hit the participant's spaceship, 10 points are deducted from the participant's score, and this is accompanied by a collision sound of 0.1 s. Otherwise, when the

participant hits an enemy unit, their score increases by 10 points. When there is fewer than five enemies in the enemy's area, a random number of new enemies (between 1 and 12) appear on the screen in the upper third of the playing area.

The key outcome during the game is the mothership, whose imminent presence can be anticipated by the presentation of the signals in the signal area of the screen. When the mothership appears, the participant's spaceship is immediately frozen, preventing any movement by the participant. The enemy ships disappear from the screen during the presence of the mothership. The mothership always appears from the left of the screen and stops in the centre of the screen. Once placed in the centre of the screen, the mothership shoots one laser for approximately 3 s impacting the entire playing area. If the participant's spaceship is in the safe area, the counter pointer remains unchanged; however, if the participant spaceship is in the playing area, the counter points turn into red font and decrease progressively until 100 points are deducted. The shot of the mothership is accompanied by an explosion sound. After this, the mothership disappears from the screen and the enemy ships return to the screen in the same position they were before the mothership appeared and the game continues.

STAI

We asked the parents/guardians of the participants to fill out a brief 6-item anxiety scale. This was the short State and Trait Anxiety Index (Al-Yateem & Brenner, 2017). This questionnaire was selected because previous laboratory studies on avoidance have used the STAI, and we aim to conduct future experiments with both adult and child populations. Therefore, we wanted an anxiety measure that would be comparable across age groups. These questions are taken from the original State and Trait Anxiety Index (Spielberg, 2012).

The questions were phrased as ‘My child is’ and the questions included words the words‘ feeling calm’, ‘relaxed’, ‘content’, ‘tense’ or ‘upset’ and ‘worried’. The parents were asked to base the questions from how their child is in general as opposed to how their child was on the day, they were completing the scale.

4.2.4 Procedure

Participants were either accompanied by their parents/guardians or they completed the experiment alone, this was the child and parents’ choice. They were read the following instructions about the task:

“You’re going to play a space invaders task. You are the yellow spaceship and can move it by pressing the left and right arrow keys. You can shoot lasers at other spaceships by pressing the space bar. If you shoot and hit them, you’ll win some points, you can see them at the top of the screen. Your job is to get as many points as possible.

But you must be careful! The enemy spaceships can also shoot you, if they hit you, you’ll lose points! In the corners are two shields where you can hide, and the enemies won’t be able to shoot you. You won't be able to shoot the enemies whilst hiding so won’t be able to win more points.

Sometimes a big enemy spaceship will appear, and you won’t be able to destroy this. When it comes on screen you won’t be able to move, and you’ll lose points. Your only chance to avoid the attack is by hiding in the corners behind your shield. To help you avoid the big spaceship there is some different coloured sensors which appear at the top of the screen. Some coloured sensors will help you know when to move to the shields to avoid losing points but not all the colour sensors are helpful so you need to learn which ones will help you.

Remember you need to win as many points as possible so be careful of how much time you spend hiding! Good luck with destroying the spaceships!"

Participants then completed a practice version of the Space Invaders task. This was the same as the training phase of the experimental task but was shortened to last five minutes. The background galaxy was different, and the sensors were also of different colours. The sensor that predicted the mothership was white and the sensor that did not predict anything was pink.

Practice Task

During the practice, the experimenter reminded the participant that they could hide behind the shields to avoid the mothership. If the participants did not avoid at all, the experimenter said "remember to look at the sensors, they'll help you know when the big spaceship is going to come". The participants had two minutes of play time before the sensors were presented. Each sensor was presented twice. The signals were presented for 4 seconds. Between each trial there was an interval of an average of 8 seconds (+/- 2 seconds).

Training Phase

After the practice task, participants were asked if they were ready to complete the actual task. They were also told that the task would be the same but they would be in a different galaxy so the sensors may also be of different colours. Participants were again given 2 minutes of game play before the signals were presented. Each of the coloured sensors were shown 8 times during the training phase. They were presented for 4 seconds and there was an inter trial interval of 8 seconds (+/- 2 seconds). On a trial a coloured sensor was presented at the top of the screen, following this presentation participants had 3 seconds to make it to the shield. If successful they retained points, if unsuccessful they

lost 100 points. Following this there was an ITI in which the participants could shoot spaceships to gain more points.

Test Phase

During the test phase there were 6 generalisation signals and the CS+ signal; these were again presented for 4 seconds and there was an inter trial interval of 8 seconds (+/- 2 seconds). All participants were told they did well on the task. Finally, the parent/guardian of the child were given the shortened 6 question STAI to complete. They were then thanked for their time and given a stamp in their booklet (to signify completion of this game) and a token which they could use to play another game at the event.

4.2.5 Data Analysis

We measured the amount of avoidance behaviour by assessing the time spent hiding behind the shields on each trial. We looked at the time spent hiding for the CS duration therefore the maximum was 4 seconds.

In order to assess the effect of age on the generalisation gradients, we divided the participants into two age categories these were 5-8 years and 9-11 years. Furthermore, we wanted to see if anxiety had an effect on the generalisation gradients therefore, we took the total scores from the STAI and conducted a median split to create a Low Anxiety Group (n =57, M = 7.72, SD = 1.18) and High Anxiety Group (n= 39, M = 11.31, SD = 1.34).

During the training, we analysed time spent hiding during the CS presentation for each stimulus (CS+ and CS-) as a function of training trials. To achieve this a 2 (CS: CS+ vs. CS-) X 8 (Trials) repeated-measures ANOVA was conducted. Critically during the test phase, we wanted to see if there were any differences in age and generalisation behaviour. We wanted to see if age had an effect on the shape of the shape of the generalisation curve. To test this, a 2 (Age Group: 5-8 years old, 9-11 years old) X 7 (Stimuli) mixed ANOVA was conducted.

Furthermore, we conducted a regression analysis in which age (in months) and anxiety (STAI scores) were entered at the same time for each of the dependent variables. As a dependent variable, we computed a slope of the gradient. This was achieved by averaging the time spent hiding to the two generalisation stimuli closest to the CS+ (GS3 and GS4), then GS2 and GS5, and GS1 and GS6. In other words, we averaged responding across both sides of the stimuli gradient. This allowed us to compute a generalisation slope using the excel function; =SLOPE(known_y's, known_x's). A positive number indicated that avoidance behaviour decreased when the stimuli moved further away from the CS+ and a negative number indicated that avoidance behaviour increased as the stimuli moved further away in similarity to the CS+.

4.3 Results

4.3.1 Training

Overall, avoidance behaviour was greater for CS+ than CS− with the discrimination improving as trials increased. A 2(CS: CS+ vs. CS-) X 8(Trials) X2 (Age Group: 5-8 years old, 9-11 years old) Repeated Measures ANOVA was conducted for avoidance when the stimuli were presented. There was a main effect of CS, $F(1,94) = 400.951$, $p < .001$, $\eta_p^2 = .81$ indicating that avoidance behaviour differed between CS+ and CS-. Additionally, there was a main effect of Trials, $F(5.577, 524.241) = 9.956$, $p < .001$, $\eta_p^2 = .096$ which suggests that avoidance responses changed over time. There was no main effect of Age Group = $F(1,94) = < .000$, $p = .994$, $\eta_p^2 < .001$; indicating that overall avoidance behaviour did not differ between younger (5–8 years) and older (9–11 years) children. A significant interaction between CS and Age Group was found, $F(1, 94) = 6.623$, $p = .012$, $\eta p^2 = .066$, suggesting that the difference in avoidance responses to CS+ and CS− varied by age. Post hoc comparisons were conducted to examine the interaction between age group and CS

condition. Both younger and older children showed significantly stronger responses to CS+ compared to CS–. For younger children, the response to CS+ was significantly greater than to CS– (t = 13.19, p < .001), and the same pattern was observed for older children (t = 15.07, p < .001). Additionally, younger children's responses to CS+ were significantly greater than older children's responses to CS– (t = 11.29, p < .001), and older children's responses to CS+ were significantly greater than younger children's responses to CS– (t = 11.30, p < .001). However, there were no significant differences between age groups within the same CS condition: younger vs. older children in the CS+ condition (t = -1.46, p = .881) and in the CS– condition (t = 1.45, p = .901). These results indicate a robust CS effect across both age groups, with similar response patterns between younger and older children.

However, there was no significant interaction between Trials and Age Group, F(5.577, 524.241) = 1.186, p = .313, ηp^2 = .012, indicating that changes in avoidance behaviour over trials were similar for both age groups. There was an interaction between CS and Trials, F(5.716, 537.263) = 14.587, p <.001, η_p^2 = .134 which showed that the pattern of responding changed as trials increased. Finally, there was no triple interaction between CS, Trials and Age Group, F(5.716, 537.263) = 1.807, p = .099, η_p^2 = .019.

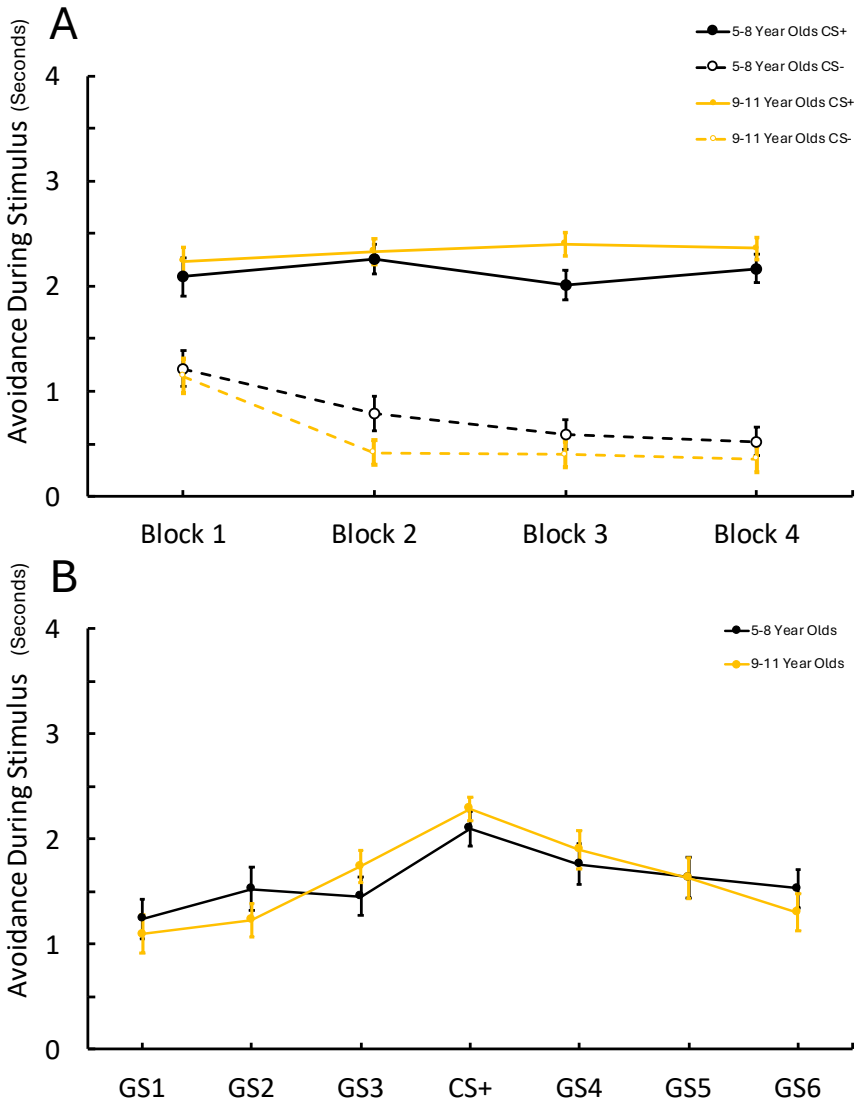

Figure 4.3
The figure shows the time hiding during ach trial (4 seconds maximum) for each age groups during training (A) and test (B). During training both age groups were able to discriminate between the CS+ and the CS-, although this was more pronounced for the older age group. During the test a generalisation curve was found with responding peaking at the CS+ and decreasing as the stimuli became less similar to the CS+, and the gradient was sharper for the older age group.

4.3.2 Test

The test data shows that both age groups are both hiding (avoiding) for similar durations during the stimulus presentation however, the younger children seem to have a flatter gradient. A 2X (Age Group: 5-8, 9-11) X 7(Stimuli) Repeated Measures ANOVA was

conducted, and the quadratic contrasts have been reported. There was a main effect of Stimuli, $F(1,94) = 42.677$, $p = .001$, $\eta_p^2 = .312$. There was no main effect of Age Group, $F(1,94) = .003$, $p = .956$, $\eta_p^2 < .000$. There was an interaction between Age and Stimuli, $F(1,94) = 4.301$, $p = .041$, $\eta_p^2 = .044$. The interaction indicates that the quadratic pattern is different for each Age Group, and it seems driven particularly by differences in that the 9–11-year-olds hide more during the CS+ compared to the CS- and lower to the generalisation stimuli furthest away from the CS+.

4.3.4 Slope Analysis

We wanted to assess whether age could predict generalisation of avoidance behaviour in the space invaders task. To do this we created a slope using the avoidance responding (time spent hiding) to the GS stimuli. We averaged the two sides of the gradient i.e., GS3 and GS4, GS2 and GS5 and GS1 and GS6. The stimuli were all equally distanced, so we used these averages to compute a slope. A positive number indicated that avoidance behaviour decreased when the stimuli moved further away from the CS+ producing a steeper gradient and a negative value indicates that avoidance behaviour increased as the stimuli moved further away in similarity to the CS+ producing a shallower gradient. An independent t test was conducted using the age groups used in the previous analysis. There was a significant difference in the steepness of the generalisation slope in that the older children had a steeper slope ($M = .28$, $SD = .41$) compared to the younger children ($M = .006$, $SD = .07$), $t(94) = 2.726$, $p = .004$, *Cohen's d* = .561.

4.3.5 Regression

Following on from the slope analysis, a multiple linear regression was conducted with Age (in months) and anxiety scores (STAI totals) entered as the predictor variables and Slope entered as the outcome variable. The regression model predicted 9 % of the

variance in the generalisation slope (R^2 = .09, Adjusted R^2 = .07) and was significantly better than the mean as a fit of the model, $F(2, 93) = 4.601$, $p = .012$. Analysis of individual predictors indicated that Age was a significant negative predictor of generalisation slope, $B = -0.006$, $SE = 0.002$, $\beta = -0.291$, $t = -2.849$, $p = .005$. This indicates that as Age increases, the generalisation slope decreases. Anxiety levels did not significantly predict the generalisation slope, ($B = -0.007$, $SE = 0.023$, $\beta = -0.032$, $t = -0.318$, $p = .751$). The results suggest that age did significantly predict the generalisation slope with older participants showing steeper slopes (*see Figure 4.4*) . However, anxiety scores were not a significant predictor of generalisation.

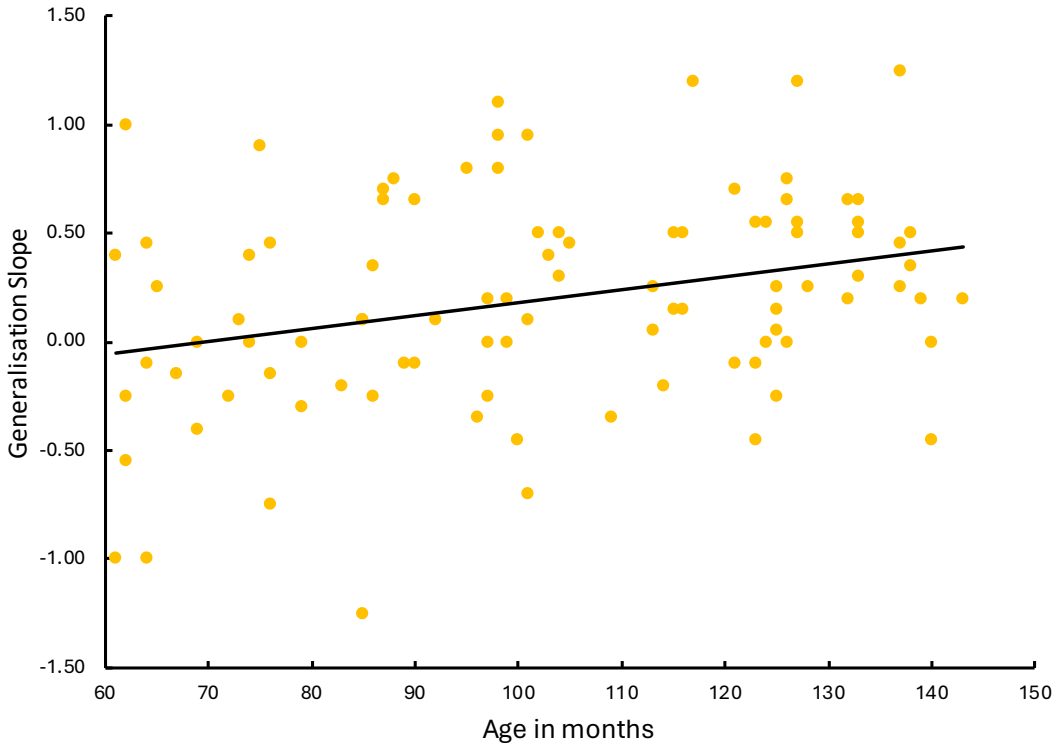

Figure 4.4
Correlation between the generalisation slope and age in moths. Age was shown to be a significant predictor of generalisation slope in that older children displayed sharper generalisation slope, which indicates a larger decrease in avoidance (hiding behaviour) as the stimuli become less similar to the CS+.

4.4 Discussion

Research on generalisation and age is a mixed literature between the human and animal literature with the animal literature finding evidence for younger ages show less, the same and more generalisation compared to adults. The human literature suggests that younger children show broader generalisation gradients meaning they generalise behaviour such as fear (Glenn et al., 2012) more to similar stimuli compared to older children or adults. The goal of the experiment was to investigate avoidance behaviour and generalisation in healthy children aged 5–11 years to understand the ontogeny of avoidance generalisation.

The results of the current experiment demonstrated that by the end of the training phase that both age groups (5-8 and 9-11) were able to successfully discriminate between the CS+ and the CS-. Critically at the end of training there were no differences between the two age groups meaning that both age groups responded similarly to the CS+ and the CS-. This is critical as previous research on generalisation with children has shown training differences in that older children seem to be better at discriminating. This is a limitation of previous research as it is difficult to conclude that the behaviour observed during the test is due to generalisation and not just a carry-over effect of different age groups reaching different asymptotes during training. Whilst it is difficult to conclude that this was due to the current study adding in a separate practice task before the main avoidance task may have helped increase younger children's exposure to using a computer and previous research has found that computer exposure can influence experimental tasks (Christakis et al., 2004). It could also be due to the task being relatively simple that children of all ages are able to understand the keys required and the goals of

the tasks. Overall, this is a strength of the task as it allows conclusions of the test phase to not be based on the learning during training.

Critically, during test when comparing the two age groups it was found there was no main effect of age group on generalisation behaviour meaning that both age groups hid during the CS presentation for a similar amount of time and therefore avoided similar. There was however an interaction between age group and generalisation curve which seemed to indicate that older children hide more when the CS+ was presented compared to the younger children and less when the two furthest GS stimuli were presented. When further examining the effect of age by using it as continuous variable (age in months) it was found that age can predict the generalisation slope with older children having steeper slopes compared to the younger children. This indicates that as age increases generalisation decreases producing a sharper slope . This suggests that using age as a continuous variable is more sensitive at capturing developmental differences. Overall, through using two different types of analyses it suggests that there are developmental differences in generalisation behaviour in that older children generalise less to similar stimuli compared to younger children.

This study conflicts with some of the previous animal literature which has found that young rodents have steeper generalisation gradients when investigating avoidance behaviour. Several researchers using different age ranges have found that, when compared to adult rats, infant rats responded less to the generalisation stimuli in a spatial avoidance task (Rohrbaugh & Riccio, 1968) and had lower heart rate indicating lower levels of fear (McGaughey & Thompson, 1975). However, the rodent literature was mixed and some studies did find evidence that aligned with our findings in that younger rodents show broader generalisation gradients (Campbell & Haroutunian, 1983; Rudy & Pugh,

1996). Moreover, the current findings also follow the same pattern of the human fear generalisation literature. When comparing adults and children's arousal rating and skin conductance responses children showed greater generalisation of fear (Schiele et al., 2016). When investigating development of generalisation in children aged 8-13 years old all participants were found to have similar fear potentiated startle responses to generalisation stimuli however, the 8-10 year olds responded more to the CS- compared to the 11-13 year olds (Glenn et al., 2012). When comparing this with adults' behaviour the older age group (11–13-year-olds) respond more similarly to the adults compared to the younger age group (8–11-year-olds). The younger children were less able to distinguish the safe signals (CS-) from the danger signals indicating less discrimination which could also be interpreted as them generalising more. Moreover, when investigating children and adolescence aged 8-17 years old it was found a relationship with age and generalisation which was that as age increased US expectancy and skin conducts responses decreased indicated less generalisation as age increases (Reinhard et al., 2022). The current experiment, using a different age range and an avoidance paradigm, aligns with the human data and overall seems to suggest that there are differences between infant rodents and human children in generalisation of fear and avoidance.

It has been suggested that a possible reason for the developmental differences seen in younger children is due to the maturational effects in the prefrontal cortex. Behavioural studies have shown that inhibition develops in line with age in that children who are older are able to control their inhibition (Moriguchi & Hiraki, 2013). Moreover, there has been research using NIRS (near infrared spectroscopy) has suggested that children aged 4-6 the fronto-parietal brain maturation plays a key part in the development of inhibition (Mehnert et al., 2013). Therefore, it could be that the younger children do not

have the capacity to inhibit responding hence show more generalisation compared to the older children who have developed their executive functioning

When exploring anxiety there was found to be no significant effects at a group level high anxiety and low anxiety, nor when regressing the anxiety scores with the generalisation slope scores. It should be noted that there was a potential confound in that there was a correlation between anxiety score and age in that older children had higher anxiety. Previous research has indicated that whilst 1 in 12 children have an anxiety disorder as age increases by adolescents this becomes 1 in 4 (Kowalchuk et al., 2022). The research also highlights that the period of 5-12 years old is a critical period for the development of anxiety symptoms and disorders (Beesdo et al., 2009). Therefore, it could indicate that as age increases anxiety symptoms are easier to spot as older children have a wider array of behaviour for parents to draw on when filling out the anxiety questionnaire.

One of the limitations of this experiment is the way in which anxiety was measured. It is noted that even though we selected a scale that had been used and validated (Al-Yateem & Brenner, 2017). It is noted that there was potential bias within the results. This can be seen particularly with the question which asks parents/guardians to rate how upset the child felt and all the parents voted 'not at all'. A Cronbach Alpha was conducted ($\alpha = .512$) which confirmed that the scale lacked validity and removing items made this lower. Potentially, having the parents fill out the scale whilst the researcher was near them could have biased their ratings furthermore, they were in a situation where they knew the research was being conducted. A future direction could be to recruit participants with diagnosed anxiety disorders and compare their behaviour with healthy age matched controls however this type of design is difficult to obtain . However, a strength of the current experiment is that we were able to use a task that has been used in adults (Alcalá

et al., 2024; Herrera et al., 2022) and adapt this to study children. We were able to train children as young as 5 years old. This task can therefore be adapted to investigate different aspects of avoidance behaviour such as contingency and continuity and these can be tested to develop a deeper understanding of avoidance behaviour.

In sum, this experiment demonstrates that age can affect the generalisation curves in a sample of children between 5 and 11 years old. We were able to adapt a task to make it suitable for children as young as 5 years old which has been . In the future taking a longitudinal approach could help to investigate whether avoidance generalisation is linked with the developmental of anxiety disorders. While the current experiment did not reveal effects of anxiety on generalisation, it represents an important first step in studying the generalisation of avoidance in children. In the future, this task could be used to further investigate related phenomena and how they vary across different ages. This experiment also contributes to the wider field of exploring avoidance phenomena which could have further benefits for the development of preventative approaches for anxiety.

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Chapter 5

Relief Review

5.1 Introduction

Relief is a concept that has existed within the modern contexts since early philosophers. Descartes for instance said, “For it often happens that one is affected with joy because one finds oneself relieved of some evil, even though one has not acquired any good”(Spinoza, 2016). This suggests that removal of something aversive can result in a positive feeling. Over time, the concept of relief has expanded, and in modern psychological discourse, it is often described as a positive emotion that arises from the absence or removal of a threat (Leng et al., 2024). However, different paradigms provide different definitions and perspectives on the nature of relief. Within the pain literature, it has been defined as ‘reward induced through omission or reduction of an aversive event…’ (Leknes et al., 2011). This definition ties relief directly to the reduction of discomfort or unpleasantness, emphasizing its role in the alleviation of physical or emotional pain. Relief can also be conceptualised as a motivational state wherein the alleviation of negative experiences creates an internal drive for avoiding similar aversive situations in the future (Deutsch et al., 2015). Collectively, what all of these definitions share in common is that something aversive is avoided or reduced (Deutsch et al., 2015). Relief has significant implications for understanding complex behavioural phenomena such as pain and avoidance. In recent years, studies have increasingly focused on how relief interacts with avoidance behaviour, especially in relation to anxiety. This is because when an individual successfully avoids an anticipated aversive outcome, they report that

they experience relief, and this is thought to reinforce the avoidance behaviour. This ultimately results in a cycle where the individual is motivated to continue avoiding perceived threats or discomforts, perhaps when these are no longer present.

Historically, it was Miller and Konorski who first distinguished between Pavlovian (or Type I) and instrumental (or Type II) conditioning (Konorski & Miller, 1937) laying the foundation for the study of Pavlovian and instrumental processes. Later, Konorski (1967) proposed the existence of two motivational systems (one aversive and one appetitive) with inhibitory mutual connections that gives rise to 4 basic emotions (hope, fear, frustration and relief) (*see Figure 5.1*). This results in the prediction that the absence of an expected aversive event should elicit relief. That is, the termination of punishments (or expected aversive events) may induce a delayed state of relief, supporting positively valanced memories.

	Excitatory	Inhibitory
Aversive	Aversive Excitor (fear)	Aversive Inhibitor (relief)
Appetitive	Appetitive Excitor (hope)	Appetitive Inhibitor (frustration)

Figure 5.1
This has been taken from (Seymour et al., 2007) and depicts the different types of motivational stimuli either excitatory 9predicts the outcome or inhibitory predicts the (absence of the outcome). The valance of stimuli can also be described as appetitive or aversive. With the these it makes four motivational states of behaviour.

This is consistent with different views in psychology including Konorski's (1967) (*see above*), and Solomon and Corbit's opponent processes (1974). Whilst the concept of relief was discussed over 50 years ago there are currently few studies directly investigating this phenomenon. This is largely due to the inherent challenges in studying relief, given that it is a subjective experience with no universal behavioural markers—

unlike fear, which can be objectively measured through physiological responses such as increased heart rate and skin conductance. However, in rodents and in particular humans, there has been a lot of work on conditioned inhibitors (Cassaday et al., 2023; Gerber et al., 2014; Krueger et al., 2024; Laing & Harrison, 2021). Aversively motivated conditioned inhibitors are stimuli that signal the absence of an aversive stimulus (Rescorla, 1969b)and as such they are ideally placed to assess whether relief reflects a positive emotion. We shall note, however, that there is a substantial literature which claims that conditioned inhibitors provide relief and this elicits appetitive conditioned responses (Gerber et al., 2014), but they make this inference from the measurement of Pavlovian responses such a changes in SCR (Andreatta & Pauli, 2017), an attenuation of the magnitude of startle responses (Andreatta et al., 2010) or changes in reward-related brain signals in the striatum (Andreatta et al., 2012). Changes in these Pavlovian responses have been assumed to reflect "appetitive processes", but intriguingly humans do not always rate safety signals as positively valued (Andreatta et al., 2012) raising questions about the inferences that can be made on the basis of Pavlovian responses such as SCR, startle attenuation or brain signals. Objectively speaking, a gold standard to assess the reinforcing properties of a conditioned stimulus is to determine whether it can reinforce instrumental behaviour (Mackintosh, 1974). That is, for a conditioned stimulus (a CS+ paired with a rewarding event, or a CS- explicitly signalling the absence of an aversive event – i.e., a safety signal) to be deemed appetitive, it needs to be shown that it can reinforce instrumental behaviour – ideally supporting the acquisition of a new response in the agent's repertoire (Mackintosh, 1974: *p*. 235). In light of this criterion, we will not review studies that did not measure instrumental responses, for they could simply be reflecting the inhibitory association between the safety signal and the aversive outcome as

it is often done in a summation test for inhibition (Urcelay & Miller, 2006). A large portion of the work has been conducted in Pavlovian conditioning paradigms due to the decline in avoidance research in the 1960s (LeDoux et al., 2017). Relief is often implied to be in operation during or conditioned inhibition training, but never directly tested behaviourally so whilst it adds insights into the nature of relief, this body of work cannot conclude that conditioned inhibitors produce relief. Relief learning is also sometimes alluded to in procedures which involve the termination of pain (or punishment) in which relief is inferred from the association between a stimulus and the offset of punishment. For comprehensive reviews on relief within Pavlovian literature, see Gerber et al., (2014) and Laing et al. (2024). However, as mentioned this review will instead focus on instrumental behaviour, based on the assumption that if relief reflects a positive emotion — that is, if it functions as a conditioned reward — then it should reinforce instrumental behaviour. This approach provides a measurable way to examine relief, allowing for a more direct assessment of its role in learning and motivation.

5.2 Research in Animals

Within animals it is difficult to study concepts such as relief with subjective measures as it is commonly done in human participants, therefore the literature has focused on instrumental behaviour, as this enables the assessment of potential reinforcing properties (see above) of signals associated with relief. Researchers have therefore focused on aversive conditioned inhibitors, which are stimuli that signal the absence of an aversive stimulus. Much of this work has been conducted by training a conditioned inhibitor using Pavlovian designs, in which the putative inhibitor is explicitly paired with the absence of an aversive event, and later tested to see if it can reinforce instrumental behaviour. Because the transfer from the Pavlovian training to the

instrumental test is often difficult (Fernando et al., 2013) studies have trained an instrumental baseline (usually avoidance behaviour) and later tested whether the safety signal reinforces such behaviour (Rescorla, 1968). Finally, some designs have trained a safety signal embedded in an avoidance schedule (which ultimately amounts to conditioned inhibition training) and later assessed whether the safety signal reinforces avoidance behaviour using the appropriate control groups (Fernando et al., 2014a; 2014b; 2015). Ultimately, the reinforcing properties of a relief-paired signal are assessed by presenting it contingent on a previously trained or a new response – preferably during extinction to prevent new learning during the test session. An alternative test is used in which a particular odour is paired with the absence of an aversive event (CS-), whereas an alternative odour is paired with the presence of the aversive event (CS+), and subjects are given a preference test to assess whether they prefer to stay in the CS+ or CS- areas (i.e. an odour preference test; Tanimoto et al., 2004; Yarali et al., 2008); see also Rogan et al., (2005) for a place preference). Whilst it has been reported that insects prefer the area with the CS- odour over the CS+ area, the instrumental status of such an approach response is unclear for it has been observed that approach responses reflect Pavlovian rather than instrumental learning (Hershberger, 1986). In other words, it is clear that such a preference is driven by an approach response, but approach responses do not necessarily reflect learning about the contingency between a response and its consequences (Balleine & Dickinson, 1998). The current review of the literature will focus assessing the reinforcing properties of avoidance-produced or relief-paired signals on instrumental behaviour because if relief is a rewarding emotion as stated in various definitions, then it should reinforce behaviour which in turn give a measurable way to examine this phenomenon. . However, safety cues are signals presented when a threat has been

avoided (or trained through inhibitory Pavlovian learning) and indicate a safe period from the threat. This allows researchers to assess whether organisms seek out and respond to safety.

One strategy initially used to test the relieving properties of safety signals is to assess whether these signals facilitate the acquisition of avoidance. In one of the first demonstrations assessing the effect of response-produced safety signals, rats were trained to perform avoidance responses to prevent an aversive stimulus (e.g., a shock). When a specific signal (e.g., a light or tone) was presented immediately following the avoidance response, it functioned as a safety signal. This contingent safety signal appeared to facilitate the acquisition of signalled avoidance, compared to groups where no such signal was present (Keehn & Nakkash, 1959). Similarly, when using the avoidance shuttle box task, it was found that adding in a signal contingent upon an avoidance response improved learning compared to a group that had delayed warning signal termination (Bower et al., 1965). These studies highlight that having a safety signal after the response is crucial. It also highlights that these findings are not solely due to the warning signal being terminated but that the safety signal is facilitating avoidance learning. This has also been supported in other studies including (Brennan et al., 2002; Dillow et al., 1972) who found that when a safety signal was introduced it facilitated acquisition of an avoidance response .

However, in all these experiments it is unclear what the source of the facilitated avoidance learning is, in that it could be the safety signals providing relief, or any other difference between experimental and control animals. Critically, these studies did not include a control signal which did not undergo any inhibitory training, so the results could be due to any change in stimulation following an avoidance response.

In order to seek clear evidence that safety signals do indeed reinforce instrumental behaviour, Rescorla (1969) trained dogs to avoid shocks by pressing either of two panels, notably both panels were trained as avoidance responses. Once dogs had learned this baseline avoidance behaviour, Rescorla trained a signal as predictor of the shock (A+) and a second signal as inhibitor of the shock (AB-; or a control signal C). Following this Pavlovian inhibitory learning (or control), Rescorla re-established the avoidance baseline and presented the conditioned inhibitor B each time that the dogs emitted an avoidance response on one of the panels, whereas the control stimulus C was presented when dogs pressed the alternative panel. He observed that dogs avoided more when such avoidance was followed by the conditioned inhibitor B in comparison with a control signal C, thus revealing that safety signals reinforce avoidance behaviour relative to a control group.

The study by Rescorla was soon replicated in an experiment with rats as subjects (Weisman & Litner, 1969). They first trained rats to avoid a shock by turning a wheel. Then, in separate chamber the rats underwent explicitly unpaired inhibition training (Pavlovian) in which an auditory signal (CS-) was explicitly paired with the absence of foot shocks (vs a Control Group which experienced random CS/shock presentations). Finally, rats were returned to the avoidance task and the CS- (or control stimulus) was presented contingently upon presentations of the CS- or control signals. Interestingly, they first reinforced the avoidance behaviour with a differential reinforcement of high rates (DRH), in which the CS- was presented only when avoidance rates were higher than baseline. They observed that rats experiencing the CS- avoided at higher rates than rats experiencing the control stimulus. Following re-baseline sessions, rats were now reinforced during avoidance but only when they avoided at rates lower than baseline (DRL), and under these contingencies rats avoided at lower rates when these were

followed by the CS- relative to the rats experiencing the control stimulus. Thus, Weisman and Litner observed bidirectional control of avoidance behaviour by a signal trained as an inhibitor (relative to a control signal), thus bolstering the case that such signals can act as a conditioned reinforcer of avoidance behaviour. Finally, research in pigeons investigated safety signals and generalisation by training pigeons to press a pedal in order to successfully avoid a shock. (Dinsmoor & Sears, 1973). When the pigeons successfully avoided, they experienced a 1000 Hz tone as a safety signal. During a test, pigeons now experienced tones of different frequencies upon responding. They found that foot pedal pressing decreased as the safety signal tones became less similar to the trained safety signal. This further supports the reinforcing properties of the safety signal and suggests that it functions like any other stimulus in that it generalises to stimuli of other frequencies to some extent, as when the safety signals were very dissimilar, avoidance responses decreased.

Finally, in a recent set of experiments by Fernando and colleagues, (2014), rats were trained in a free-operant avoidance task involving two distinct levers, each trained separately in individual sessions. Pressing either lever avoided a foot shock and was followed by a 5-second auditory safety signal. During testing, both levers were presented simultaneously (for the first time), but responses in only one were followed by the safety signal. Rats chose to respond on the lever followed by the safety signal even through both levers actively avoided. In addition, rats changed their preference when the signal now was presented upon responses on the alternative lever. Finally, they also observed a preference for the lever followed by the safety signal over the one which was not followed by the safety signal in a test on extinction, in the absence of any shocks which prevent any conclusion based on learning during the test sessions. Fernando and colleagues went on

assess a critical characteristic of safety-signal driven avoidance behaviour, its goal-directedness. It is well known that instrumental behaviour can be goal-directed, that is dependent on the incentive value of its consequences (Dickinson, 1985). In the case of Fernando and colleagues, the safety signal was a consequence of avoidance behaviour, and as such was subject to a revaluation manipulation to change its value. If avoidance behaviour to obtain a safety signal is goal-directed, then it should change when the value of the signal is changed, and this is what Fernando and colleagues set to test. They increased the value of the safety signal by pairing it with morphine (a control group received unpaired presentations of the signal and injections of morphine), an opioid agonist that acts as a reward when administered systemically. Rats that had the safety signal's value increased by pairings with morphine pressed more to obtain the safety signal than control rats that received unpaired presentation of the signal and morphine (also see Sears et al., 2024). This latter finding not only bolsters the case that safety signals reinforce avoidance behaviour, but they also suggest this depends on the incentive value of the safety signal.

Overall, safety signals have historically been investigated in animals ranging from dogs to pigeons to rodents in different types of avoidance tasks. Together the research in animals seems to suggest that safety signals can have a reinforcing effect on avoidance behaviour and avoidance learning. Furthermore, because safety signals evoke relief, this seems to be the reason why they become reinforcing, thus supporting the notion that relief is a positive emotion that can drive aversively motivated behaviour.

5.3 Research in humans

Research on relief has been limited in humans, consistent with a decline in research on avoidance in the 1960s (LeDoux et al., 2017). However, in the last decade

there has been an increase in avoidance research in humans, due to the translational value and potential applications for an understanding of anxiety disorders. Within this resurgence of studies on avoidance in humans, relief is becoming a popular topic.

There is no go to procedure for studying relief in humans, therefore there is a plethora of different tasks that have been used. There have been many different methodologies to investigate avoidance behaviour, and they can often be divided into categories of high (Pittig et al., 2021; Pittig & Scherbaum, 2020; Wong & Pittig, 2020) and low cost (Flores et al., 2018; Urcelay et al., 2019; Vervliet & Indekeu, 2015). Much of the high-cost tasks are observed in the pain literature (Meulders et al., 2024)whereas other fields use low-cost tasks that involve pressing a button to avoid. Unlike the animal literature working with humans allows more options on how to measure relief, so researchers have tried several different ways, but they can broadly be divided into subjective self-report measures and objective behavioural measures.

5.3.1 Subjective Measures

Because it has been proposed that avoidance produces the pleasant feeling of relief, and it is this pleasant feeling that then drives this avoidance behaviour, studies in human participants have focused on this construct directly using subjective measures. This has been achieved for example by using a scale within the experimental which asks participants to rate how pleasant was the relief they felt after they avoided a shock (Vervliet et al., 2017) . That is, in the study participants had to press a button once to avoid an electric shock upon presentation of visual stimuli on a computer screen. One stimulus (CS+E) signalled that shock was imminent, and that an avoidance response would cancel the shock, a second stimulus CS+U was also presented but shock was unavoidable, and a third stimulus (CS-) served as a control and was not paired with shock (irrespective of the

avoidance). After each visual stimulus presentation during training, if participants were allowed to emit an avoidance response, they were then asked to rate the pleasantness of their relief. They found that after initial omissions of the aversive outcome, relief pleasantness was rated highly (CS+E) and this pleasantness rating decreased over training. They suggested that this could be due to a decrease in the prediction error as avoidance training progressed. Initially the prediction error is high resulting in more pleasant relief, however, with more trials the prediction error becomes weaker which results in less relief. Overall, this research using these measures of relief enable researchers to get an insight into the participants emotions and thoughts which can help us better understand their behaviour.

An experiment also set out to measure the effects of relief as well as individual differences (intolerance to uncertainty on avoidance behaviour (San Martín et al., 2020). They were trained with three stimuli (coloured lamps), a CS-, and two CS+ one of which was avoidable and one of which was not. They measured relief with a scale which asked participants how much relief they experienced, and they also presented generalisation stimuli (colours between the two CS+'s and the CS-. They found that individuals with lower distress tolerance and higher intolerance of uncertainty reported greater relief when they successfully avoided the aversive outcome. Moreover, both avoidance behaviour and relief generalised beyond the initial groups, spreading from avoidable to unavoidable threats and even to stimuli similar to the CS-. Similar results were found by Vandael et al., (2023) who investigated generalisation of pain related avoidance. They were trained with two stimuli one of which was paired with pain and one which was not, participants were then split into two groups one of which received a positive affect induction (exercise) and the other group was a control group. They found that during a generalisation test in which

colours between the CS+ and CS- were presented that avoidance relief did generalise to novel stimuli replicating previous findings by San Martín et al., (2020). They also found that the induction of positive affect had no effect on generalisation of avoidance and relief suggesting that while positive emotions are linked to resilience against chronic pain, merely inducing positive affect may not be sufficient to stopping avoidance and the relief it brings, generalizing. Moreover, a study also using these relief scale ratings investigated the effect of anhedonia on avoidance behaviour and relief (Leng et al., 2024a). They trained participants with a CS- and two CS+ both were paired with a shock however for one of the stimuli the shock could be avoided by participants pressing a button. After several trials the button effectiveness was reversed. It was found that hat individuals with higher levels of anhedonia experienced less relief following threat omission. In terms of behaviour, they were less inclined to engage in avoidance actions early on, especially when facing an avoidable threat cue. These results suggest that anhedonia may diminish the reinforcing impact of relief.

Overall, the research using relief rating scales has allowed us to understand the relationship between avoidance and behaviour and the participants subjective experience. It also allows ways of assessing how the amount of relief participants experience and how these changes across trials and experimental phases. As all measures there are limitations of using these scales, one such is that they typically repeated each trial which could induce demand effects and interrupt natural emotional processing. A possible way to mitigate this would be to use behavioural measures to assess the role of relief.

5.3.1 Behavioural measures

Research using behavioural measures allows us to compare the literature in nonhuman animals and humans to see if the findings are consistent and can be replicated across species. Research into safety signals in humans using behavioural measures has been investigated using a novel treasure task (Angelakis & Austin, 2015a). In this task, participants played a computer game which involved them clicking on different parts of a map to find treasures, some of the clicks resulted in winning points (treasures) and others resulted in losing points (bombs). Participants could also depress a foot pedal to avoid upcoming bombs, and when they depressed the pedal, a white bar at the bottom of the screen turned blue (safety signal). In other words, during training participants could avoid losing points by using the pedal, and this was signalled by a discrete stimulus on the screen. During the test phase, bombs were no longer scheduled to appear, and there were two phases: one in which, upon participants acting on the pedal, the coloured bar turned from yellow to blue (safety signal) and a second phase in which the bar started blue and would turn yellow when the foot pedal was depressed. The results found that foot pedal depressing remained high when the threat (bombs) was removed however when the safety signal was given freely, they did not respond which indicates the blue bar was a conditioned safety signal. Furthermore, a follow up experiment in which participants were explicitly told that the bombs had been disabled at the start of the test phase the same results were found which indicated even when participants knew that there were no more threats, they continued to respond to obtain the safety signal. Finally, this experiment was also replicated with a safety signal which was aversive (Angelakis & Austin, 2015b). The task was similar, and participants could avoid the next scheduled bomb by depressing a foot pedal however, this would produce an aversive stimulus (a loud tone). This was

included to explore whether participants would continue to depress the foot pedal when there was both minimal danger (no bombs) and when the safety signal was no longer presented to investigate whether it was reinforcing. It was found that when there was minimal threat, but the tone was still presented, then participants continued to press the foot pedal however, when the foot pedal did not produce the tone then participants foot presses decreased. Whilst this provides interesting insights into the reinforcing properties of safety signals (and hence relief) it should be noted that this experiment (and those in the previous report) only recruited 7 participants, and no statistical tests were used to analyse the results. Interestingly, the latter experiment also highlighted that negative safety signals can reinforce behaviour which could be used to explain why individuals put themselves in harm's way to feel safe with specific relations to disorders such as OCD in which individuals may repeat behaviours that are harmful (i.e., hairpulling in trichotillomania) (Grant & Chamberlain, 2016). This could indicate that relief reinforces behaviour but also that this experience of this feeling can outweigh negative and aversive events. This highlights why relief and specifically safety signals are important to study.

In order to provide conclusive evidence that safety signals reinforcer avoidance behaviour in human participants, we recently conducted a series of experiments in an attempt to overcome the limitations of previous research (Fisher & Urcelay, 2024). In this series of experiments, we observed that safety signals can reinforce avoidance behaviour in humans against multiple controls. In all experiments, during avoidance training participants were trained with two Gabor stimuli which differed in orientation (vertical vs horizontal), one of which was paired with an aversive event (loud noise or aversive image). They were able to avoid the aversive stimulus by pressing the space bar within 1 second of when the aversive stimulus would be presented (which was scheduled to be variable,

following the report by Flores et al., 2018). If avoidance was successful, they were shown a coloured shape which served as the safety signal. During a test phase participant were presented two new Gabor stimuli (45 or 135 degrees), if participants emitted the avoidance response one of these produced the trained safety signal, and the alternative was the control. When the control was nothing or a dissimilar control signal, it was found that participants made more avoidance responses to the Gabor that produced the trained safety signal. However, when the control was a similar signal (only differed in colour) it was found there was no differences in avoidance responses, suggesting that the properties of the safety signal generalised to the control stimulus. Moreover, in Experiment 5 to further assess the reinforcing properties of relief the response was changed to a mouse click during the test to investigate whether the avoidance behaviours would generalise to a new response. Participants were shown both Gabor stimuli on screen and now had to click the Gabor in order to produce the safety signal. The results showed that participants clicked more eon the Gabor that produced the trained safety signal compared to the Gabor that produced a novel signal. This provides strong evidence for the relief being able to reinforce behaviour as it shows that not only does it generalise to other stimuli but also to new responses.

It is important to note that both methods for studying safety signals and relief have positives and negatives. Whilst behavioural measures can give a good indication of the direct behavioural responses' relief may be involved in, they fail to capture the emotional aspect of relief the person is experiencing. Therefore, in future studies it would be beneficial to combine both measures to get both cognitive and behavioural measures of relief. In a recent unpublished experiment (Fisher & Urcelay, 2024), we trained participants with a similar safety signal and assessed at the end of the experiment whether

participants rated them as providing relief. We observed a correlation between the number of safety signals experienced during training, and how relieving participants judge them at the end of the experiment, therefore substantiating the claim that a combination of both approaches can be useful.

5.3.3 Individual differences

Studies using different individual differences measures have been used to investigate whether the effects of safety signals can predict (or correlate) with individual differences and clinical features. One such study used the treasure map task (*described above*) to investigate whether OCD scores had a relationship with responses to safety signals (Angelakis & Austin, 2018). Their participants completed the Obsessive-Compulsive Inventory-Revised (OCIR) and were then allocated into high and low OCD subgroups. They used the same original task with the coloured bars as the safety signals, and documented results were similar to previous reports. In addition, they observed that those with high OCD pressed the foot pedal more when the safety signal was presented which highlights that potential those with high OCD levels find the coloured bar more reinforcing and will therefore work more to experience it. Similarly, (Fisher & Urcelay, 2024) also investigated trait anxiety scores using the STAI, and found that those with high anxiety made more avoidance responses overall, but they did not find any differences in responses to the safety or control signals. This could indicate that trait anxiety does not have a relationship with relief and avoidance. However, before definitive conclusions can be drawn the research should be conducted with clinical samples of those with OCD, PTSD, and clinical anxiety. This would also help to further build on the understanding of the role of relief in avoidance behaviour in specific groups to help improve and inform treatments and interventions.

In order to address this last point, recent research was conducted recruiting patients with a range of different anxiety disorders (panic disorder, agoraphobia and PTSD and OCD) (De Kleine et al., 2023).The task comprised aversive negative pictures (unconditional stimulus, US) that followed pictures of tow-coloured lamps (conditional stimuli, CS+), but not a third coloured lamp (safety stimulus, CS-), and could be avoided by pressing a button during one CS+ (CS+ avoidable) but not the other (CS+ unavoidable). Participants rated their US-expectancy and level of relief on a trial-by-trial basis. They found that those with anxiety exhibited more avoidance responding to the safe stimulus (CS-). In addition, anxiety patients also indicated higher threat expectancies than the healthy controls which indicates impaired safety learning, this was particularly the case in the CS- and the avoidable CS+. Also, the anxiety patients were less certain with the avoidance responses even though they had higher motivation (higher threat expectancies) particularly to the unavoidable CS+. Critically, those with anxiety reported higher relief ratings when the US was avoided. The results suggest that people with anxiety found the omission of the US more surprising and therefore experienced more relief, which obviously illuminates further avenues for research on this topic.

5.4 Theoretical framework

5.4.1 Two factor theory

There are many different theories that have proposed a role for safety signals in avoidance behaviour. A large part of early research followed Mowrer's Two factor theory which proposes that avoidance learning involves Pavlovian and instrumental conditioning (Mowrer, 1951). Firstly, Pavlovian conditioning establishes fear to a warning signal associated with an aversive event (CS+); second, instrumental conditioning (i.e., avoidance responding) is reinforced by terminating the presentation of the CS+ (and

aversive event). According to Mowrer, it is the signal termination (and not the outcome of avoidance behaviour) what reinforces avoidance behaviour, primarily through fear reduction (*see Chapter 1 for a more in-depth discussion*). In a revised and much expanded version of the theory (Mowrer, 1960), he argued for the importance of emotions such as hope, disappointment, fear and relief, much in line with the theorizing by Konorski (1969; see Introduction and below). In this context, safety signals play a role when an organism learns that certain stimuli predict the absence of danger, leading to a reduction in fear and reinforcing avoidance behaviour. However, unlike conditioned inhibitors—stimuli that explicitly suppress conditioned responses—safety signals do not feature in Mowrer's original two-factor theory of avoidance learning. Instead, the theory posits that avoidance behaviour is maintained through classical conditioning of fear and its subsequent reduction via operant reinforcement, without invoking safety signals as a necessary component.

5.4.2 Safety Signal hypothesis

Moreover, other theorists challenged the ideas of Two Factor theory. These alternatives viewed avoidance behaviour as resulting from negative reinforcement as opposed to solely fear reduction. One such theory is the Safety Signal Hypothesis (Seligman & Binik, 1977). This theory suggests that avoidance behaviour is not only maintained by escaping an aversive event but also by signals associated with safety (safety signals). The safety signal hypothesis suggests that fear is limited in the space and time in which when safety signals are present (Seligman & Binik, 1977). It is suggested that in predictable aversive situations, animals learn that the CS+ predicts an aversive event, while its absence signals safety. As a result, fear occurs during the CS+ but not outside of it. In unpredictable situations, there is no stimulus that reliably signals safety, leading to

chronic fear because the subject cannot identify when they are safe. It is this safety which is the sole reinforcement of avoidance behaviour. Research supports this idea in that animals not only learn what predicts danger, but also what signals the absence of danger.. Thus, Seligman and Binik argued that the perception of reliable safety signals is key to regulating fear in response to aversive events. Therefore, if this is the case, then organisms should not only look to escape an aversive event but also actively seek safety. There is evidence that can support this theory in rats. For example, Weisman and Litner (1969) found bidirectional control of avoidance behaviour by a signal that was explicitly unpaired with a shock, whereas no bidirectional control was observed in control rats. Moreover, in the human literature, our own work is evidence that during the test phase, human participants preferred to act on a novel stimulus that produced the trained safety signal (relative to different controls) which suggests that they are actively seeking out safety (Fisher & Urcelay, 2024). These results align with the Safety Signal Hypothesis, demonstrating that in humans, as in nonhuman animals, avoidance behaviours can be maintained through the positive reinforcement provided by safety signals.

5.4.3 Relaxation Theory

Denny's Relaxation and relief theory proposed that avoidance persists due to it producing a rewarding state of relaxation. It has broad similarities to the Safety Signals Hypothesis in that it suggests that conditioned inhibitors can become positive reinforcers. When an individual experiences successful avoidance they experience psychological relief, this feeling then acts as a positive reinforcer which then strengthens subsequent avoidance behaviour (Denny, 1971). There is a distinction within this theory between relaxation and relief. Relief is the removal of a stressor or a predictor of an aversive event, which in turn reduces stress or pain and it is a relatively short feeling. In fact, Denny (1971)

referred to relief as short latency relief. They argued that relief starts 3 to 5 sec after cessation of stimulation, and is over within the next 10 to 15 sec. This time course of relief followed by relaxation has received support from experiments measuring heart rate in dogs, where these dynamics were observed (Church et al., 1966). Relief and relaxation are two concepts are linked which makes studying them difficult, however they can be distinguished on the basis of their time course. Relief is directly related to the removal of an aversive event, or a predictor of such aversive event, whereas relaxation appears after relief. Evidence in cats suggests that sometime after successful avoidance, cats show behaviours that were categorised as those of relaxation such as upright relaxed ears (Masserman, 1943). It was also found that in rats when a safety signal was available during extinction, then rats took longer to meet the extinction criteria (Roberts et al., 1970). They suggest this could support Denny's, (1971) theory of relaxation as the periods of no shock when the feedback is available acquire properties of positive conditioned reinforcers. Whilst there is evidence that can be used to support this theory a difficult aspect of this theory is how to separate and measure fear reduction and relief. As relief and relaxation are internal emotions it can be difficult to measure these. As the suggestion that there is time sensitivity between relief before relaxation occurs later on however, in avoidance it could be that both of these processes are having an effect. In rats, evidence described in Denny (1991) assessed the isolated contribution of relief and relaxation, and their potential additive effect, and found support for the latter. However, there have been no experiments in humans which have attempted to assess relief vs relaxation in avoidance paradigms, potentially this could be a way to assess the difference between the two concepts (there are experiments using Pavlovian fear conditioning but as described in the

introduction these experiments do not necessarily show that these cues are reinforcing and therefore are not discussed here).

5.4.4 Dual-system theory of motivation

Konorski's theory (1967), as mentioned in the introduction, proposes the existence of two distinct yet interacting motivational systems: the appetitive and the aversive. These systems regulate behaviour by inhibiting one another. This helps to ensure that the appropriate responses occur depending on the differing environmental stimuli. When the appetitive system is activated, it elicits the expectation of a rewarding outcome, which could be considered a feeling of hope, while simultaneously suppressing the aversive system. Conversely, stimulation of the aversive system elicits an expectation of a negative outcome, eliciting fear and inhibiting the appetitive system. Importantly, the theory also accounts for the role of safety signals—cues indicating the absence of an aversive stimulus—which, by inhibiting the aversive system, disinhibit the appetitive system and produce a sense of relief, understood as a positive emotion. This dynamic interplay between the two systems helps explain how organisms adapt their emotional and behavioural responses based on environmental conditions. There has been work in pavlovian conditioning to support this (Dickinson & Dearing, 1979) and the results of Fisher and Urcelay (2024) provide the instrumental evidence for this theory, which has recently been formalized by Perez and Dickinson (2024). However, there is a need for more research to assess these two systems in avoidance behaviour. What is perhaps a bonus in this theory is that it also accounts for the transition from goal directed behaviour to habitual forms of behaviour, this making predictions about a number of different manipulations that hitherto have not been tested.

5.4.5 Opponent Processing Theory of emotion

This is a general theory that offers an explanation emotional states that can reinforce behaviours such as avoidance – and this includes the emotion of relief (Solomon, 1980). The premise of this theory is that emotions are regulated by two opposite responses these are known as A and B processes. In the case when an organism encounters an aversive event it will experience immediate fear which is the A process, once the threat has been avoided or terminated the organism experiences relief which is the B (opponent) process. The A process is seen as automatic as it quick to activate and gives rise to the primary emotional responses. Whereas the B process is the opponent responses that works to bring emotional balance back and this process is slower to activate ("sluggish" as Solomon called it) however its effects last for longer. Critically, B process responses can be learned, which means that as an organism experiences more and more an emotionally charged event, the A process will start eliciting the B process faster with repeated exposures, thus changing how big the A process is. The diminution of the A process by the B process is crucial because it indicates that fear is not the reason organisms persist in avoidance, it is the reinforcing effects of relief. The theory is somewhat silent about instrumental processes, but with the assumption that relief can act as a reinforcer the theory handles well the available evidence in terms of reinforcement by relief.

There are several studies which seem to support this theory showing that fear responses decrease over time whereas avoidance responses persist (Mineka & Gino, 1980). Rats were trained to a avoid a shock and initially the fear was high however, overtime fear declined where avoidance behaviour remained consistent. This could indicate that the initial A process of fear decreased, because the B counter process grew

with experience, which then became the primary driver of this behaviour. Moreover this is supported by other studies in humans (Vervliet & Indekeu, 2015) and rats (Mineka, 1979) which also evidence persistence of avoidance despite fear reduction. This theory can also be applied to anxiety disorders and explain why maladaptive avoidance continues. For example, a person with a phobia of dogs may experience intense fear initially (A process), but as they repeatedly avoid places where they could encounter dogs, their fear decreases while their sense of relief (B process) strengthens, reinforcing avoidance even when fear is no longer a strong driver. This perspective has important implications for treatment strategies for anxiety and related disorders, suggesting that reducing reliance on relief-seeking behaviours, rather than just extinguishing fear, could be the key to overcoming maladaptive avoidance patterns.

5.4.6 Prediction Error Theory

In more recent year's other researchers have offered other theories upon relief. One such is prediction theory which novel theory connecting the concept of prediction error to the emotional experience of relief. This theory builds on the idea that emotional responses are often shaped by the discrepancy between anticipated and actual events, a concept central to predictive coding models of the brain. In particular, Vervliet and colleagues emphasise that relief is not merely the absence of threat but occurs specifically when the absence of threat is surprising (Vervliet et al., 2017). These predictions guide their emotional responses and behavioural actions. When a perceived threat fails to materialise, meaning there is a prediction error between what was expected (the threat) and what actually occurred (the absence of the threat), this discrepancy elicits an

emotional reaction of relief. Crucially, this sense of relief is most pronounced when the lack of threat is unexpected or surprising. If an individual was highly anticipating danger or discomfort, and it does not occur, this unexpected change leads to a positive emotional response. Vervliet argues that this surprising absence of threat is a key determinant of the intensity of relief (Vervliet et al., 2017). In contrast, if the absence of threat is anticipated or expected (for example, in a safe situation that has been predicted), the emotional reaction is less pronounced. This suggests that relief is a reward-like response that signals the update or correction of an overestimated threat, helping to recalibrate the individual's predictions about future risks.

In summary theories into relief and safety signals provide insights into how avoidance behaviours maybe reinforced and maintained. The traditional models such as Two factor theory emphasise the role of fear reduction as the main motivator for avoidance behaviour. However, research has shown that this may not be the full picture, and subsequent theories have highlighted that negative reinforcement and relief, rather than solely fear reduction can motivate avoidance behaviour and overtime this can become the dominant process such as in opponent processing theory. Similarly, the Safety Signal Hypothesis proposes that cues associated with safety can serve as positive reinforcers, further encouraging avoidance behaviours. Denny's Relaxation Theory complements this understanding by suggesting that avoidance is strengthened not just by the removal of fear but by an active process of relaxation, which becomes a learned response over time. Together these theories help explain why individuals and animals continue to engage in avoidance even in the absence of immediate threats, offering

valuable perspectives for understanding anxiety disorders and developing more effective therapeutic interventions.

5.5 Applications

Although limited there has been some research on treatments using safety signals. Sartory et al. (1989) used patients with agoraphobia as this is a disorder which is associated with 'safe' stimuli and in this case, patients seek out safety (own homes) and do not venture out of this. In this case those who experienced the safety signal treatment had to leave their homes to meet their therapist and were told they had to make it to landmarks for example go to the supermarket and the therapist would be inside. It is hypothesised that the therapist would become a safety signal resulting in relief in the participants and reinforce the approach behaviour as opposed to avoidance. At the end of the treatment, it was found those in the safety signal group experienced fewer panic symptoms and were able to venture into more unknown situation alone compared to the control group. This was a first step in establishing the usefulness and effectiveness of using safety signals to reduce avoidance behaviour. In recent years there has not been much further research into using safety signals within treatments.

5.6 Conclusions

In summary, there has been a vast amount of research into safety signals and relief across a range of species including flies, rats, dogs and humans. The notion of relief particularly within human research has surged in intertest due to the connection with anxiety. There's still a need for further research into safety signals and relief to understand the parameters of this and whether there are ways in which this can be manipulated

(experience more or less relief). Further research would also benefit to understand the theoretical accounts of relief and avoidance behaviour.

5.7 References

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Chapter 6

Safety signals reinforce instrumental avoidance in humans

Abstract

Safety signals reinforce instrumental avoidance behaviour in non-human animals. However, there are no conclusive demonstrations of this phenomenon in humans. Using human participants in an avoidance task, Experiments 1-3 and 5 were conducted online to assess the reinforcing properties of safety signals and Experiment 4 was conducted in the laboratory. Participants were presented with a CS+ and a CS-, and they could avoid an aversive outcome during presentations of the CS+ by pressing their spacebar at a specific time. If successful, the aversive outcome (IAPS image or a loud noise in the laboratory) was not shown but instead a safety signal was. Participants were then tested – whilst on extinction - with two new ambiguous test CS's. If during test participants avoided, one of the new stimuli produced the trained safety signal and the other was a control. In Experiments 1 and 4 the control was followed by no signal, In Experiment 2 the control was followed by a signal that differed in one dimension (colour) with the trained safety signal, and in Experiment 3 the control was followed by a signal that differed in two dimensions (shape and colour) from the trained safety signal. Experiment 5 tested the reinforcing properties of the safety signal using a choice procedure and a new response during test. We observed that participants made more avoidance responses to the ambiguous test CS when followed by the trained signal in Experiments 1, 3, 4 and 5. We conclude that the trained safety signal reinforced avoidance behaviour. However, in Experiment 2 there was no difference in avoidance behaviour to the test CSs, suggesting that when the trained signal and the control signal are similar, generalisation occurs. Overall, these results suggest that trained safety signals can reinforce avoidance behaviour in humans.

6.1 Introduction

Avoidance behaviour is a hallmark of all anxiety disorders. Avoidance can be defined as behaviour that prevents the onset of an aversive outcome (Dinsmoor, 1977). In the context of social anxiety, for example, this could mean not going to social events and/or seeing certain people to prevent disapproval by others. Research within the anxiety field has largely focused on fear acquisition and extinction (Graham & Milad, 2011;

Urcelay, 2012). This has been a success in terms of developing new treatments for anxiety disorders (for example exposure therapies) however, there is still a large relapse rate (Scholten et al., 2013) so researchers have been exploring new avenues of research, for example targeting avoidance behaviour (Urcelay & Prével, 2019). One of the most well-known theories of avoidance is Mowrer's two-factor theory (Mowrer, 1951) which argues that avoidance involves two components, the first being classical fear conditioning. It is these classically conditioned signals that elicit fear, which result in instrumental avoidance behaviours reinforced by terminating the fear experience elicited by the signals. In other words, in this conceptualization, (classically conditioned) fear drives instrumental (avoidance) behaviour. However, we know from subsequent research in rats (Mineka, 1979) and humans (Vervliet & Indekeu, 2015) that when fear has been extinguished avoidance behaviour persists. This suggests that fear alone does not always account for the persistence of avoidance behaviour. A burgeoning question within this literature is concerned with what drives avoidance behaviour – given that fear alone does not fully account for it. In recent years, this has led to a resurgence in interest on avoidance behaviour to better understand what drives avoidance behaviour and why it persists - particularly in human participants.

One of those theorised drivers of avoidance behaviour is relief provided by safety signals. Relief is a pleasant emotion that is triggered by the omission of an expected aversive event (Vervliet et al., 2017). Therefore, when people avoid, they prevent an aversive stimulus which in turn results in relief (Denny, 1971). Relief can be particularly difficult to study because it depends on participants actively avoiding. Researchers have therefore tried to infer the reinforcing nature of relief by testing whether stimuli paired with

relief produced by the absence of an aversive event (safety signals) can reinforce instrumental avoidance (Fernando et al., 2014).

Historically, the literature on avoidance and safety signals has predominantly focused on non-human animals and whilst this provides insights into avoidance behaviour, it is unknown whether this translates to humans. In experiments by Fernando and colleagues (Fernando et al., 2014) rats were trained in a free-operant avoidance task where two different lever presses (trained alone, on separate sessions) could result in avoidance of a foot shock, and responses were followed by a 5-sec auditory (safety) signal. Rats were then tested in sessions in which both levers were presented, but responses on only one of the levers were followed by the safety signal. They observed that safety signals increased avoidance behaviour to the lever that was followed by the safety signal, both when the shock was presented during the session, and in a choice test conducted on extinction (i.e., in the absence of shocks). This suggests that the safety signals reinforced avoidance behaviour, which is in line with prior evidence by Weisman & Litner (1969; also see Rescorla, 1969 for evidence in dogs). They trained rats using a free-operant avoidance procedure in which rats had to turn a wheel to avoid shocks. Following this, rats experienced explicitly unpaired training in which a tone was uncorrelated with a shock, thus endowing the tone with inhibitory properties. After explicitly unpaired training of the tone, rats were re-baselined on the free-operant avoidance task and behaviour was reinforced according to a differential reinforcement of high (DRH) rates schedule, in which the inhibitor was presented when rats avoided at higher rates than in the baseline. Rats which received explicitly unpaired training avoided more than control rats trained with a CS/US random schedule. Following another re-baseline period, avoidance was now reinforced according to a differential reinforcement of low (DRL) rates schedule, in which

the signals are presented when subjects pressed a lower rate than in the baseline. Again, rats slowed their responding more when avoidance was followed by the inhibitor relative to the control stimulus. The results revealed that safety signals trained in a Pavlovian explicitly unpaired procedure (CS-/US) were able to bi-directionally control avoidance behaviour in rats (reinforcing either high or low rates of avoidance), further showing the reinforcing effects of the safety signal. Finally, (Dinsmoor & Sears, 1973) trained pigeons to avoid a foot shock by pressing a pedal, and presented a 1000Hz tone immediately after a successful avoidance as a safety signal. During test, they varied the frequency of the tone safety signal and observed generalisation decrement of the safety signal's reinforcing properties. That is, lower avoidance responses were observed at test when the safety signal was different in frequency (500 or 2000Hz) from the trained safety signal (1000Hz).

Although there is convincing evidence that safety signals can reinforce instrumental behaviour in non-human animals, there is a dearth of convincing evidence in humans. In a report by (Angelakis & Austin, 2015), participants played a computer game in which they could gain or lose treasures by clicking on a map. Whilst playing, participants could also press a pedal to avoid bombs (and point losses), and this avoidance resulted in the presentation of a blue bar on the screen. During test sessions, the bar was yellow and would turn to blue when participants pressed the avoidance pedal. Participants pressed more the avoidance pedal when the bar changed from yellow to blue than the opposite, presumably showing the reinforcing properties of the (blue) safety signal. However, the report only recruited six participants, did not counterbalance the identity of the safety signal (blue or yellow), and importantly did not provide any statistical tests in support for the descriptive findings, making it difficult to conclude that the safety signal was indeed reinforcing avoidance behaviour.

Moreover, there have been studies in which humans could avoid a shock that was signalled by a predictive CS+, and were asked immediately after an avoidance response to subjectively rate the extent to which they felt "relief". In line with the notion that avoidance responding provides relief, participants gave higher subjective ratings of relief following shock avoidance, in particular early in training (Vervliet et al., 2017). A second report replicated these findings and further revealed that subjective relief ratings were higher following avoidance responses to a CS+ than to the presentation of a CS (San Martín et al., 2020). Finally, it has been observed that subjective relief was higher in participants with PTSD and Panic disorder relative to healthy controls (De Kleine et al., 2023). However, these studies in humans used self-reported measures of relief such as asking participants how much relief they experienced following a successful avoidance response. Therefore, despite the subjective measures suggesting that avoidance response results in relief, there is hitherto no behavioural evidence in humans that safety signals reinforce avoidance behaviour in humans.

The aim of this study was to investigate whether safety signals can act as reinforcers in a human instrumental avoidance task. Unlike previous reports, during avoidance training we presented a discrete safety signal following a successful avoidance response, and later assessed whether the safety signal reinforced avoidance responses to novel stimuli. Because presenting the aversive outcome during the test can result in new learning during test, we developed a procedure in which participants were tested in extinction (no aversive outcome presented during the test session) and using novel stimuli. Of course, the problem with using novel stimuli during test is that participants are unlikely to respond to the new stimuli. To overcome this, during training participants experienced a discrimination between two stimuli in which the angle dimension was the

relevant one to solve the discrimination (CS+ 90 degrees, CS- 0 degrees, counterbalanced). During test, we presented 45- and 135-degree stimuli, which are in between those used during discrimination training. Pilot experiments revealed when we used one CS+ (e.g., 90 degrees) and one CS- (e.g., 0 degrees) during training, the novel test stimuli (45 and 135 degrees) were too novel, and participants made little to no responses during test. To facilitate transfer, during training we used two sets of stimuli (CS+: 80, 90, and 100 degrees; CS-: 350, 0, and 10 degrees; counterbalanced) as we observed that this variability during training facilitated the observation of responses during the test session.

In other words, in this series of experiments, participants were trained to avoid the appearance of an unpleasant image (or loud noise) which was signalled by one stimulus (CS+), whilst a second stimulus (CS-) was not paired with the aversive outcome. CS+ and CS- were Gabor patches with variable (+/- 10 degrees) orientation lines but around either 0 or 90 degrees (counterbalanced for CS+ and CS-; see Figure 6). The unpleasant image (or loud noise) could be avoided by pressing the space bar on the keyboard. Critically, and following previous reports (Flores et al., 2018; Urcelay et al., 2024) in order to successfully avoid participants had to respond one second before the US was scheduled to appear, and the exact time of appearance within the CS was variable, which leads to numerous responses per trial. When participants avoided the US, they were then shown the safety signal (an image on the screen) for 3 seconds. During the test phase the US was no longer presented however participants were not informed of this, and they were presented with new Gabor patches (45 and 135 degrees). Due to the ambiguity of these new Gabor patches (the orientation was exactly in between the orientation values of the CS+ and CS-), participants could respond or not. One of the new Gabor patches (45 degrees) was followed by the trained safety signal if participants responded, and the other (135 degrees;

counterbalanced) served as the control (this differed per experiment). In Experiment 1 during test, we measured avoidance responses to a Gabor patch that was followed by the trained safety signal and compared it with responses to one that was followed by nothing. In Experiment 2 we measured avoidance responses to a Gabor patch that was followed by the trained safety signal and compared it to a Gabor patch that was followed (if participants responded) by a somewhat similar safety signal (same shape but a different colour from the blue-green colour continuum). In Experiment 3 we measured avoidance responses to a Gabor patch that was followed by the trained safety signal and compared it to responses made to a Gabor followed by a dissimilar signal (differed both in shape and in colour). In Experiment 4, we replicated Experiment 1 but conducted the experiment in the laboratory with a biologically relevant aversive outcome (i.e., a 95-dB tone). Finally, in Experiment 5 we used the same stimuli as Experiment 3 but, we changed the response in the test phase to a mouse click so participants now saw both Gabor patches on screen at the same time and had the choice to respond to either, by directing the mouse pointed and clicking on them.

6.2 Experiment 1

6.2.1 Introduction

The first experiment in this series was designed to investigate whether safety signal reinforce behaviour. A design such as this has not been documented within the literature so it was decided that we would adapt an already established avoidance task (Flores et al., 2018). To keep the design as simple as possible we decided to use a control of no signal during test. This way we could assess whether people would make more avoidance responses to be presented with the safety signal.

6.2.3 Methods

6.2.3.1 Participants

Participants were recruited via Prolific with the same selection criteria being the same for all experiments. The participants were from unique participant pools with one of the screening criteria being that they had not taken part in any of the previous experiments on safety signals. Participants had to be between 18-60 years old, have normal or corrected vision, no colour-blindness and could speak English fluently. We had a training criterion which participants had to pass. This was included so that the participants understood the task and what was expected (no safety signals were shown in this phase). Participants had to respond more to the CS+ compared to the CS- for two consecutive blocks. If they did this they moved on to the experiment and if they did not pass then the experiment went straight to the end screen. 131 participants were recruited, however, 18 did not complete the full experiment and 13 people did not pass the pre-training criteria (see below). The final sample was 100 participants which consisted of 49 male and 51 females. The ages ranged from 18 to 60 years old (M = 30.66, SD = 8.52).

As the objective of this study was to assess the reinforcing properties of safety signals, we excluded participants that during training did not experience any safety signals. After applying the criterion that participants had to earn at least one safety signal during training, Experiment 1 had a final sample of 72 participants. There were 37 males and 35 females. The ages ranged from 18-60 (M = 30.96, SD = 8.55).

6.2.3.2 Materials

Scales

Participants completed a short questionnaire to assess their anxiety levels. The first was the Spielberger's State-Trait Anxiety Inventory (Spielberger, 2010) which contains 40 questions, all of which have a 4-point Likert scale from 1 to 4 (with 1 being not at all and

4 being very much so). The questions assess participants' current feelings, for example 'I feel calm' and 'I feel frightened'.

Aversive outcome

The aversive outcome in Experiments 1-was an aversive image. These images were selected from the international affective picture system (IAPS). The images chosen were aversive but not traumatic and all images had similar arousal and aversive ratings (see Appendix). At the beginning of the experiment, participants had to rank a series of six images from least to most aversive. The image that was selected as the second most aversive was used as the outcome image during the experiment. The images included a spider, snake, a dirty toilet, a cockroach on a pizza, a surgery and a person vomiting.

Pre-Training Stimuli

There were two fractal images used during a pre-training phase for all experiments (*see Figure 6.1*). These images were abstract fractals of different colours. They were 50% of the screen's height. One was paired with the aversive outcome, and one was not, and participants had to press the space bar to avoid seeing the aversive outcome.

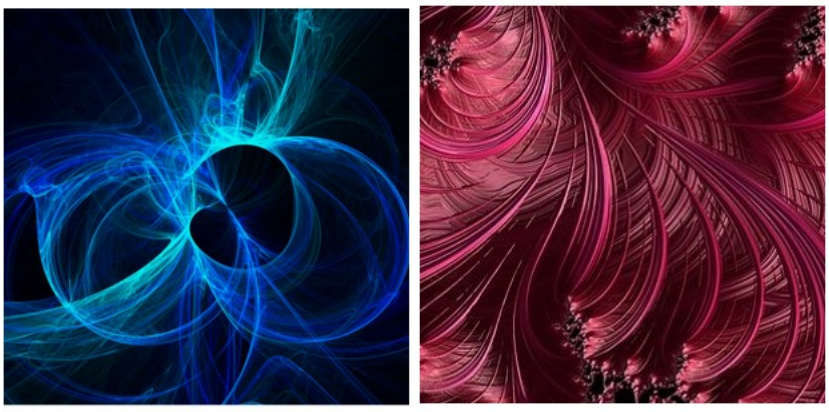

Figure 6.1
The fractal images used for pre training.

Training and Test Stimuli

There were eight Gabor images used as CSs in this experiment (*see Figure 6.2A,6.2B and 6.3C*). They all had the same spatial frequency (10c/deg) and size but differed in terms of the orientation. They were 50% of the screen's height. There was a vertical set (Figure 6.2Ba) and horizontal set (Figure 6.2Bb) used during training, both of which included three stimuli. These sets were used as the CS+ and the CS- (these were counterbalanced between participants). The horizontal set included Gabor patches at 0, 10 and 350 degrees and the vertical set included stimuli at 90, 80 and 100 degrees. During the test (Figure 6.2C), two other Gabor's were used (45 and 315-degree angles).

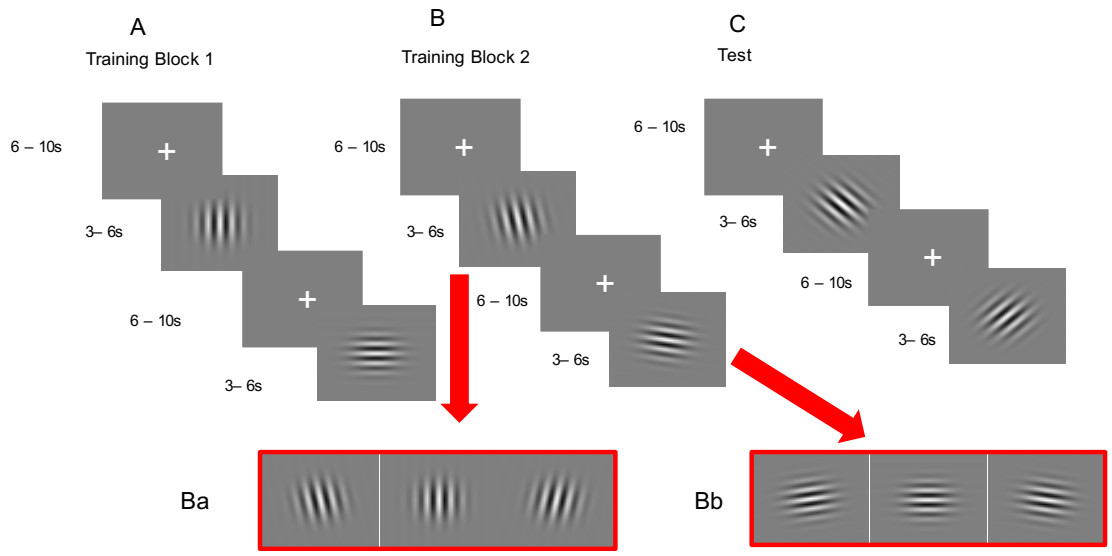

Figure 6.2
There are two phases within these experiments. Training and test. Training was first started with an easy Block 1 (Panel A) which were followed by more difficult Blocks (Blocks 2-5 in Experiments 1, 3 and 5, and Blocks 2-3 in Experiment 4). This was followed by a test with novel stimuli (Panel C), one of which was followed by the trained safety signal and the other served as a control. (A) shows Training Block 1. Participants were shown either a horizontal or vertical Gabor patch. One was paired with an aversive image or a loud noise (CS+) one was not (CS-), this was counterbalanced. Panel B shows Training Blocks 2-5 in which more stimuli were incorporated. Four new stimuli were added (panels Ba and Bb). Each of the new Gabor stimuli were 10 degrees apart in orientation from the stimuli used in Training Block 1, except Experiment 5 in which Block 2 had 5 degrees of difference. This made the vertical" vs "horizontal" discrimination more difficult, but also facilitated transfer of responding during test to the new stimuli. (C) in the Test Phase participants were shown new stimuli. These Gabor patches were in between the horizontal and vertical Gabor stimuli (135 and 45 degrees). One of these produced the trained safety signal and the other one was the control.

Safety signal

The trained safety signal was an aqua colour that was selected from the middle of the blue green colour continuum (Figure 6.3A). This was presented as a square (in the centre of the screen whilst the background was grey).

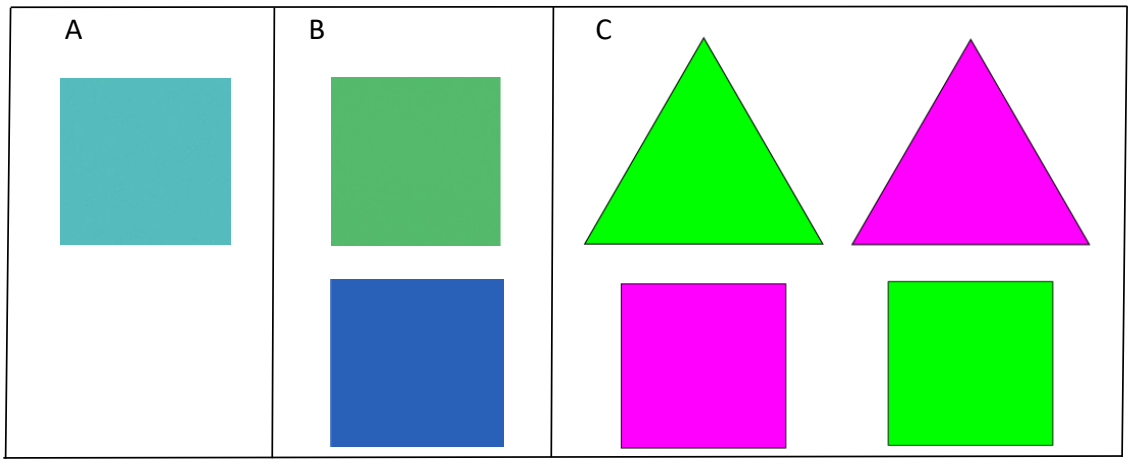

Figure 6.3
This figure shows the different stimuli used as safety signals (and control) for each experiment. (A) shows the stimulus used as safety signal Experiments 1 and 4. All participants were trained with the same safety signal (aqua square) and the control during the test phase was no safety signal. (B) shows the stimuli used in Experiment 2. Participants were trained with either green or blue squares. During the test, the control was the square that they had not been trained with. (C) shows the stimuli used in Experiment 3. Participants were trained with either a square or triangle and this was either pink or green. During the test, the control was opposite shape and colour. For example, if a participant was trained with a green triangle, then the control during the test was a pink square. Stimuli were counterbalanced.

6.2.3.3 Procedure

Experiments 1took place online. After filling out a consent form, participants filled out the anxiety scale (STAI). Following this, the participants ranked each of six aversive images which served as the aversive outcome. They ranked them from least to most aversive and the image selected as the second most aversive was used as the aversive outcome for the remainder of the experiment. This experiment involved four phases. These were pre training, training, test and expectancy.

Pretraining

The first phase was the pretraining phase. During this phase participants were presented with two fractal images. These were square images (they were 50% of the screen height and presented in the middle of the screen) and were presented in the centre

of the screen. The background was grey. One fractal served as the CS+ and was followed by the aversive outcome (aversive image). The other was the CS- and was followed by nothing. Participants were told that they could avoid the aversive image by pressing the space bar on the keyboard. In the CS+ trials the US could appear on seconds 4, 5 or 6 of this trial. If avoidance response was performed one second before the us was scheduled to appear, avoidance was successful, and the trial ended. If the avoidance response was unsuccessful, then the aversive outcome was played for 1 second. The fractal image also remained on screen whilst the aversive outcome was presented. Each trial was variable in length due to the variability in CS duration (3-6 seconds), and the inter trial interval was variable (6-10 seconds) with an average of 6 seconds. During the ITI a white fixation cross was presented in the centre of the screen. There were two presentations of the CS+ and CS- per block. The participants had to meet a criterion before they were able to move on. For them to move on to the next phase, they had to respond more to the CS+ than the CS- for two consecutive blocks. Pre-training had a maximum of 10 blocks and was performed to make sure all participants understood the nature of the avoidance task.

Training

The second phase of the experiment was the training phase, which was similar to the pre training phase, except that it used the Gabor stimuli instead of fractals (see Figure 6.2A). This phase was split into two parts. During training block 1 participants were shown two Gabor patches. One was horizonal and the other was vertical. One of these was paired with the aversive image (CS+) and the was not (CS-). The aversive outcome could be avoided if the participants pressed the spacebar 1 second before the aversive outcome would appear. If avoidance was successful, the CS terminated, the aversive image was not shown and instead the trained safety signal was presented for 3 seconds. If

unsuccessful the CS was terminated, and the aversive image (US) was shown for 1 second. The presentation of the aversive image was variable and could occur on seconds 4, 5 or 6 of the 6-second trial. Therefore, the response windows for successful avoidance were seconds 3, 4 and 5. Each of the Gabor patches was presented 3 times each.

Training blocks 2-5 were the same as training block 1 (3 trials) except that new stimuli were added and thus made more difficult (see Figure 6B). Participants were presented with 4 new Gabor patches. Two of these new stimuli differed 10 degrees from the horizontal stimuli and two differed 10 degrees from the vertical stimuli. They therefore made two sets of stimuli: a horizontal set and a vertical set. If the CS+ was 90 degrees, then the CSs+ during blocks 2-5 were 80, 90 or 100 degrees, and the CSs- were 350, 0 and 10 degrees. There were 4 difficult blocks and each of the 6 stimuli were shown once per block so there were 24 trials in total.

Test

The next phase of the experiment was the test phase which occurred during extinction, meaning that the aversive outcome was no longer presented. However, participants were not explicitly informed of this and moved straight from the training phase into the test phase with no instructions in between. They were presented with two new Gabor gratings which were 45 and 135 degrees. The participants only needed to respond 1 second after the CS first appeared on the screen in order for the safety signal to appear at the end of the Gabor presentation. The alternative (control) Gabor patch produced nothing if the participant responded. The test included 8 trials of each degree angle gratings (16 in total).

Expectancy ratings

Participants completed two contingency Likert scales to assess participants expectation of the aversive image for each stimulus to ensure they learned the basic

contingencies during training. They were shown the 90 and the 0-degree Gabor patches and asked to rate how likely the aversive image is to follow them. The scales ranged from 1 – 9 with 1 being will not follow and 9 being most certainly will follow. They also answered a question about how aversive the aversive image was, with 1 being not aversive and 9 being extremely aversive. They were then thanked for their time and the experiment ended.

6.2.3.4 Data Analyses

In the training phase, the effect of stimulus was examined by comparing responses to the stimulus set that was paired with the aversive outcome (CS+) with responses to the one that was not (CS-), as a function of training trials. This was achieved by conducting a 2 (Stimulus; CS+ vs. CS-) x 15 (Trials; 1-15) repeated-measures ANOVA. Furthermore, during training, we also analysed the number of safety signals participants produced over the 15 CS+ trials. Because safety signal presentation is a binary outcome (0 or 1) and this violates the assumptions of parametric statistics, we analysed 5 blocks of 3 trials with a one-way ANOVA assessing the effect of blocks (1-5).

Responses in the test phase assessed the effect of stimulus to determine whether participants responded similarly to the stimulus that produced the trained safety signal versus the control stimulus, over eight test trials. This was achieved by conducting a 2 (Signal; Trained Safety Signal vs Control) x 8 (Trials; 1-8) repeated measures ANOVA.

6.2.4. Results

6.2.4.1. Training

During training, participants (n = 72) responded more to the CSs+ than the CSs- (see Figure 6.4A). To assess this, we measured the rate of responding for each trial during the training phase. A 2 X CS (CSs+ vs CSs-) 10 (Trials) repeated-measures ANOVA revealed a main effect of CS, $F(1,71) = 18.86$, $p < .001$, $\eta_p^2 = .210$, Trial $F(6.78,481.54) =$

4.78, p <.001, η_p^2 = .063, and a significant interaction between CS and Trials F(8.41, 597.1) = 3.85, p < .001, η_p^2 = . 51, suggesting that as trials progressed, participants responded more to the CSs+ compared to the CSs-. We also analysed the number of safety signals that participants experienced during the training phase by block (3 trials per block; see Table 6.1 for descriptives). As training trials progressed, the number of safety signals received increased. A one-way ANOVA assessing the effect of Blocks (1-5) revealed a significant effect, F(3.66,260.11) = 10.01, p < .001, η_p^2 = .124.

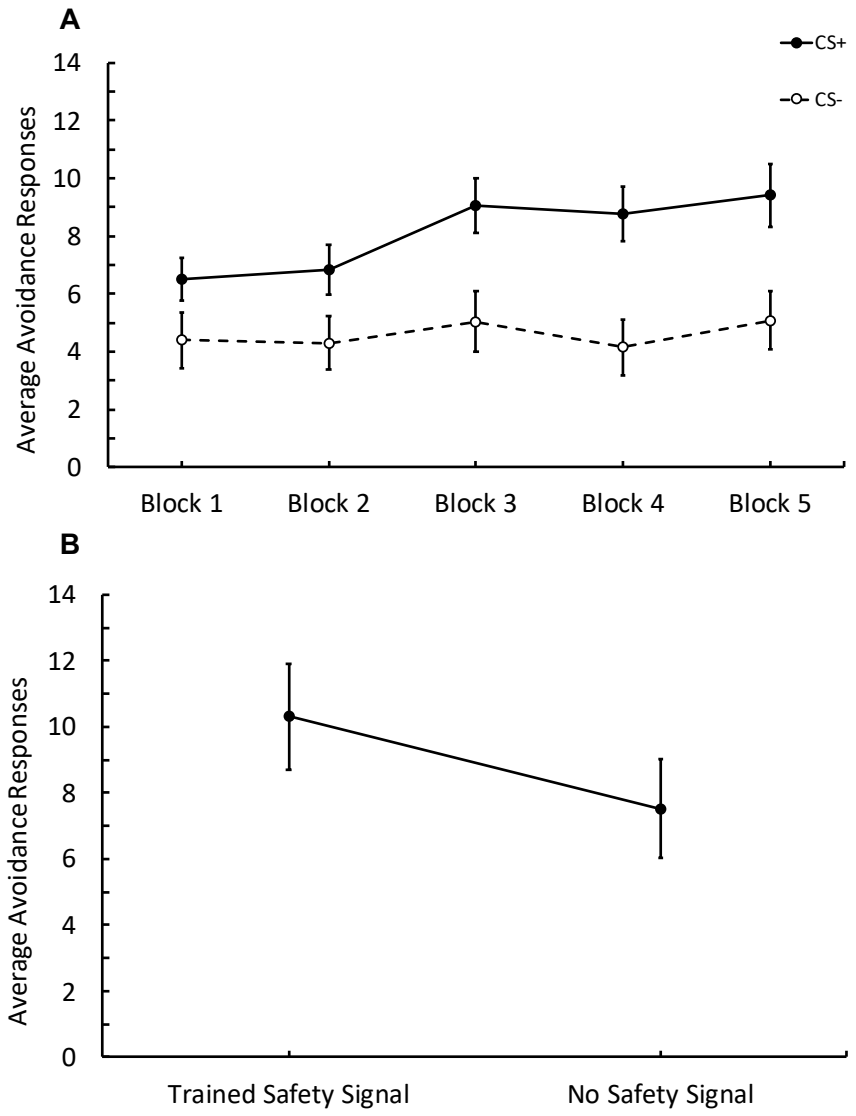

Figure 6.4
Results from Experiment 1 comparing avoidance responses to obtain a response-produced safety signal relative to no signal. *(A)* Training data depicting avoidance responses to the CSs+ and CSs-. Each block contains 3 trials. Participants made more responses to the CSs+ across blocks compared to the CSs-. *(B)* Test data showing avoidance responses to the Gabor that was followed by the trained safety signal versus responses to a Gabor that was followed by no signal. Participants made more responses to the trained safety signal than no signal. Error bars depict standard error of the mean.

6.2.4.2. Test

Critically, during the extinction test participants made more avoidance responses to the Gabor stimuli that was followed by the safety signal compared to the one that was not (see Figure 6.4B). A 2 Signal (Signal vs No Signal) X 8 (Trials) repeated-measures

ANOVA compared avoidance responses to the Gabor followed by the safety signal vs the one which was not followed by a signal. There was a main effect of Signal $F(1,71) = 16.28$, $p < .001$, $\eta_p^2 = .187$, revealing more avoidance responses to the Gabor followed by the safety signal, a marginal effect of Trial in that responding decreased as trials progressed $F(2.81, 199.82) = 2.19$, $p = .095$, $\eta_p^2 = .030$, but there was no interaction between Signal and Trials; $F(3.74, 265.89) = 1.26$, $p = .285$, $\eta_p^2 = .018$.

6.2.4.3 Expectancy

Following the behavioural test, we assessed the expectancy data for the CS+ and the CS- and found that participants rated the CS+ more likely to be followed by the aversive stimulus than the CS-. A paired t-test revealed there was a significant difference in the expectancy scores for the CS+ ($M = 6.38$, $SD = 2.146$) and the CS- ($M = 3.46$, $SD = 2.181$); $t(71) = 8.8$, $p < .001$, Cohen's $d = 1.03$.

6.2.5. Discussion

Experiment 1 revealed that participants emitted more avoidance responses to an ambiguous Gabor patch which resulted in the safety signal relative to one which did not result in the safety signal. These findings suggest that the safety signal reinforced avoidance behaviour. However, it could be possible that the results on Experiment 1 are due to any perceptual signal providing reinforcement, a phenomenon that has been named sensory reinforcement (Lovaas et al., 1987). Experiments 2 and 3 explored this possibility by using a control group in which avoidance responses to the Control Gabor stimulus were followed by a stimulus that was to some extent perceptually similar to the trained safety signal (Experiment 2) or dissimilar to the trained safety signal (Experiment 3).

6.3 Experiment 2

6.3.1 Introduction

Following experiment 1 we wanted to replicate the findings but using a different control to test whether it was just the feedback that reinforced the behaviour. If the trained safety signal is reinforcing, then participants should respond to a Gabor when it is followed by a safety signal that has been trained compared to a Gabor that is followed by a new stimulus. In Experiment 2, participants received avoidance training with the same stimuli and procedure as that used in Experiment 1. The test was also the same, except that now one Gabor (45 or 135 degrees, counterbalanced) was followed by the trained safety signal and the control Gabor was followed by another signal that was of a different colour (green or blue, counterbalanced), but similar in shape to the trained signal (i.e., square; see method and materials for more details).

6.3.2 Method

6.3.2.1 Participants

Participants were recruited online via Prolific and the same exclusion criteria as Experiment 1 was applied. 143 participants were recruited however, 28 people did not complete the full experiment, and a further 15 people did not pass the pre-training criteria. The final sample was 100 with 49 females and 51 males. The ages ranged from 18 to 40 years old (M = 29.4, SD = 5.73). After applying the criteria that participants had to have earned at least one safety signal during training, there were 55 participants with 26 females and 29 males. The ages ranged from 18-40 (M = 29.6, SD = 6.43).

6.3.2.2 Materials

Safety Signals

The safety signals used within this experiment were coloured squares (similar to Experiment 1). The trained signal was either a dark blue or dark green (*see Figure 6.3B*) and this was counterbalanced for the participants. The control signal during test was the other coloured square (either blue or green).

6.3.2.3 Procedure

The procedure was the same as Experiment 1 except during the test phase. Instead of the control Gabor patch producing no signal it produced a control signal which was the same shape (square) as the trained signal, but it was a different colour.

6.3.2.4 Data Analysis

This was the same as Experiment 1 additionally, we compared the overall number of trained safety signals participants produced during test compared to the new (control) safety signal. This was achieved with a paired t-test using the total number of trained safety signals produced versus the new safety signals produced.

6.3.3 Results

6.3.3.1 Training

During training, participants (n = 55) made more avoidance responses to the CSs+ than to the CSs-, and this difference became larger as training progressed (Figure 6.5A). This was supported by a 2 (CSs+ vs CSs-) x 15 (Trials) repeated-measures ANOVA, which revealed an effect of stimulus $F(1, 54) = 7.62$, $p = .008$, $\eta_p^2 = .124$, a main effect of Trial, $F(7.10,383.83) = 5.18$, $p < .001$, $\eta_p^2 = .088$, and a significant interaction between CS and Trials, $F(8.70, 470) = 3.30$, $p < .001$, $\eta_p^2 = .058$. We also assessed the number of safety signals participants produced in the training phase by conducting a one-way ANOVA with

Blocks (1-5; *see Table 6.1 for descriptives*). As the Blocks progressed, the number of safety signals produced increased $F(3.54, 191.13) = 7.56$, $p < .001$, $\eta_p^2 .123$.

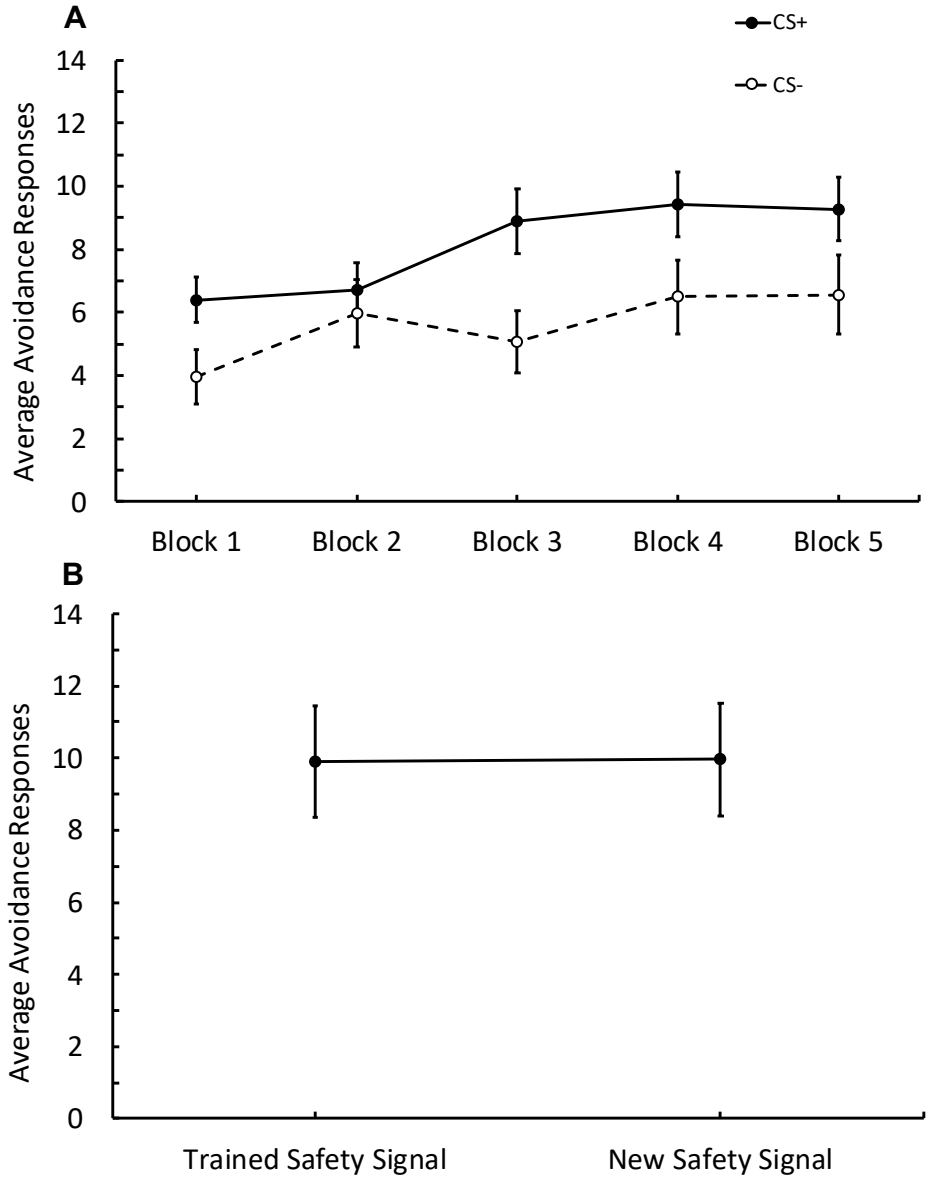

Figure 6.5
Results from Experiment 2 comparing avoidance responses to obtain a response-produced safety signal relative to avoidance responding to obtain a new signal which only differs in colour. *(A)* Training data depicting avoidance responses to the CSs+ and CSs-. Each block contains 3 trials. Participants made more responses to the CSs+ across blocks compared to the CSs-. *(B)* Test data comparing avoidance responses to Gabor that was followed by the trained signal versus responses to the new signal. Participants made a

similar number of avoidance responses to obtain the trained safety signal and the new signal. Error bars depict standard error of the mean.

	Block 1	Block 2	Block 3	Block 4	Block 5
Experiment 1	1.51 (.13)	1.40 (.14)	1.96 (.14)	1.99 (.13)	1.9 (.15)
Experiment 2	1.6 (.11)	1.45 (.13)	1.91 (.15)	2.04 (.15)	2.05 (.16)
Experiment 3	1.46 (.11)	1.36 (.14)	1.92 (.14)	1.99 (.14)	2.09 (.13)
Experiment 4	1.68 (.18)	2.46 (.13)	2.61 (.09)	-	-
Experiment 5	1.24 (.14)	1.39 (.15)	1.46 (.17)	1.63 (.17)	1.63 (1.7)

Table 6.1
Summary table of means and standard error of the number of safety signal presentations experienced during the training phase (blocks of 3 trials). Note that Experiment 4 contained 9 training trials therefore there are only 3 training blocks instead of 5.

6.3.3.2 Test

During the test phase (Figure 6.5B), participants responded similarly to the Gabor that was followed by the trained safety signal and that which was followed by the new signal. These impressions were confirmed by a 2 (Signal: Trained Signal vs New Signal) and Trial (1-8) repeated-measures ANOVA, that revealed that a main effect of trials - as test trials progressed responding decreased, $F(3.26,176.53) = 6.60$, $p =< .01$, $\eta_p^2 = .109$. There was however no effect of signal, revealing that participants made the same number of avoidance responses to the Gabor that was followed by the trained safety signal and that followed by the new signal $F(1,54) = .003$, $p = .958$. Furthermore, there was no interaction between the type of signal and trials $F(5.9,318.58) = 1.55$, $p = .16$. Because responding to either Gabor patches during test was followed by a signal, we also assessed the overall number of signals participants produced in the test phase with a paired t-test. There was no difference in the overall number of trained safety signals produced ($M = 5.71$, $SD = 2.95$) and the overall number of new safety signals produced ($M = 5.35$, $SD = 2.93$), $t(54) = 1.018$, $p = .31$.

6.3.3.3 Expectancy

After the behavioural test, we assessed the expectancy data for the CS+ and the CS- and found that participants rated the CS+ as more likely to be followed by the aversive stimulus than the CS-. A paired t-test revealed there was a significant difference between the CS+ (M = 6.24, SD = 2.63) and the CS- (M = 3.36, SD = 2.54); $t(54) = 6.34$, $p < .001$, Cohen's d = .856.

6.3.4 Discussion

A possible reason for the participants responding similarly to both signals is due to sensory reinforcement. This is where a stimulus provides feedback, and this feedback then reinforces the behaviour (Lovaas et al., 1987). Therefore, having a signal whether trained or novel provided feedback which led to similar levels of avoidance responding. Another possible reason for the participants responding similarly to both signals is that, during training the discrimination between CS+ and CS- was not very strong, despite it being significant, and this somehow transferred to the new Gabors presented during test. To assess this possibility, we calculated a discrimination score during training (CS+/CS-) and assessed the correlation of this with the responses to obtain the trained signal / responses to obtain the new signal. This correlation was not significant, $r(53)=.122$; $p=.376$. A second possibility is that responding was similar because of generalisation. Because the signals used in this experiment only differed in one dimension (colour), it could be possible that participants responded similarly to the two Gabor patches because they generalised form the trained safety signal to the new (control) signal at test. This speculation is supported by findings from Dinsmoor and Sears (1973), who observed that pigeons avoided during test to response-produced auditory signals in a way that resulted in a generalisation gradient. Avoidance responding was highest when the response-

produced safety signal was the same as that presented during training (1000 Hz), somewhat lower to stimuli of similar frequency (500 and 2000 Hz) in some subjects, and much lower to stimuli that were different from the trained safety signal (200 and 4000 Hz). As the response-produced signal during test was made more different from the trained safety signal, responded decreased. If this were the case, we expected to observe different response rates to Gabors followed by the trained safety signal versus a new safety signal, provided that the new signal at test was sufficiently different from that presented during training. Experiment 3 was designed to test this hypothesis.

6.4 Experiment 3

6.4.1 Introduction

Experiment 3 was similar to Experiment 2 in all aspects, except that the trained safety signal and the new (control) signal presented at test were made more dissimilar. That is, the signals were different in colour (green vs pink) and shape (square vs triangle). In this experiment we assess evidence that safety signals have reinforcing properties at test when comparing avoidance responding to a Gabor that produced the trained signal (e.g., green triangle) to a Gabor that is followed by a new dissimilar signal (e.g., pink square).

6.4.2 Methods

6.4.2.1 Participants

In Experiment 3 recruited 129 participants. However, 16 did not complete the experiment and were excluded and 13 did not pass the training criteria so were also excluded. Therefore, the final sample had 100 participants which consisted of 45 Females, 1 non-binary person and 54 males. The ages ranged from 20 to 49 years old (M = 30.57, SD = 6.32). After applying the criteria that participants had to have earned at least

one safety signal during training, there were 74 participants, 34 females and 40 males and the ages ranged from 21-49 (M = 31.12, SD = 6.49).

6.4.2.2 Materials

Safety Signals

The safety signals used within this experiment were colored squares and triangles. The trained signal was either a green or pink or a square and a triangle (*see Figure 6.3C*) and this was counterbalanced for the participants. The control signal during test was then other colour and shape. For example, if the trained signal was a pink triangle, then the control signal would be a green square.

6.4.2.3 Procedure

The procedure was the same as Experiments 1 and 2.

6.4.2.4 Data analysis

This was the same as Experiment 2.

6.4.3 Results

6.4.3.1 Training

In line with what we observed in previous experiments, participants responded during training more to the CSs+ compared to CSs- and this changed throughout training (*see Figure 6.6A*). A2 (CS: CSs+ vs, CSs-) X 15 Trials repeated-measures ANOVA revealed a significant interaction between CS and Trials, $F(7.90,577.19) = 5.32$, $p < .001$, $\eta_p^2 = .068$. There were also main effects of Stimulus $F(1,73) = 31.73$, $p < .001$, $\eta_p^2 = .303$ and Trials in that as trials increased responding also increased $F(7.75, 565.81) = 9.02$, $p < .001$, $\eta_p^2 = .11$. Like previous experiments, we also assessed the number of safety signals participants produced during the training phase by conducting a one-way ANOVA (Blocks: 1-5; see Table 1 for descriptives). As training blocks progressed, the number of safety signals participants produced increased $F(3.30, 240.99) = 12.27$, $p < .001$, $\eta_p^2 = .144$.

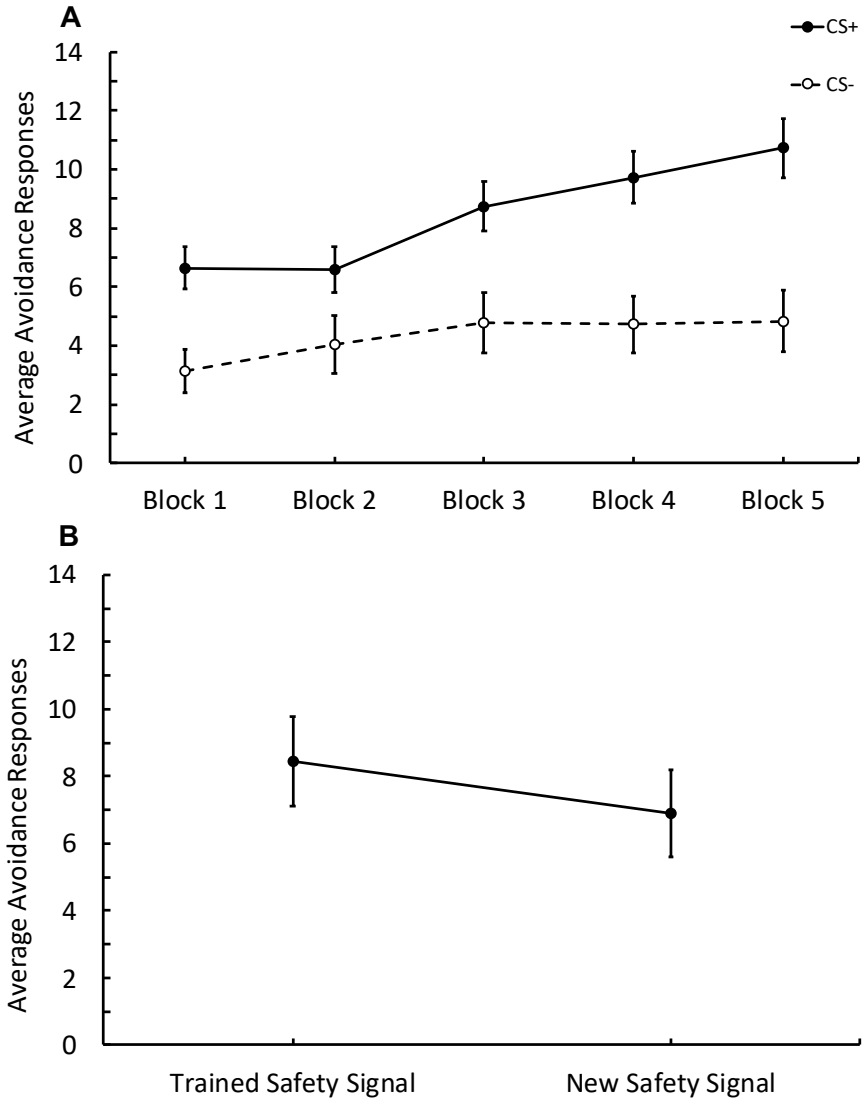

Figure 6.6
Results from Experiment 3 comparing avoidance responses to obtain a response-produced safety signal relative to a new dissimilar signal. *(A)* Training data depicting avoidance responses to the CSs+ and CSs-. Each block contains 3 trials. Participants made more responses to the CSs+ across blocks compared to the CSs-. *(B)* Test data showing avoidance responses to the Gabor that was followed by the trained safety signal versus responses to a Gabor that was followed by a new dissimilar signal. Participants made more responses to obtain the trained safety signal relative to the new dissimilar signal. Error bars depict standard error of the mean.

6.4.3.2 Test

Critically, during the test phase (*see Figure 6.6B*) participants responded to the

Gabor that was followed by the trained safety signal more than that followed by the new

dissimilar signal. A repeated measures ANOVA 2 (Signal: Trained Signal vs New Signal) X 8 Trials conducted on avoidance responses during test revealed an effect of signal, showing that participants made more avoidance responses to the Gabor which was followed by the trained safety signal and relative to that followed by the new signal $F(1,73) = 4.90$, $p = .029$, $\eta_p^2 = .064$. The ANOVA also revealed an effect of Trials (as the test trials progressed, responding decreased), $F(3.46,252.67) = 4.76$, $p = .002$, $\eta_p^2 = .061$, but there was no interaction between Signal and Trials, $F(3.90,284.89) = .72$, $p = .574$. Similarly, a paired t-test was conducted to assess the number of trained safety signals produced compared to the new safety signal. It was found that the number of trained safety signals produced ($M = 4.3$, $SD = 3.13$) was higher than the number of new safety signals produced ($M = 3.61$, $SD = 3.01$), $t(73) = 3.60$, $p < .001$, Cohen's $d = .419$.

6.4.3.3 Expectancy

Finally, we assessed the expectancy data for the CS+ and the CS- and found that participants rated the CS+ as more likely to be followed by the aversive stimulus than the CS-. A paired t-test revealed there were significant differences in expectancy scores between the CS+ ($M = 6.72$, $SD = 2.67$) and the CS- ($M = 2.49$, $SD = 2.26$); $t(73) = 10.69$, $p < .001$, Cohen's $d = 1.24$.

6.4.4 Discussion

Collectively, experiments 1 and 3 provide convincing evidence that response-produced safety signals reinforce avoidance behaviour. However, the experiments were conducted online and under these groups there is little experimental control over the situation. Experiment 4 was run to address this concern, by attempting to replicate Experiment 1, but recruiting participants from the School of Psychology and using a loud tone as the aversive stimulation.

6.5 Experiment 4

6.5.1 Introduction

We wanted to conduct an experiment in controlled groups using a biologically relevant aversive stimulus. All the previous experiments provide good evidence that safety signals can be reinforcing however, as they were conducted online, we had less experimental control. By conducting the experiment in the laboratory with a loud noise as the aversive stimulus then this gives more validity to the protocol that has been used and showcases the results can be replicated with different parameters.

6.5.2 Methods

6.5.2.1 Participants

Experiment 4, 51 people were recruited, 1 person did not pass the pre-training criteria, so the final sample was 50. The sample consisted of 12 males and 38 females. The ages ranged from 18-28 years old (*M* = 19.32, *SD* = 2.025). After applying the criteria that participants had to have earned at least one safety signal during training, there were 41 participants, 11 males and 30 females. The ages ranged from 18-28 (*M* = 19.46, *SD* = 2.203).

6.5.2.2 Materials

Aversive stimulus

The aversive outcome in Experiment 4 was a loud tone. The tone was delivered via headphones which were calibrated to ensure the tone was (95db). Participants were aware before taking part in the experiment that an aversive sound would be used and that if they found it too loud, they could request for the volume to be reduced, however none of the participants requested this.

6.5.2.3 Procedure

The procedure was the same as Experiment 1 except for two changes. Instead of an aversive image the aversive tone was used instead. The sound was played for 1 second of participants did not successfully avoid. Also during training there were a reduced amount of difficult blocks (2 blocks) so participants experienced a total of 9 CS+ trials and 9 CS- trials.

6.5.2.4 Data Analysis

This was the same as experiment 1 as the control in this Experiment was no signal.

6.5.3 Results

6.5.3.1 Training

As observed in the three previous experiments, during training participants responded more to the CSs+ than the CSs- and this changed as the blocks progressed (see Figure 6.7A) We conducted a 2 (CS: CSs+ vs. CSs-) X 9 (Trials) which revealed by a significant CS by Trial interaction, $F(5.4, 216.04) = 2.81$, $p = .015$, $\eta_p^2 = .066$. There was also a main effect of CS $F(1,40) = 16.98$, $p < .001$, $\eta_p^2 = .298$, but no effect of Trials, $F(4.69, 187.78) = 2.01$, $p = .083$, $\eta_p^2 = .048$. Furthermore, we assessed the number of safety signals produced and observed that these increased throughout the 3 training Blocks (see Table 6.1 for descriptives), $F(1.64, 65.66) = 20.54$, $p < .001$, $\eta_p^2 = .339$.

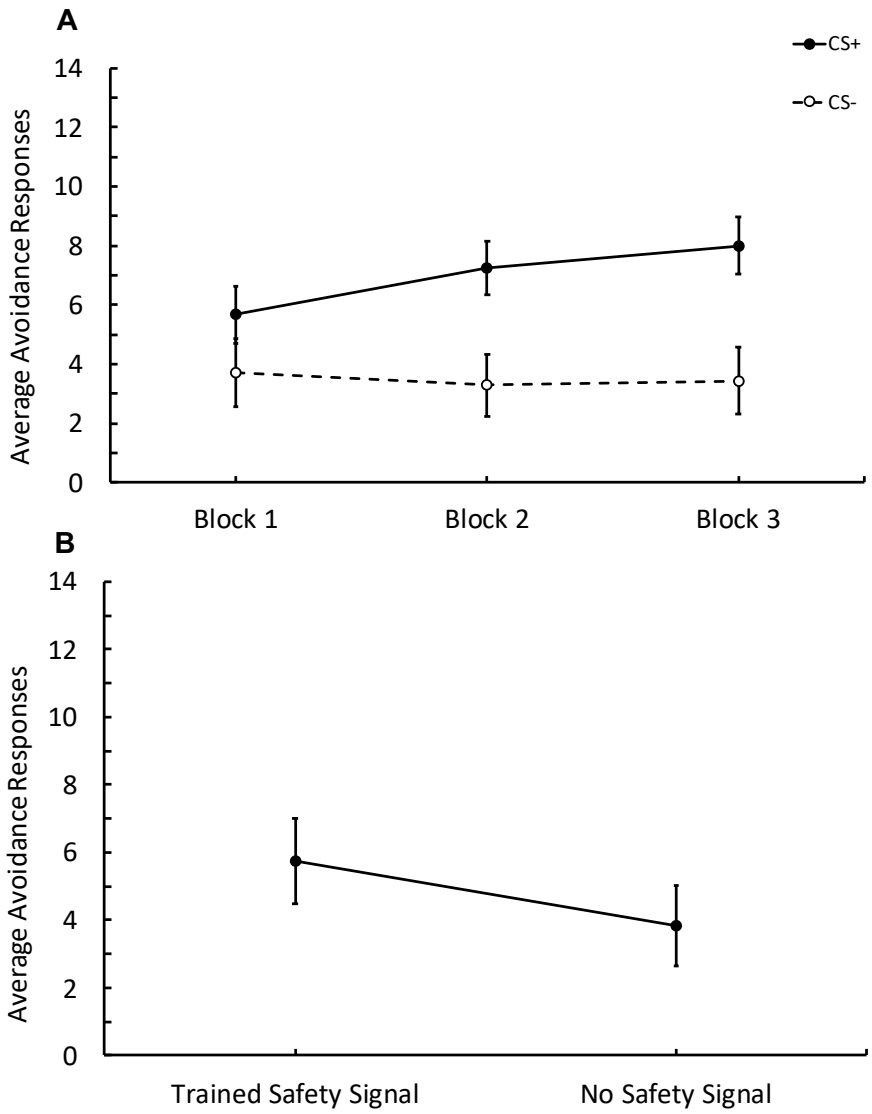

Figure 6.7
Results from Experiment 4 conducted in the laboratory comparing avoidance responses to obtain a response-produced safety signal relative to no signal. *(A)* Training data depicting avoidance responses to the CSs+ and CSs-. Each block contains 3 trials. Participants made more responses to the CSs+ across blocks compared to the CSs-. *(B)* Test data showing avoidance responses to the Gabor that was followed by the trained safety signal versus responses to a Gabor that was followed by no signal. Participants made more responses to the Gabor followed by the trained safety signal than to the Gabor that was followed by no signal. Error bars depict standard error of the mean.

6.5.3.2 Test

Critically during the test phase participants made more avoidance responses to the Gabor that was followed by the trained safety signal (see Figure 6.7B). A 2 (Signal:

Trained Signal vs New Signal) X 8 (Trials) repeated measures ANOVA revealed a main effect of Signal $F(1,40)$ 6.20, $p = .017$, $\eta_p^2 = .134$. There was also a significant effect of Trials in that as they progressed responding decreased, $F(3.06, 122.56)$ 5.64, $p = .001$, $\eta_p^2 = .124$, however there was no interaction between Signal and Trials, $F(4.39, 175.79)$, .55, $p = .71$, $\eta_p^2 = .014$.

6.5.3.3 Expectancy

After the behavioural test, we assessed the expectancy data for the CS+ and the CS- and found that participants rated the CS+ as more likely to be followed by the aversive stimulus than the CS-. A paired t-test revealed there was a significant difference in expectancy scores between the CS+ ($M = 7.12$, $SD = 2.08$) and the CS- ($M = 2.59$, $SD = 2.12$); $t(40) = 9.07$, $p < .001$, Cohen's $d = 1.41$.

6.5.4 Discussion

Experiment 4 revealed that, in line with the findings from Experiment 1, participants made more avoidance responses to the ambiguous Gabor patch that produced the safety signal compared to the one which did not result in any signal. Thus, this experiment conducted in person confirms previous findings and reinforces the finding that response-produced safety signals reinforce avoidance behaviour in humans. This shows that the findings from Experiment 1 are reliable and can be replicated in the laboratory with a different aversive stimulus (loud tone) which strengthens these overall findings. In summary, these experiments show that safety signals have reinforcing properties in human avoidance behaviour. We observed this in Experiments 1 and 4 when we tested avoidance responses to a novel stimulus which as followed by the trained safety signal in comparison to another stimulus that as followed by nothing. Experiments 2 and 3 further clarified the role of the safety signal by revealing differential responses to stimuli

when followed by a trained safety signal relative to a novel stimulus followed by a dissimilar (Experiment 3) but not similar (Experiment 2) control signal. We wanted to further test the reinforcing properties of the safety signal by investigating if they transfer to a new response. Therefore, in Experiment 5 we set out to test this by changing the response in the test phase of the experiment.

6.6 Experiment 5

6.6.1 Introduction

In this experiment we wanted to assess whether the avoidance response would transfer from a button press to a mouse click. If the safety signal is reinforcing then the participants should continue to respond to produce the safety signal even with a new response.

6.6.2 Method

6.6.2.1 Participants

Experiment 5 was preregistered (https://doi.org/10.17605/OSF.IO/ZXAES), and on the basis of Experiment 3 we conducted a power analysis which revealed that we needed 49 participants to achieve .95 power to detect a difference at test. On the basis of the participant attrition observed in previous online experiments, we recruited 73 participants, which were recruited via Prolific. The sample consisted of 47 females, 25 males and 1 non-binary person. The ages ranged from 18-65, (M = 34.8, SD = 10.87). After applying the criteria that participants had to have earned at least one safety signal during training, there were 54 participants ages ranged from 18-65 (M = 35.13, SD = 11.05), there were 35 Females, 18 males and 1 non-binary person.

6.6.2.2 Procedure

The task was the same as Experiment 3 however, there were two crucial differences. Experiment 5 had the same Training in block 1 but block 2 introduced new stimuli 5 degrees away from those in block 1 (85, 90, 95 degrees and 355, 0 and 5 degrees). Blocks 3 to 5 were similar to Experiments 1-4. This was to make the task easier for participants and bridge the differences between the first block and subsequent blocks as in previous experiments there was a drop in responding from Block 1 to Block 2 due to the change in stimuli.

During the test phase, the two novel Gabors were used (45 and 135 degrees), as in previous experiments. However, they were now both presented on the screen at the same time, so participants had the choice between the stimuli. Furthermore, we also changed the response required from the participants. Instead of pressing the spacebar they now had to direct the mouse pointer and click on the Gabor image. If they pressed more to one of the Gabors, the stimulus (safety signal or control) that the Gabor produced was presented. If they did not press either, then nothing was presented and if they pressed the same number of times to each Gabor, the stimulus produced by the Gabor they pressed first was presented. The timings of the stimuli and all other aspects of the task were the same as Experiment 3. If safety signals reinforce avoidance behaviour, we expected participants to respond (click) more on the Gabor patch that produced the safety signal when given a choice between the two despite both Gabor's being novel and never paired with the aversive outcome. Additionally, in Experiment 5 the participants were also asked to rate the novel test Gabor images as well as the CS+ and the CS-.

6.6.2.3 Data Analysis

This was the same as Experiment 2 and 3.

6.6.3 Results

6.6.3.1 Training

During training, as trials progressed participants (n = 54) responded more to the CSs+ than the CSs- (see Figure 6.8A). To assess this, we measured the rate of responding for each trial during the training phase. A repeated-measures ANOVA with CS (CSs+ vs CSs-) X 15 (Trials) revealed a main effect of CS, $F(1,53) = 34.95$, $p < .001$, $\eta_p^2 = .39$, trial $F(7.47,395.89) = 2.48$, $p = .014$, $\eta_p^2 = .045$, and a significant interaction between CS and Trials; $F(8.79, 466.16) = 5.02$, $p < .001$, $\eta_p^2 = .087$. We also analysed the number of safety signals that participants experienced during the training phase. As training blocks progressed, the number of safety signals received increased (see Table 6.1 for descriptives). A one-way ANOVA revealed a significant effect of Blocks $F(3.38,179.44) = 3.17$, $p = .021$, $\eta_p^2 = .057$.

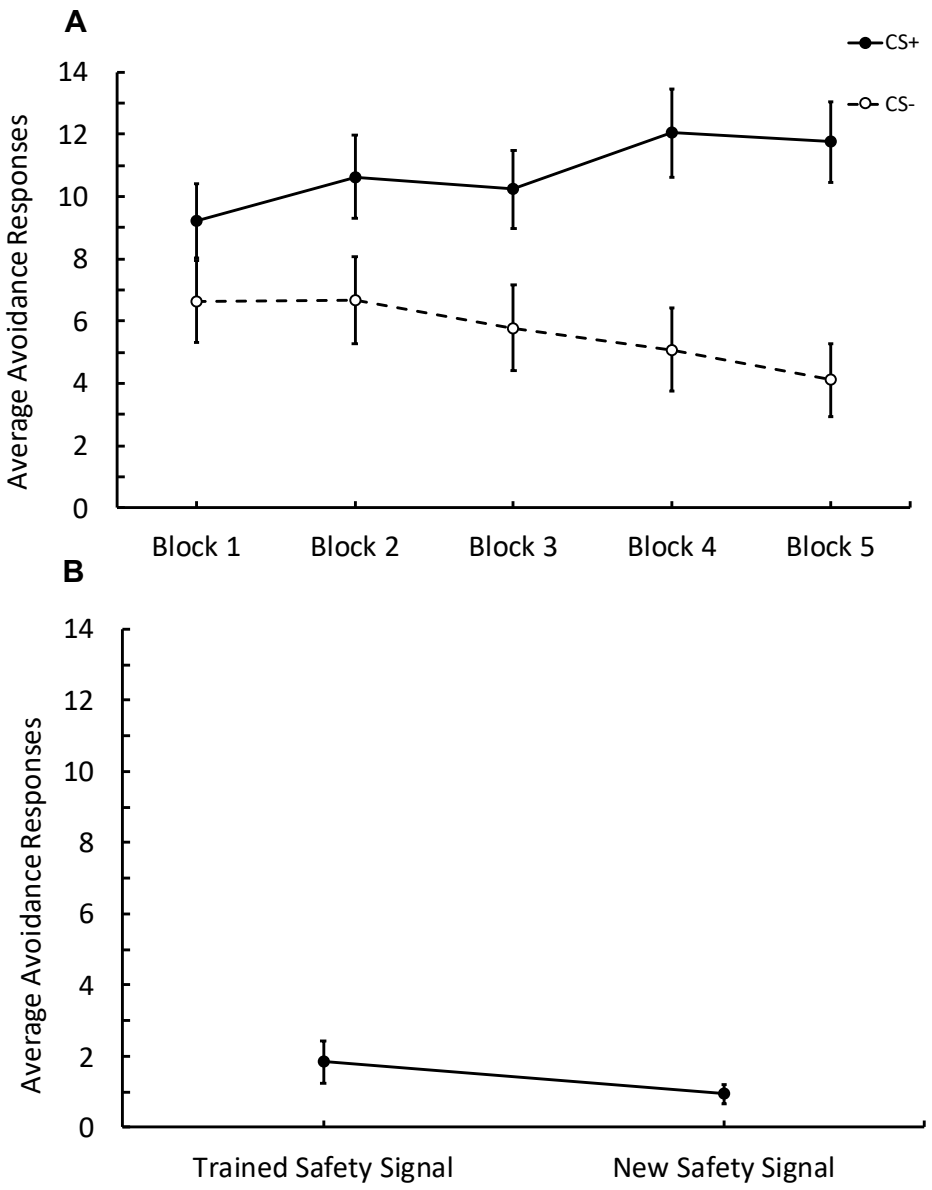

Figure 6.8
Results from Experiment 5 comparing avoidance responses to obtain a response-produced safety signal relative to a new dissimilar signal. *(A)* Training data depicting avoidance responses to the CSs+ and CSs-. Each block contains 3 trials. Participants made more responses to the CSs+ across blocks compared to the CSs-. *(B)* Test data showing avoidance responses (new response compared to training) to the Gabor that was followed by the trained safety signal versus responses to a Gabor that was followed by a new dissimilar signal. Participants made more responses to obtain the trained safety signal relative to the new dissimilar signal. Error bars depict standard error of the mean.

6.6.3.2 Test

During the test we found a marginal difference between responding to the Gabor followed by the trained signal and the Gabor followed by the new signal (see Figure 6.8B). A 2 Signal (Trained Signal, New Signal) X 8 (Trials) repeated measures ANOVA revealed there was a marginal effect of Signal, $F(1,53) = 3.29$, $p = .075$, $\eta_p^2 = .058$. Furthermore, there was no effect of Trial, $F(3.52, 186.68) = .707$, $p = .57$, and there was no interaction between Signal and Trials, $F(3.76, 199.59) = .56$, $p = .68$. Visual observation of the test results revealed that responding decreased numerically after trial 4, therefore we analysed the first four test trials alone. Participants made more avoidance responses to the Gabor stimulus that was followed by the safety signal compared to the one that was not (see Figure 5B). A repeated-measures ANOVA with Signal (Trained Signal vs New Signal) and Trials (1-4) compared avoidance responses to the Gabor followed by the safety signal vs the one which was followed by a new signal. There was a main effect of Signal $F(1,53) = 5.48$, $p = .023$, $\eta_p^2 = .094$, revealing more avoidance responses to the Gabor followed by the safety signal, there was no effect of Trial $F(1.86, 99.01) = .256$, $p = .759$, there was also no interaction between these Trials and Signal $F(2.27, 120.39) = .502$, $p = .630$. A paired t test was conducted to assess the number of trained and new safety signals produced during test. It was found that that the trained safety signal was produced more ($M = 2.91$, $SD = 2.69$) than the new safety signal ($M = 1.54$, $SD = 2.07$), $t(53) = 2.89$, $p = .006$, Cohen's $d = .394$.

6.6.3.3 Expectancy

Finally, after the choice tests we assessed the participants expectancy ratings for the CS+, CS- and the two novel test stimuli. We found that participants rated the CS+ (M= 6.8, $SD = 2.3$) higher than the CS-, ($M = 3.19$, $SD = 2.23$); $t(53)$ 8.30, $p <.001$, Cohen's $d = 1.13$. Finally, there were no differences in expectancy ratings to the test CS paired with the

training signal and the test CS paired with the new signal; $t(53)$ 1.49, $p = .141$, although there was a trend towards more expectancy ratings to the novel CS that was followed by the safety signal ($M = 5.41$, $SD = 2.17$) relative to the one which was followed by the new signal ($M = 5$, $SD = 2.29$).

6.6.4 Discussion

Experiment 5 revealed that, when given the choice between two novel stimuli, participants emitted more avoidance responses to an ambiguous Gabor patch which resulted in the trained safety signal relative to one which resulted in a new signal. It should be noted that during the test, the number of responses (i.e., mouse clicks) was appreciably lower than the responses observed at test in previous experiments. This is not surprising given that there is an expected decrement that results from the transfer from one response during training (space bar presses) to a different response during test (mouse clicks). Nevertheless, there was a significant difference (during the first four test trials) and hence these findings suggest that the safety signal reinforced avoidance behaviour, even when tested with a new response. This builds on the previous experiments and showcases that when the response changes, participants still have a preference for the trained safety signal as opposed to the new signal suggesting the reinforcing properties can transfer not only to new stimuli, but also to new responses.

6.7 General discussion

This study assessed the reinforcing properties of safety signals in a human instrumental avoidance paradigm. We observed that safety signals can reinforce avoidance behaviour elicited by stimuli without a history of avoidance reinforcement, and we also found that the reinforcing properties of safety signals can easily generalise to other stimuli. Experiments 1 and 4 revealed that trained safety signals reinforced

behaviour when compared with a control group that was not followed by a signal. Because the findings in Experiments 1 and 4 can be explained by sensory reinforcement, Experiments 2, 3 and 5 used a new signal as a control for the trained safety signal. In Experiment 2, when the control signal was similar to the trained safety signal, no differences in avoidance responses (nor in terms of number of signals earned) between trained and similar control signals were observed at test. It was only when the trained safety signal differed from a new signal in two dimensions (colour and shape) that higher avoidance responses for the trained safety signal were observed. To our knowledge this is the first quantitative demonstration of safety signals reinforcing avoidance behaviour in humans, despite a recent resurgence of research interest on the topic (Gillan et al., 2016; Urcelay & Prével, 2019; Vervliet et al., 2017; Vervliet & Indekeu, 2015)

There have been several experiments conducted in animals which support the notion that safety signals reinforce avoidance behaviour. Previous work in rats has shown that when given the choice between a lever that produces a safety signal and one that does not, rats preferred the one with the signal, despite both levers resulting in successful avoidance of a shock (Fernando et al., 2014a). This finding was further confirmed by a choice test on extinction, which revealed more avoidance responses to a lever which was followed by the safety signal relative to a control lever which was not. Additional studies with selective infusions of dopaminergic agonists and antagonists in sub-regions of the ventral striatum documented that the reinforcement of safety signals is a dopamine-dependent phenomenon (A Fernando et al., 2014b)Furthermore, work by Dinsmoor and Sears (1973) showed that pigeons pressed a pedal to produce a tone trained as a safety signal compared with no tone, or a tone of a different frequency. In our Experiment 2, participants responded at equal rates to the trained safety signal and a control signal that

was somewhat similar to the trained safety signal. It was only when the control signal was sufficiently different from the trained safety signal that we observed a difference in Experiment 3 and 5. This could be seen as similar to the pattern of results observed Dinsmoor and Sears (1973) although it would be interesting to test participants with a wider range of new signals – that is future research may want to better assess the generalisation of the properties of the safety signal. Furthermore, in Experiment 5 we observed that safety signals can reinforce a new response which has been proposed as the ultimate way to determine the reinforcing properties of a conditioned stimulus (Mackintosh, 1974).

The current findings in humans add to the existing literature suggesting similar motivational processes in positive reinforcement (for rewarding outcomes) and negative reinforcement (for aversive outcomes) that has been documented at neural (Leknes et al., 2011; Seymour et al., 2005)and behavioural levels (Leng et al., 2023). Overall, these results are consistent with an architecture that assumes two separate motivational systems that interact by inhibiting each other (Dearing & Dickinson, 1979; Konorski, 1967). According to this model, stimulation of the appetitive system results in expectation of an appetitive outcome (hope) and also in inhibition of the aversive system. Similarly, stimulation of the aversive system results in expectation of an aversive outcome (fear) and inhibition of the appetitive system. On the contrary, inhibition of the aversive system by signals associated with the absence of aversive reinforcement (safety signals), disinhibits the appetitive system giving rise to the positive feeling of relief. Thus, the reciprocity between appetitive and aversive systems, which has been demonstrated with Pavlovian procedures (Dearing & Dickinson, 1979) is here substantiated with instrumental avoidance responses in humans. A recent computational instantiation of a dual-process

theory of instrumental behaviour assumes that instrumental behaviour is controlled by a goal-directed component and a habitual component (Perez & Dickinson, 2023). According to this account, safety signals reinforce the habitual component of avoidance behaviour by strengthening the connection between environmental stimuli and avoidance responses, as has been observed in experiments in rodents (Fernando et al., 2014a).

To strengthen the findings of this study further research could assess physiological responses with the use of the in-person procedure. It would also allow for physiological measures such as skin conductance to be taken which would further add to the behavioural (i.e. avoidance) measures we have obtained from the current study. It would also be interesting to gather participant subjective ratings, such as those used by Vervliet, Lange and Milad (2017), for example by asking participants how much relief they felt after avoiding. Having a combination of the physiological, behavioural, and self-report measures may allow a more complete understanding of avoidance behaviour.

Furthermore, a potential limitation of the first 4 experiments was that during the expectancy test the two test stimuli were not included. Without this it opens the opportunity for the suggestion that participants classified the test stimuli as threatening (belonging to the CS+ stimuli set), depending on whether the safety signal was presented or not at test. This logic could potentially explain why participants responded to the stimuli that produced the trained safety signal more than the stimuli that was used as control. However, in Experiment 5 this was investigated as we assessed expectancy ratings to the test stimuli, and participants rated the two test stimuli similarly: notably both test stimuli were rated descriptively lower than the CS+. This means that perhaps the current findings can only be observed in situations in which there is high ambiguity, so further research

using free-operant procedures (as was used in the study by Fernando et al., 2014a) is needed to clarify this possibility.

Finally, this study was conducted with healthy individuals so it would be interesting to assess a clinical population of people with diagnosed anxiety disorders to see if their behaviour follows the same pattern as those found in this study, and critically if anxiety mediates the reinforcing properties of safety signals as was recently documented with subjective measures (De Kleine et al., 2023). In our experiments (see supplementary materials) we recruited healthy participants and asked them to complete the STAI. In each experiment, participants were split into high and low anxiety based on a median split of scores. Although we did not see any relevant interaction between safety signal responding and anxiety group, we did see across all experiments that participants high in anxiety tended to press more both during avoidance training and test, consistent with the notion that high avoidance responding is a hallmark of anxiety.

In summary, we observed that safety signals can reinforce instrumental avoidance behaviour in human participants. The role of safety signals has been highlighted as important in the development and maintenance anxiety disorders (Lohr et al., 2007), and there is currently interest in how inhibition interacts with fear and avoidance to better understand anxiety disorders (Cassaday et al., 2023; Sangha et al., 2020) Hence, understanding the reinforcing properties and their boundaries is of interest to the field. The current demonstration in humans is a first step into understanding safety signals and their reinforcement of avoidance behaviour. These findings in humans will allow us to begin understanding the role safety signals play in maladaptive avoidance.

6.8 References

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Chapter 7

The effects of context on the generalisation of avoidance behaviour

Abstract

The context and environment in which fear and avoidance responses occurs has been shown to be important, in particular in therapy interventions. Whilst much is known about how fear generalises across contexts, there has been limited work assessing whether there is generalisation of avoidance behaviour across contexts. In this experiment, participants were trained in either a blue or green context (counterbalanced) with two fractal warning signals, one predicted an aversive noise (CS+) and one did not (CS-). Participants could avoid the aversive noise by pressing the space bar within 1 second of when the aversive noise was scheduled to appear. Participants were then tested in a range of different coloured contexts, ranging from blue to green and the number of avoidance responses to the CS+ and CS- were assessed. After the avoidance test, we assessed expectancy ratings for all the CS-context combinations. It was found that avoidance behaviour for the CS- remained consistently low through each different test context, however for the CS+ there was a decrease in responding as the context became less similar to the trained context. No such results were observed with expectancy ratings. The results indicate that the context can influence avoidance behaviour (but less so expectancy ratings), and this may have implications for the understanding and treatment of avoidance behaviour.

7.1 Introduction

Avoidance that persists without the presence of threatening stimuli can negatively impact the lives of individuals with anxiety disorders. However, avoidance behaviour remains an understudied area relative to fear and threat (LeDoux & Pine, 2016; Urcelay & Prével, 2019). One of the aspects that poses an issue with maladaptive avoidance behaviour is generalisation (Bennett et al., 2020). It has been suggested that generalised avoidance can be problematic for treatment, and may result in people experiencing relapses (Craske et al., 1991). Context refers to an array of stimuli that surround in time and space a particular learning experience, and this can include both external stimuli and

internal states (Urcelay & Miller, 2014). External contexts include the environment, the time, and stimuli within the environment, whereas internal states can include emotions and altered states such as drugs(Overton, 1991). Behaviour can differ depending on the context and the presence of other retrieval cues (Alfei et al., 2025) and certain environments can serve as a trigger for many anxiety disorders (Grillon, 2002) for example someone with social anxiety may feel more anxious in crowded rooms (Bolt et al., 2014). In the case of disorders such as social anxiety it has been proposed that the context could be part of the process in which influences the tendency for social anxiety and the materialisation of symptoms (Ballespí et al., 2019). The research on avoidance behaviour and its generalisation across context has been limited considering the potential clinical implications for treatment.

Avoidance behaviour is a likely candidate to generalise to novel contexts, because it is unclear whether an avoidance response was necessary when harm is successfully averted (Meulders et al., 2024). This can obviously be adaptive as it allows the reduction of missing potential threats, however when this generalises to safe contexts then this can become maladaptive which if often the case in anxiety disorders. Drawing from the research conducted in animals, contextual conditioning has been studied in rats as an animal model of generalised anxiety disorder (Luyten et al., 2011). This is due to the similarities in GAD which involves participants being anxious about a wide range of stimuli (Tyrer & Baldwin, 2006). Research in rats using Pavlovian conditioning where rats were trained in one context and then tested in a novel context or the same context (Met Hoxha et al., 2024), revealed that animals that were trained and tested in the same context had high levels of conditioned responding relative to those trained in one context and tested in a novel context. Presumably, the latter were able to distinguish the two contexts and

responded less however this was only the case when they were trained in a dark and tested in a light context, not the other way around. Furthermore, a series of experiments using an odour avoidance task (which presumably engages instrumental learning), two groups of mice were trained with shocks in the presence of an ethanol odour. Their avoidance of a chamber with ethanol odour relative to another chamber with acetate odour and a third neutral chamber (with odour from the mice's home cages) were then tested for avoidance either two days or 28 days later (Pamplona et al., 2011). They found that conditioning initially resulted in specific avoidance of the context-associated odour, which then evolved into generalised avoidance following a 28-day period of fear incubation. Overall, this suggests that in certain parameters fear and avoidance behaviour can generalise to other contexts, but they can also show context specificity.

In humans there has been research which has investigated context and fear generalisation. An preliminary experiment used a novel paradigm with images of the same woods in different seasons as the context (McGlade et al., 2019). The CS+ was a winter woods and the CS- was sunny summer woods (counterbalanced). The generalisation stimuli were in between these seasons, for example had less snow, no snow but the grass was brown. They observed a linear gradient of generalisation using multiple dependent measures, and when assessing US expectancy based on CS+, CS- and the different context in between, they observed a clear linear gradient from CS+ to CS-. In addition, they observed that anxiety (measured with the DASS anxiety subscale –(Lovibond & Lovibond, 1995) predicted context generalisation, although this is not clear based on visual inspection of the data. This highlights that fear, when considering a self-report measure, can generalise to other contexts, and this can be related with anxiety levels. Another study trained a discrimination between CS+ and CS- in a dangerous context in which CS+ was

reinforced (CS- was not), and again presented these cues (not reinforced) in a safe context. They then tested for generalisation to cues in between CS+ and CS- in both the dangerous and safe context (Klein et al., 2021). They found that participants made more avoidance responses in the danger context compared to the safe context (Klein et al., 2021). This suggests that whilst avoidance behaviour generalised to different warning signal colours, the behaviour was context dependent. They also found that intolerance to uncertainty correlated with avoidance behaviour which could indicate that the more ambiguity there is, the more people avoid.

Furthermore, whilst studies have not investigated solely the generalisation of the context on avoidance behaviour there have been some studies that investigate how generalised avoidance behaviour is affected by context changes. An experiment, investigating ways to mitigate generalised avoidance behaviour to new contexts, trained participants to avoid in one context and then trained competing behaviours to the CS's were trained in different contexts. Participants were then tested in the acquisition context and a new novel context (ABC style design) (Bennett et al., 2020). They tested participants with a generalisation CS in these contexts. They found that reinforcing a new competing behaviour in a different context reduced the generalisation of avoidance behaviour in a novel context. This highlights that avoidance behaviour can be context dependant using other manipulations, otherwise avoidance generalises to other contexts.

Another area of the literature that has revealed clear context dependence in fear and avoidance is extinction learning. Several studies have documented renewal in humans (see Vervliet et al., 2013 for a review) with a recent meta-analysis (Wang et al., 2024) showing that renewal can be observed in fear conditioning when analysing US expectancy ratings (Effting & Kindt, 2007) electrodermal responses (Alvarez et al., 2007)

and fear potentiated startle responses (Landkroon et al., 2019). Similar renewal effects have been observed when training, extinguishing and testing avoidance behaviour (Urcelay et al., 2024)

Finally, research within the pain literature has explored generalisation of avoidance behaviour in different contexts (Meulders et al., 2020). In this procedure participants control a robotic arm and can avoid a painful stimulus by manoeuvring the robotic arm in trajectories that require more effort (longer and more force required). When tested in different contexts (background cues which were shades of grey) it was found that there was a linear trend in avoidance behaviour as the context became less alike the training context with participants avoiding more in the training context however, similar responding was observed to the two contexts of generalisation (these were both different from avoidance in the training context), suggesting context specificity of avoidance behaviour. A further experiment using this procedure and investigating trait anxiety, a black context was used to train participants (hence, excitatory), and the white context was always safe (no shock; inhibitory). Participants were then tested in these two contexts plus two grey contexts with values in between (Meulders et al., 2024). Overall, they observed a context generalisation gradient, with most avoidance responses in the training context, and these decreasing when testing was conducted in contexts more similar to the safe, inhibitory context (in which there were no shocks during training). However, it is unclear from these results whether this reflects generalisation of context excitation (from the threatening context) or generalisation of context inhibition (from the safe context). They further found that high anxious avoided more in the novel context that was similar to the safe context but not the one that resembled the threat context. This was not observed in the expectancy data, which showed high anxious people only generalised fear to the

threat context. This indicates that participants are using a 'better safe than sorry' strategy even when they report that the context is safe. These studies highlight that avoidance behaviour can generalise to other context, but because of the design it is unclear whether the gradient that they observed (which was descriptively not linear) results from generalisation of excitation or inhibition. Because gradients of excitation and inhibition differ (Rescorla, 2006) the source of generalisation in these experiments is not clear.

Finally, it has been argued that contexts have qualitatively different properties than discrete cues (Fanselow, 2010) and others have challenged these claims suggesting that contexts can function like any other cues, and the reverse is also true (cues can function like contexts), provided the correct parameters are used (Urcelay & Miller, 2010, 2014). In other words, it has been argued that other than parametric differences, there is no fundamental difference between the way that cues and context can function. One way to distinguish between these different views is to test whether a gradient of generalisation can be observed to variations in contextual stimuli, just like it can be seen when testing variations of discrete cues.

The aim of this experiment was to build on the previous research and assess the direct role of context on avoidance behaviour. We aimed to do this by training participants with a CS+/CS- discrimination whereby they were required to avoid a loud noise with presses of the keyboard space bar in one context, and tested responding (and expectancy) in the training context and 4 additional generalisation contexts that differed in similarity to the training context. Linear gradients have been reported for generalisation of contextual fear (McGlade et al., 2019) Although again it is unclear if the gradient results from generalisation of excitation [CTX+] or inhibition [CTX-]), but there is a dearth of research in instrumental avoidance. In line with the notion that contexts can function like any other

cues (Urcelay & Miller, 2010; 2014), we hypothesised that as the test context became less similar to the training context, avoidance behaviour would decrease, and a generalisation slope would be observed. We also wanted to assess if trait anxiety differences mediated context generalisation. We expected that those with higher anxiety to avoid more overall during training, and also during test they would continue to avoid more to the generalisation contexts.

This preliminary experiment set out to investigate whether avoidance behaviour generalises to different contexts. We wanted to assess whether a gradient of behaviour could be captured by changing the experiments background colour (context).

7.2. Method

7.2.1 Participants

Thirty-two undergraduates form the University of Nottingham were recruited via the experiment participation scheme and received credit for taking part in the experiment. This was open to all first-year undergraduates in the School of Psychology except those who had partaken in other experiments by the lab. This study was approved by the University of Nottingham's School of Psychology ethics committee (reference code: S1402) . There were 4 males and 28 females, the ages ranged from 18 – 30, (M = 18.72, SD = .85).

7.2.2 Design

This experiment utilised a within subjects' design to understand the role of context in the generalisation of avoidance behaviour. The independent variable being the colour of context background during test, which included the training context and four other variations (from green to blue, in total 5 levels). The dependent variable was the number of avoidance responses during the CS presentation of each trial during training and the test

phases, and expectancy ratings to the CS context variations. Trait anxiety scores were also assessed and used to investigate the relationship with the generalisation of avoidance behaviour across contexts. There were 6 key phases in the experiment: 1) STAI scales, 2) pretraining, 3) training, 4) test, 5) retraining and 6) expectancy.

7.2.3 Materials

This experiment was programmed using Psychopy version 2023.2.2 (Pierce et al., 2022).

State and Trait anxiety scale

Participants completed a short questionnaire to assess their anxiety levels. The was the Spielberger's State-Trait Anxiety Inventory (Spielberg & Craighead, 2010).

Pretraining Stimuli

In the pretraining phase, participants were shown two Gabor patches: one was horizontal, and one was vertical (*see Figure 7.1*). There were presented on a grey background. They were programmed to appear 50% of the size of the screen and were always presented in the centre.

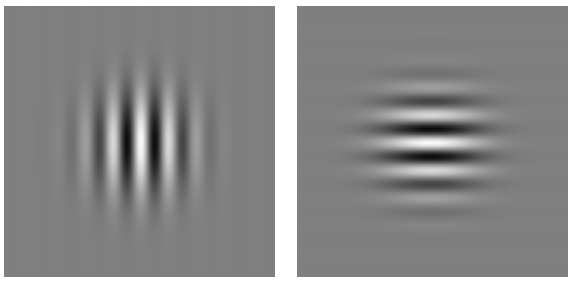

Figure 7.1
The two Gabor images used in the pre training phase.

Avoidance Task Stimuli

This experiment used the blue-green continuum as background context. Five colours were selected to be the context (background colours) (*see Figure 7.2*). These were equal distance apart from each other, along the blue-green continuum. Context were

counterbalanced so that for half of the participants the training contest was green (as shown in the Figure 7.2) and the remaining contexts were generalisation contexts. For the remaining half of participants, the training context was blue (GSC4 in Figure 7.2) and the rest were generalisation contexts.

Figure 7.2
This figure depicts the stimuli used as background contexts in this experiment. During the training phase the participants were trained with the greenest (or bluest) context, and then during the test phases they were tested with four other coloured contexts, generalised contexts (GSC) from the blue-green continuum.

7.2.4 Procedure

After filling out a consent form and agreeing to take part, participants completed the anxiety scale (STAI). Following this, the participants began the avoidance task. The whole experiment took participants 20 minutes to complete (*see Figure 7.3*).

Pre-Training

The first phase was the pretraining phase. During this phase, participants were presented with two Gabor patches. The background was grey throughout the pretraining stage. One Gabor served as the CS+ and was followed by the aversive outcome (aversive sound). The other was the CS- and was followed by nothing. Participants were instructed that they could avoid the aversive noise by pressing the space bar on the keyboard. The presentation of the CS's were variable between 2 and 5 seconds and during the CS+ trials the US could occur during seconds 3-6 of that trial. If an avoidance response was

performed one second before when the US was scheduled to appear, avoidance was successful, and the trial ended. If the avoidance response was unsuccessful, then the aversive noise was played for 1 second. The inter trial interval (ITI) was variable with an average of 6 seconds. During the ITI, a white fixation cross was presented in the centre of the screen. There were two presentations of the CS+ and CSs- per block. The participants had to meet a criterion before they were able to complete the pretraining phase. For them to move on to the next phase, they had to respond more to the CS+ than the CS- during two consecutive blocks. If participants failed the criterion, the pre-training continued for 20 blocks maximum, but once the participants met the criteria they then automatically progressed onto the next phase. If the participants did not pass the criteria they were shown the end of the experiment screen, and the task ended and this participants pretraining data was disregarded. All participants passed the pre-training stage.

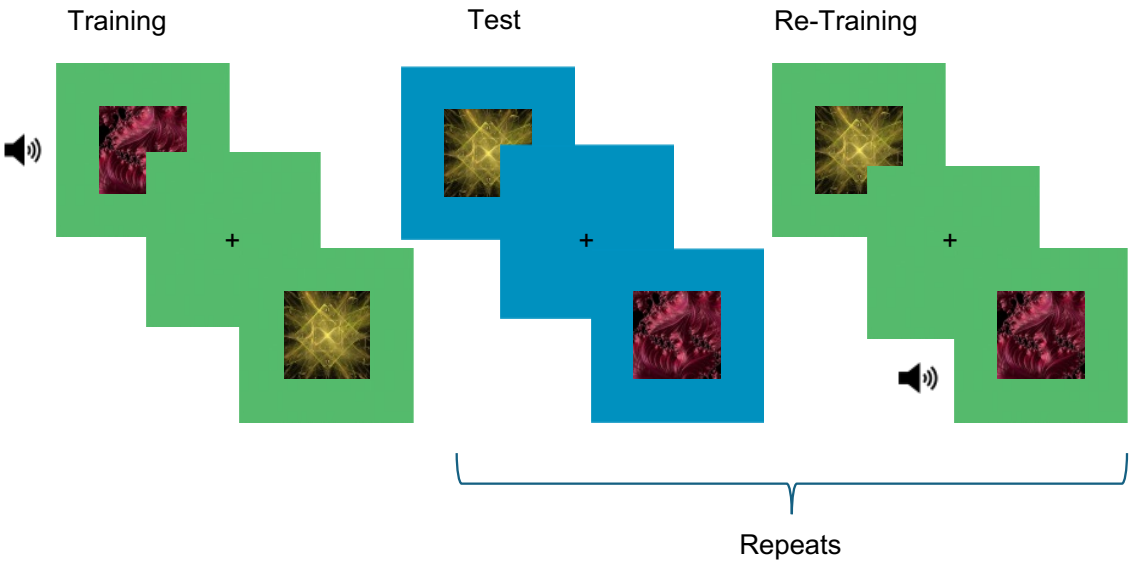

Figure 7.3
This figure shows the avoidance task. Participants are trained in one context with two CSs, one predicts an aversive noise, and one does not. They are able to avoid the aversive noise by pressing the space bar. During the test phase, they are tested with either the trained context or one of the 4 generalisation contexts. No aversive noises are presented during this phase. After each test, participant experienced a re-training block in the training context and the aversive noise was presented (unless participant correctly avoided). The test and retraining repeated until all the generalisation contexts had been tested.

Avoidance Training

The second phase of the experiment was the avoidance training phase, which was similar to the pretraining phase, except that it used fractals instead of the Gabor patches. These were square images which were 50% of the screen height and presented in the centre of the screen. One of the fractals was paired with the aversive image (CS+) and the other was not (CS-). The background colour served as the context. This was either a dark green or a dark blue (counterbalanced).

The aversive outcome could be avoided if the participants pressed the spacebar 1 second before the aversive outcome would appear. If avoidance was successful, the CS was terminated, and the aversive noise was not presented. If unsuccessful the CS was terminated when the outcome was scheduled to occur, and the noise was played for 1

second. Each of the fractal stimuli were shown 2 times per block in a randomised order and there were 5 blocks, which totalled to 10 training trials of each CS stimulus.

Avoidance Test

The next phase was similar to the training phase however the aversive noise was no longer presented (i.e., participants were tested on extinction). The other differences were that the background colour (context) also changed. This was a colour on the blue-green continuum (see Figure 7.1). This was programmed to be randomised and one of the test contexts was chosen. The participants received no instructions and went straight into the test phase. The CS's were shown on the screen for 6 seconds and were the same size as the stimuli during the training phase. The ITI was variable the same as during avoidance training. Participants could press the space bar at any point during the test phase, and responses during the CSs were recorded. The participants were tested with all 5 of the contexts however after each test phase there was one block of retraining, so 5 in total. This involved one block of the avoidance training phase with the trained context. The aversive noise was presented during this block.

Expectancy Test

Participants were then asked to rate each of the 2 training stimuli on the likelihood that the aversive outcome was to follow each of them, and this was conducted in all five background colours. They read the following instruction: 'Please rate how likely the loud noise will follow this stimulus on a scale of 1-9'. Each stimulus was presented separately with a 9-point scale with 9 being 'will certainly follow' and 1 being 'will not follow'. The order of the two stimuli superimposed over the 5 background contexts was randomised. Finally, they were then presented with the aversive outcome used in the experiment and asked: "Please rate how aversive the loud noise is on a scale of 1-9", with 1 being not aversive at all and 9 being extremely aversive.

7.2.2.5 Data analysis

The number of avoidance responses on each trial were used to measure avoidance behaviour and the data from both training and test were analysed. During training, avoidance responses to the CS+ and CS- were analysed to assess whether participants discriminated between the two stimuli. This was achieved using a 2(CS: CS+; CS-) x 10 (Trials) repeated-measures ANOVA.

During the test we wanted to investigate the number of avoidance responses made to each CS in each of the different contexts. We achieved this by conducting a 2(CS: CS+; CS-) x 5 (Context) repeated-measures ANOVA. This allowed us to assess avoidance responses to each of the conditioned stimuli in each of the contexts. A similar analysis was used for expectancy ratings. Moreover, using the test, data we were able to calculate a generalisation slope by taking the total number of responses made to the CS+ in each of the five contexts. We were then able to correlate this with participants trait anxiety scores to test whether there was a relationship between anxiety and generalisation slopes.

7.3 Results

Training

As the trials progressed, responding to the CS+ increased whilst responding to the CS- remained low (*see Figure 7.4A*). A 2(CS: CS+ vs. CS-) x 10 (Trials) repeated measures ANOVA revealed a main effect of CS, $F(1, 31) = 11.19$, $p = .002$ and a main effect of Trial, $F(9, 279) = 3.24$, $p < .001$. Additionally, there was an interaction between CS and Trial; $F(9, 279) = 5.14$, $p < .001$, indicating that the effect of stimulus type differed across trials.

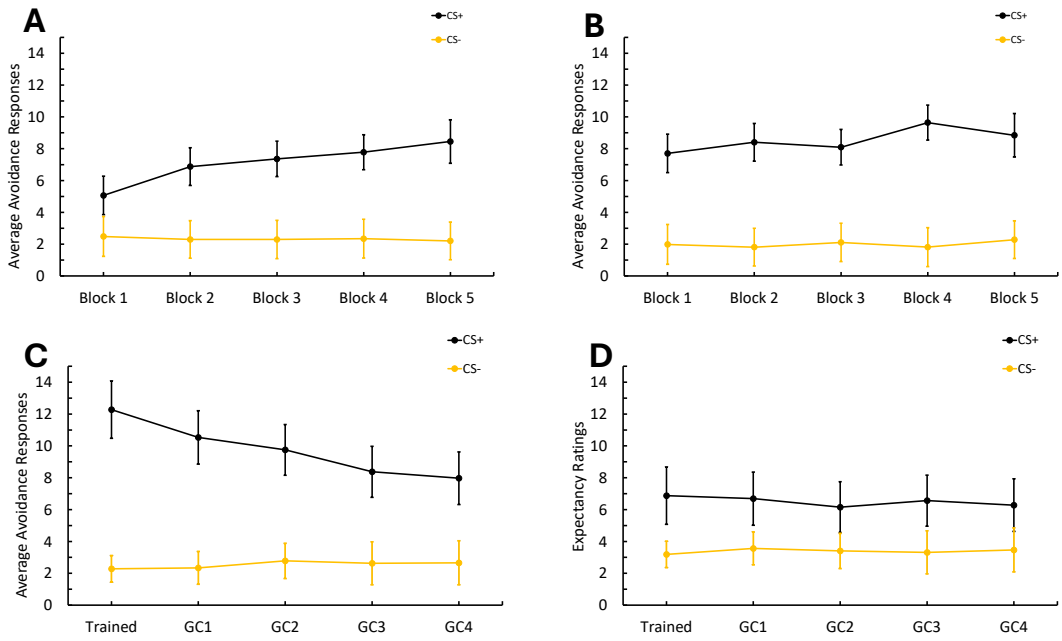

Figure 7.4
This figure shows the average avoidance responses to the CS+ and CS- in each phase of the experiment. Panel A) shows the responses during training in which participants learn to avoid more to the CS+ compared to the CS= as trials progress. Panel B) shows the responses during the retraining blocks in between each test trial with responding remaining higher to the CS+ compared to the CS-. Panel C) shows the responses during the test phase for each of the generalisation contexts, responding to the CS- remains constant however responding to the CS+ peaks in the trained context and then these decreases as the context becomes less similar to the trained context. Panel D) shows the expectancy ratings for the CS+ and CS- in each of the 5 contexts.

Retraining

Responding during the retraining indicated that participants continued to respond to the CS+ and responded low to the CS- (*see Figure 7.4B*). A 2(CS: CS+ vs. CS-) x 10 (Trials) repeated measures ANOVA was conducted to examine the effects of CS and Trial on avoidance responses during the retraining blocks in between each test block. This revealed a main effect of CS, $F(1, 31) = 15.97$, $p < .001$, indicating that there was more responding to the CS+ compared to the CS-. There was no main effect of Trial, $F(9, 279) =$

1.55, p = .131, suggesting that responses did not significantly vary across trials. However, there was an interaction between CS and Trials, $F(9, 279) = 2.71$, p = .005, suggesting as can be seen in the figure that responses to the CS+ continued growing during retraining, although less than during training.

Test

Critically, during test responses for the CS+ deceased as the test context became less similar to the training background, whilst responses to the CS- remained consistently low (*see Figure 7.3C*). A 2(CS: CS+ vs. CS-) x 5 (Context) repeated-measures ANOVA was conducted to examine the effects of CS and Context on the avoidance behaviour. There was main effect of C, $F(1, 31) = 18.64$, $p < .001$, $\eta^2 = .310$, indicating avoidance responses differed for the CS+ and CS-. There was a significant main effect of Context, $F(4, 124) = 4.78$, $p = .001$, $\eta^2 = .012$, suggesting that background colour influenced avoidance responses. Furthermore, there was an interaction between CS and Context, $F(4, 124) = 7.77$, $p < .001$, $\eta^2 = .017$, indicating that the effect of CS varied depending on the Context.

Expectancy

The results from the expectancy show that participants rated the CS+ as being followed by aversive outcome higher than the CS- however, there seemed to be no differences in expectancy for the different contexts (*see Figure 7.3D*). A 2 (CS: CS+ vs. CS-) x 5 (Context) repeated-measures ANOVA was conducted to examine the effects of CS and Context on expectancy ratings. It revealed a main effect of CS, $F(1, 31) = 34.19$, $p < .001$; however, there was critically no effect of Context, $F(4, 124) = 0.55$, p = .701, and no interaction between CS and Context, $F(4, 124) = 1.12$, p = .350, meaning that the effect of CS did not differ significantly across the different test Contexts.

Anxiety

In order to explore the relationship between context generalisation and anxiety, we calculated a generalisation slope for each participant, in which a positive number indicates a sharper gradient, that is less generalisation across contexts. A Pearson's correlation analysis was conducted to examine the relationship between generalisation Slope and Trait anxiety. The results indicated a small negative correlation between Slope and Trait anxiety however, this correlation was not statistically significant, r (31) = -0.234, p = .198.

7.4 Discussion

This experiment set out to investigate whether avoidance behaviour generalises to other contexts as does fear. This was achieved by training participants to avoid in one context (either blue or green), and then testing in similar contexts (differing in colour along the blue and green dimension). During avoidance training, participants learned to discriminate between the two CSs with more avoidance responses to the CS+ compared to the CS-. During the retraining blocks in between each test block, it was found that avoidance responses to the CS+ remained high compared to the CS- which remained low. This all indicated that participants were able to discriminate which CS predicted the aversive outcome and adjust their avoidance responding based on this. Critically, during the generalisation tests it was found that there were differences in responding patterns for the CSs. Avoidance responses to the CS- remained low as they had in the training and retraining trials, regardless of context of testing. However, responding for the CS+ changed based on the context. Responding was highest in the trained context, and this gradually decreased as the context became less similar to the trained context depicting a linear gradient. These results seem to indicate that avoidance generalisation can occur to the

context as it does with discrete cues, thus suggesting that there are no fundamental differences in how cues and contexts are processed (Urcelay & Miller, 2014)

The findings of this experiment align with others which have investigated generalisation of the context in avoidance behaviour. One is a recent study which used a robotic arm, and people had to navigate a ball to a target (Meulders et al., 2024). Choosing the more effortful option enabled them to avoid a shock. They were trained in one context which then became excitatory (white or black background) and received similar exposure to the task and avoidance but in the alternative context which then became inhibitory. They then tested in the two contexts presented during training and in other contexts (two levels of grey, in between black and white). It was found that high anxiety individuals avoided more in the contexts that were similar (shades of grey). However, it is unclear here whether the generalisation results from the excitation elicited by the avoidance training context, or the inhibition elicited by the control context. Our findings revealed a gradient that is fully linear and only reflects generalisation from the excitation elicited by the training context. Of course, we did not detect significant correlations between generalisation slopes and anxiety (although the correlation goes in the correct direction [more anxiety, more generalisation which is revealed by a smaller slope]), although our sample may be underpowered to detect significant correlations, so further research is needed to clarify these discrepancies.

An interesting finding from this experiment was the observation of different patterns of generalisation between the two dependent measures used (avoidance responses and expectancy ratings). Whilst the behavioural avoidance behaviour revealed a generalisation gradient as the test context differed from the training context, no such gradient was observed in the expectancy measure. Whilst this could simply emerge from

differential sensitivity of these two measures, the different patterns in the two measures are surprising because in previous research investigating the renewal of avoidance following extinction - using a similar method as the one using here - these two measures correlated well (Urcelay et al., 2024; Figure 4). This dissociation is intriguing from the perspective of theories which emphasize expectancy processes in avoidance behaviour (Lovibond, 2006) as these would anticipate more sensitivity in the expectancy rather than the behavioural measure. In addition to differential sensitivity of the two measures, this highlights a disassociation between behavioural and cognitive measures of avoidance behaviour. Using instrumental preparations (although not aversively motivated), other studies have also revealed similar dissociations. For example, Pérez and Soto (2020) observed in a free operant experiment that instrumental behaviour did not align with causal beliefs, and it was the behavioural data which indicated the expected difference between groups in this experiment, unlike the expectancy data. We have also observed in instrumental task that behaviour does not always show the same patterns as causal ratings (Alcalá et al., 2024; Figures 2 and 4). This could indicate that perhaps some behavioural and cognitive aspects of behaviour are not underpinned by the same underlying psychological mechanisms, but this is only observed under some yet undefined circumstances. Regardless, because we expected our dependent measures to reflect context changes, the present results suggest that behavioural measures are more sensitive than subjective measures, as least in this paradigm.

The research within the field of exploring the context within learning has highlighted that the context may serve different influences depending on the type of learning. A possible distinction has arisen between Pavlovian and instrumental research. It has been suggested that Pavlovian learning is less context dependent, and therefore

transfers to new contexts without disruptions (Bouton & Todd, 2014), a finding that has received extensive support (Bouton & King, 1983; Bouton & Peck, 1989), although there are report that it can be context dependent (Bonardi et al., 1990)Bouton et al., (2014) proposed that instrumental behaviour is more susceptible to context changes because the memory of the learned action-outcome relationship is often retrieved in a context-specific manner. They highlighted that in instrumental scenarios, the context could establish direct associations with the response, and hence the context acts as a modulator of the response and outcome association. There is evidence of such mechanism (Bouton et al., 2011), in a study of renewal in which rats were trained in one context and then half of the rats were moved into a different context to extinguish the responses. They found the rats that underwent extinction in a different context showed decreased responding compared to the rats that remained in the same context for extinction, which is similar to a context change effect that we observed in instrumental avoidance (Urcelay, 2024). Other studies have found similar results when changing instrumental behaviour form one context to another (Bouton et al., 2014; Todd, 2013). The findings from this current experiment are in line with the finding that instrumental behaviour is context dependent and that once the context changes and is no longer similar then this impacts instrumental behaviour. What is new and unique about the current results is that the context shift effect is a linear function of the distance in psychological space (in this case operationalized as changes in colour in the green-blue continuum) between training and test contexts. This reinforces the idea that context can serve as a critical factor in the maintenance and generalisation of avoidance learning, and that there is no need to invoke a special for contextual information, in that it works in a similar way to discrete stimuli.

In this experiment we assessed we explored the relationship between context avoidance behaviour generalisation by using trait anxiety scores. We found no relationship between avoidance behaviour and trait anxiety scores. There are a few potential reasons for this finding, firstly it has been highlighted that the STAI whilst being a popular measure of anxiety within the literature, it may not be the best way to asses anxiety levels (Balsamo et al., 2013). Therefore, in the future it would be better to include either an alternative measure of anxiety (for example, the DASS; Lovibond & Lovibond, 1995)or to use multiple measures to assess whether they correlate. A limitation of this research is that the stimuli used as the contexts were simple, in that they only changed in colour (one dimension). Contexts within the real world are much more complex than this so whilst this research can provide insights into generalisation behaviour it limits the applicability of these findings. Previous experiments have used seasonal images as the contexts which could be considered to be more similar to real world contexts (McGlade et al., 2019). Therefore, future research could explore different and more complex types of contexts perhaps differing in more than one dimension (colour) to assess the parameters of the context and its effect on the generalisation of avoidance behaviour.

Overall, these findings contribute to the growing literature on the acquisition and generalisation of avoidance behaviour and are one of the first steps in assessing the effects of context on the generalisation of avoidance behaviour. The results suggest that while avoidance responses can generalise in a systematic manner based on context similarity, expectancy measures do not necessarily reflect the same pattern highlighting a potential dissociation between behavioural and cognitive mechanisms underlying avoidance. Overall, this study the importance of context in avoidance learning and key directions for future research in this area.

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Chapter 8

General Discussion

8.1 Introduction

This thesis investigated avoidance behaviour in a healthy population. The previous research in avoidance behaviour had a period of stagnancy with a resurgence over the last decade and a half (LeDoux et al., 2017; Urcelay & Prével, 2019). However, the generalisation of avoidance behaviour remains somewhat understudied despite the potential implications for the understanding and treatment of anxiety and related disorders. The introduction of this thesis explored the need for systematic research on avoidance behaviour to better understand the potential links to anxiety disorders. It also highlighted the key theories of avoidance behaviour and the limited research in humans. Furthermore, it stated the objectives of the thesis to explore avoidance behaviour and performance when systematically making variations in warning signals, safety signals and the context. An initial objective was to develop a novel trace avoidance procedure (*Chapter 2*) once this was established, we explored the effects of contiguity on the generalisation of avoidance behaviour. After this protocol was established, we then set out to explore the effect of stress on the generalisation of avoidance behaviour when varying warning signals (*Chapter 3*), and also the paedology of generalisation behaviour (*Chapter 4*). The next objective was to explore safety signals and their reinforcing properties. Firstly, we reviewed the current literature on the concept of relief and the

existing empirical findings (*Chapter 5*). We then investigated the reinforcing properties of safety signals in avoidance behaviour, and explored across experiments the generalisation of avoidance behaviour reinforced by safety signals (*Chapter 6*). Lastly, we set out to investigate the effect of the context of avoidance behaviour and whether variations in contextual features result in systematic variations in avoidance behaviour (Chapter 7). This chapter will summarise the key findings across the thesis; answer the key questions set out in the introduction, discuss theoretical and practical implications. It will also explore some if the limitations of this work, as well as the avenues for further research on avoidance behaviour.

8.2 Summary of findings

This thesis investigated three key areas in avoidance generalisation which are warning signals, safety signals and the context. In Chapter 2 we designed a protocol for assessing the effect of contiguity by adding a trace in between the CS termination and the US. This was incorporated as it has been suggested that the relationship between, generalisation and anxiety may be more easily detected when using ambiguous situations (Wong & Lovibond, 2018). Therefore, we opted to use a novel trace procedure to introduce ambiguity. The temporal gap (6 seconds) between the CS and the aversive outcome introduces uncertainty as to when the aversive event will occur which in turn makes it ambiguous compared to the control group (delay) in which the aversive outcome occurs immediately after the CS. We measured the number of times participants pressed the 'space' key which allowed them to avoid an aversive outcome. After piloting a group without the trace and one with the 6 second trace, we conducted two experiments online using a between subject's design to compare avoidance training and generalisation between those with and without the trace. The final experiment used a within-subjects

designing in which participants completed both the trace and delay groups, this was run in the laboratory. Across experiments, and regardless of the outcome (aversive images vs loud noise) recruitment (online vs laboratory) and design (between or within-subjects), we observed in both groups that participants were able to discriminate between the CS+ and the two CSs. Those in the trace group responded more in general to both the CS+ and the CSs. This could be due to the increase in ambiguity of when the aversive outcome will occur so therefore they consistently press the space bar potentially developing a 'better safe than sorry strategy' (Lommen et al., 2010). Moreover, whilst trace findings have been found to weaken CS and US associations in humans there is mixed findings (Boakes & Costa, 2014). This inconsistency is likely due to humans' ability to comprehend the task and its demands, allowing them to maintain focus and bridge the temporal gap between stimuli (Lieberman et al., 2008). Furthermore, in the generalisation test, it was consistently found that the trace procedure resulted in broader generalisation gradients, meaning that participants made more avoidance responses to the stimuli that were similar to the CS+ in the trace group compared to the delay group. When assessing the relationship with anxiety we found that those with high anxiety made more avoidance responses overall compared to those with low anxiety. However, high trait anxiety participants did not differentially generalise in delay or trace procedures, thus there was no overall relationship between anxiety and contiguity, as participants responded the same across groups.

In Chapter 3 we took the delay protocol developed in Chapter 2 and explored the influence of stress on the generalisation of avoidance behaviour. We firstly assessed this online, using a perceived stress scale and dividing the participants into high and low perceived stress groups. It was found that participants were able to discriminate between

the CS+ and CSs- in the training phase. Moreover, in the test phase, it was found that participants responded the most to the CS+ and as the stimuli became less similar avoidance responses decreased. Critically, when investigating the effect of perceived stress, it was found that both high and low perceived stress groups responded similarly during generalisation. In the second experiment, we aimed at manipulating stress levels in the laboratory using a social stressor task and compared those in the stress group with those in a control group. Across the two experiments we found that participants were able to discriminate the CS+ from the CS-, but there was no effect of stress (perceived or experienced) on the generalisation of avoidance behaviour.

In Chapter 4 we continued to explore the generalisation of warning signals but in this experiment, we used a modification of a space invaders task to look at the paedology (i.e., development) of this avoidance behaviour and generalisation in children. We collected data in children aged 5- 11 years old. Participants had to shoot at spaceships to score points and avoid a large spaceship (which took away a large number of points) which was predicted by a coloured signal. We assessed the amount of time spent hiding in the shields when the coloured signal was presented. We were able to assess both the discriminating during training, and the generalisation of avoidance behaviour to variations of the coloured signal during test. We found that all participants were able to discriminate between the CS+ and the CS- (i.e., the spent more time hiding in the CS+ compared to the CS-). During the test if was found that the younger children had broader generalisation gradients compared to the older children, a finding that is in line with the preexisting literature. Furthermore, age was able to predict the amount of avoidance generalisation. When exploring anxiety, we found no differences in those with high and low anxiety on the generalisation of avoidance behaviour.

Chapter 5 reviewed the literature on the role of relief in reinforcing avoidance behaviour in humans and other animals. There has been a rise in support for the notion that relief plays an important role within the maintenance of avoidance behaviour. This review examined the instrumental literature in both animals and humans and explored the theoretical and applied considerations. Overall, there is little research into avoidance behaviour however, emerging findings seem to indicate that relief plays a role in avoidance behaviour in humans. However, more research is needed, particularly in humans, to better understand the links with anxiety disorders.

In Chapter 6 we investigated the reinforcing properties of safety signals in human avoidance behaviour. We adapted the previous avoidance task so that during training, after a successful avoidance response participants were presented with a safety signal. This was done in a procedure in which there was perceptual variability during CS+/CS- discrimination training, which enabled then to assess transfer of avoidance behaviour to two new signals which had never been presented before. During test, avoidance responses to one signal was followed by the trained safety signal, whereas a second test signal was used as a control. Across the experiments we found that when presented with the trained signal or a novel signal/no signal (i.e., control), participants made more avoidance responses to a CS that produced the trained signal. However, when the trained signal and the novel signal were similar, participants made a similar number of avoidance responses, highlighting potential generalisation of the safety signal's reinforcing properties. Overall, we found that safety signals did reinforce avoidance behaviour in human participants, consistent with the notion that relief can reinforce avoidance behaviour in humans. When assessing anxiety, we found that overall, those with high anxiety made more avoidance responses than those with low anxiety however, there were

no differences between responding to the two signals (trained safety signals and novel/no signal).

Finally, Chapter 7 reports a preliminary experiment in which we investigated the context dependence of avoidance behaviour. Previous literature has revealed that avoidance behaviour can be context dependent, however there is no systematic assessment of such context dependency. We developed a modified version of our avoidance task in which participants were trained on a CS+/CS- discrimination task, and then both stimuli were tested in the training context (background colour) and in a range of variations using the blue-green continuum to assess generalisation to the CS+ and CS-. We observed a systematic gradient of generalisation with variations in similarity between training and testing contexts. We calculated a slope of generalisation and assessed whether this relates to trait anxiety levels and found no relationship between anxiety and context generalisation. The preliminary study is obviously underpowered but reveals a systematic relationship between avoidance behaviour and context change. No such relationship was observed when we used expectancy measures.

8.3 Thesis Questions

Overall, this thesis aimed to address some key questions within these projects to expand the current knowledge on the generalisation of avoidance behaviour – in human participants – and lay out foundational work in which relationships are systematically mapped. The following questions were addressed in different chapters. These questions include Does avoidance behaviour generalise to similar stimuli; is there a link between anxiety and avoidance behaviour and is there a link between anxiety and the

generalisation of avoidance behaviour. These will be addressed separately in the next sections.

8.3.1 Does avoidance behaviour generalise to similar stimuli?

At the beginning of this thesis, we expected that, across all of the different strands (warning signals, safety signals and context), avoidance behaviour would generalise to other events (warning signals, safety signals and context) that were similar to those that were used during training. This hypothesis was found to be true across all of these experiments across the thesis, and there is not much novelty in this. Of course, it is good to see those foundational constructs in psychology such as generalisation (Pavlov, 1927)Lecture VII];(Shepard, 1987) are readily observed when investigating avoidance behaviour in humans. In Chapters 2, 3 and 4 the generalisation of warning signals was investigated and across all three projects investigating contiguity when comparing delay and trace procedures, development and stress, there was generalisation of avoidance. All three experimental chapters provide evidence that participants continue to respond to the stimuli that are close in similarity to the CS+ used in training (colour), and this decreases as the stimuli become less similar. Generalisation sometimes varied as a function of the relevant constructs tested in each chapter. For example, in Chapter 2 using trace procedures (a six second temporal gap between the CS+ and the US presentation) it was found that in comparison to a control Delay group that Trace Group had broader generalisation gradients, in that participants continued to make avoidance responses to stimuli that were less similar to the CS+. In the Delay Group, they show a sharper decrease in avoidance responses (although they do continue to respond to stimuli too and

also show generalisation). This was consistently seen in the data across experiments in the chapter. Whilst the effect of trace and delay conditioning on generalisation were described almost a century ago by Pavlov (1927), and work in nonhuman animals has revealed this relationship, there is no data in human avoidance that speaks about this, and the experiments reported in the chapter are first to document this.

Using a Delay task, Chapter 3 reports two experiments with delay procedure in which the effect of stress on generalisation of avoidance behaviour were studied. We observed no effect of stress on the generalisation of avoidance behaviour. The literature on stress shows mixed findings so it is unclear as to whether the current experiments failed to capture differences or whether these differences do not exist. It is also noted that in the second experiment in which stress was manipulated, that the manipulation may not have worked as the pre and post state anxiety showed no differences in the stress and control groups therefore there needs to be further work into exploring the skin conductance measures taken form this experiment to rule out this explanation.

Chapter 4 documents an experiment which children looking at generalisation across development. The literature has suggested that generalisation gradients sharpen as children grow, but the available evidence always confounds developmental differences in learning and motivation with generalisation. The experiment in this chapter reported that developmental age can affect the generalisation curve with younger children showing broader curves in that they continue highly responding (hiding in the shield) to generalisation stimuli than the older children, and this was observed in the absence of developmental differences during training in terms of responding to the CS+.

In Chapter 7 we explored context generalisation in which participants were trained in one context (blue or green background; these were counterbalanced across

participants) and were then tested in 4 other contexts which differed in similarity to the trained context (colours from the blue-green continuum). It was found during the generalisation test that responding to the CS- remained low across all contexts however, responding to the CS+ differed across contexts. Avoidance responding was the highest in the trained context and then as the contexts became less similar the responding gradually decreased creating a linear gradient. This suggests that the context functioned in a similar way to discrete cues (such as the warning signals used in Chapter 2). There has been little research into the generalisation of context and this experiment could be the first evidence in a human instrumental task showing this function of the context.

Finally, in the safety signals project (Chapter 6) a traditional generalisation paradigm was not used as generalisation was not the central question, we wanted to see if safety signals could reinforce avoidance behaviour. However, we can draw conclusions by comparing the different experiments within the chapter. When the safety signal differed in two dimensions (colour and shape) then participants responded more to the CS that produced the trained signal however, when the new safety signal only differed in one dimension (colour) then there was no preference. This suggests that when the signals are similar there is generalisation between the two. More research is needed to explore this more within the safety signal protocol perhaps with a between-subjects design in which participants are divided into different groups and receive a different signal which differ in different dimensions (size, colour, shape, position) to investigate whether a generalisation curve can be observed.

Overall, the findings from this thesis provide strong evidence that avoidance behaviour generalises to similar stimuli across different experimental groups, supporting existing theories of associative learning and generalisation (Pearce, 1987; Shepard, 1987).

The results demonstrate that factors such as temporal contiguity, developmental age, and context all influence the extent of avoidance generalisation, with broader generalisation observed under groups of trace procedures (which may produce uncertainty), and in younger children. Furthermore, together with the findings on safety signals, the results suggest that generalisation depends on perceptual similarity, but other factors can also change generalisation gradients. We interpreted these results with a modification of the framework proposed by Pearce (1987), in which events are encoded as configurations and at test responding is a function of prior learning and the similarity between what was trained and what is tested. Critically, we have proposed that trace procedures diminish the influence of unique elements to generalisation, and this explains why gradients are broader with trace in comparison with delay procedures (Alcalá et al., 2023; Herrera et al., 2022). These results contribute to our understanding of the generalisation of avoidance learning by highlighting the mechanisms that drive generalisation and the groups that modulate it.

8.3.2 Is there a relationship between avoidance behaviour and anxiety?

Avoidance is a hallmark of all anxiety disorders; it has been suggested that the relationship between anxiety and avoidance is central to understanding and treating anxiety disorders (Pittig et al., 2020; Urcelay, 2024; Vandael et al., 2023). Clinically, addressing avoidance through therapies like exposure therapy and cognitive-behavioural therapy is essential for breaking the cycle of anxiety and enabling recovery (Dobson & Dobson, 2018). Researching the fear-avoidance dynamic will ultimately help understanding the underlying mechanisms of avoidance behaviour to further recognize how it drives or maintains anxiety. This thesis set out to investigate avoidance behaviour

and levels of trait anxiety in a healthy population. Due to the proposed relationship outlined in the clinical literature and from recent findings in fear research (Sep et al., 2019), this thesis expected to find a relationship between avoidance behaviour and reported anxiety levels. The findings of previous studies suggested that high anxious people avoiding more (Pittig & Scherbaum, 2020) so it was hypothesised across experiments within this thesis that those with high anxiety levels would avoid more than those with low anxiety levels. This was assessed by having participants complete the State and Trait Inventory (STAI) at the start of each experiment. This scale was chosen as a recent meta-analysis investigating trait anxiety and fear generalisation found that a majority of the papers used this scale (Sep et al., 2019). Using this scale, we used two main methods to assess the relationship between anxiety and avoidance behaviour. The first was comparing those with high trait anxiety and those with low trait anxiety. This was achieved by conducting median splits based on trait anxiety scores to create two groups which then enabled us to conduct the same analysis we had in each chapter but incorporating anxiety as a between-subjects variable. We could then use these two groups within the Bayesian Gaussian model (Lee et al., 2021) to explore whether there were group differences in Chapters 2 and 3. Additionally, within some of the chapters we incorporated an additional analysis in which we calculated a generalisation slope and then either correlated this with anxiety scores (*Chapters 4 and 7*) or conducted a regression (*Chapter 4*). This method has advantages as it captures the continuum of anxiety scores and avoids losing interpretations which can become lost when dichotomising a continuum variable. However, in other chapters such as Chapter 6 we were not able to find a suitable way to analyse the data in this way, this was due to the fact that we could not compare different safety signals in the same participants.

The first method was used across all experiments within this thesis and overall, there were some consistencies in the findings. That is, that there were no differences between those with high anxiety and with low anxiety in terms of the amount of avoidance responses made during test. This finding was observed across the experiments testing generalisation to different warning signals, safety signals and the context when focusing on individual experiments and when combining the online experimental data within Chapter 2 (Experiments 1-3). There were exceptions of two experiments in Chapter 6 which found high anxious people avoided more in training (Experiment 3) and during the test (Experiment 4). Furthermore, when combining the data in Chapter 6 there is a marginal effect of anxiety in that those with higher anxiety responded more than those with low trait anxiety levels (these comparisons can be found in the Appendix).

Overall, it seems that the findings from this thesis are not clear, but there seems to be a pattern in that some chapters show differences between anxiety groups (Chapter 6) and those that do not. A possible reason for differences in anxiety being found in the safety signals experiments and not the other experiments within this thesis (when looking at the data as a whole chapter) could be because whilst the task is similar across chapters, it is more difficult in the safety signals experiments. This is because in those experiments the stimuli during the training phase are varied which (to avoid generalisation decrement in the test phase) and this makes it more difficult to learn which set produces the aversive outcome and which one does not. This is somewhat consistent with the suggestion that in order to detect individual differences in anxiety, then the task needs to involve training situations that result in "weaker" learning, typically achieved by the use of partial reinforcement (Allen, 2023). Across the fear conditioning literature partial reinforcement is widely used (Laing et al., 2025). However, in this thesis we only ever used continuous

reinforcement in that the CS+ was always paired with an aversive outcome and if a successful avoidance response was made then it always avoided the aversive outcome. Of course, experiencing continuous and partial USs in avoidance depend on the successful avoidance, unless the contingency between responding and successful avoidance is partially reinforced. A study in human avoidance manipulated the latter contingency and found systematic effect, but they did not test for potential relationships with anxiety (Xia et al., 2017) Finally, it could be argued - as mentioned in other sections of this thesis - that it is the ambiguity that is crucial to find differences in avoidance (Wong & Lovibond, 2018, 2021).

Another possible limitation and reason for the lack of finding a relationship between avoidance and anxiety is the method used to divide individuals into high and low anxiety groups. Throughout this thesis median splits were used and whilst these have been used in the avoidance literature (Klein et al., 2020) they have limitations (Iacobucci et al., 2015) in that they dichotomise data and remove individual differences due to individuals being categorised into the high anxiety group even though their score is only slightly above the mean and this can notably increase Type II errors.

8.3.3 Is there a relationship between the generalisation of avoidance behaviour and anxiety?

Within the anxiety literature there is a wide literature which has shown that those with both high trait level anxiety (Sep et al., 2019)and anxiety disorders (Cooper et al., 2022) overgeneralise fear. Across both of these meta-analyses the findings are robust in that they find that those with high anxiety levels have broader fear gradients meaning they show fear responses for a broader range of stimuli. Whilst much of the literature has focused on fear generalisation, we wanted to assess whether avoidance behaviour also

generalises to other stimuli in a similar way to fear. Across this thesis there were no differences in generalisation of avoidance behaviour, across the thesis, for those in the high and low anxiety groups. Therefore, whilst those with high anxiety make more avoidance responses the pattern of the responding was the same amongst groups. When using the correlational analysis with anxiety in Chapters 2 and 3 it was also found that anxiety was not correlated with generalisation slopes and in Chapter 4 anxiety could not predict generalisation slopes.

There could be several possible reasons for not finding a relationship of differences in anxiety scores and generalisation of avoidance behaviour. Firstly, it could be that there is something that moderates or interplays this relationship. There has been a growing literature on traits which are associated with anxiety, and one such is intolerance to uncertainty (IU) (Morriss et al., 2016). This refers to the tendency to negatively react to uncertainty or unpredictability (Birrell et al., 2011). Originally, this was thought to be a construct specific to generalised anxiety disorder (GAD), however more recent research has shown that it can be considered a risk factor for many other anxiety disorders (Carleton, 2012) such as panic disorder (Carleton et al., 2013). Moreover, research investigating intolerance to uncertainty and avoidance has found that in a healthy sample IU was significantly related to anxiety and experiential avoidance (internal avoidance of thoughts and feelings) (Buhr & Dugas, 2012). Furthermore, when investigating active avoidance there was a positive relationship between frequency of correct avoidance responses and intolerance to uncertainty (Flores et al., 2018). Moreover, the work by Jayne Morris has highlighted many findings relating to IU and anxiety. In a study investigating generalisation they trained participants with threat and safety cues and then tested stimuli that were perceptually similar (Morriss et al., 2016). They found that high IU

was associated with more generalisation of responding to threat and safety cues during acquisition. Similar results were replicated when using skin conductance responses (Bauer et al., 2020). Therefore, in hindsight it would have been better to include multiple individual measures to explore the traits associated with anxiety and see how these factors interact or correlate together. This would be particularly insightful in the experiments that involved using a trace procedure (*Chapter 2*) as this involves creating ambiguity and uncertainty as to when the aversive outcome will occur.

Moreover, another possibility it could be due to the way in which anxiety was measured, as stated the STAI was used as this has been used in a large volume of different studies within this field. However, the effects within a meta-analysis (Sep et al., 2019)were small so this could indicate that this measure does not capture trait anxiety best or that the effects in trait anxiety are small. The validity of the STAI have been questioned. Validation studies found that when assessing a large sample of clinical and non-clinical individuals that the trait subscale of the STAI correlated more with measures of depression than with other measures of anxiety (Bados et al., 2010; Balsamo et al., 2013). Also, a recent meta-analysis of 388 papers found that people with anxiety disorders had a higher trait anxiety than those in the nonclinical samples however, it was also found that people with a depressive disorder also had elevated trait anxiety scores (Knowles & Olatunji, 2020). In addition, trait anxiety was highly correlated with the severity of both anxiety and depressive symptoms. This suggests that the STAI trait measure may not be specific to anxiety and capture aspects of depression too therefore should be considered a measure of negative affect as opposed to solely anxiety. Therefore, in future studies other measures of anxiety could be incorporated into experiments including Depression and Anxiety Stress Scales (DASS) (Lovibond & Lovibond, 1995) or the State-Trait Inventory

for Cognitive and Somatic Anxiety (STICSA) (Ree et al., 2008) which in a recent study was found to better distinguish between anxiety and depressive traits (Elwood et al., 2012). Moreover, to improve the clinical implications measures that are used to diagnose anxiety disorders could also be used such as the generalised anxiety disorder scale (GAD 7) (Williams, 2014). Overall, future research should prioritize incorporating more precise and validated measures, such as the STICSA, DASS or GAD-7, to improve the distinction between anxiety and depression and strengthen the clinical relevance of findings and expand the literature using alternative measures of trait anxiety.

Overall, this thesis did not find any evidence of an interaction between anxiety and avoidance generalisation. Previous research on avoidance generalisation is limited but, some research has found that avoidance behaviour in a virtual farming game did generalise to other stimuli that were similar to the CS+ (Van Meurs et al., 2014). There was also a positive relationship between the fear and avoidance which provides some evidence of a link between anxiety and generalisation of avoidance behaviour. Furthermore, studies investigating avoidance generalisation age and trait anxiety found that avoidance generalisation was exhibited by low and high anxious individuals that

the tendency to generalise avoidance to these similar stimuli was associated with higher trait anxiety levels (Klein et al., 2020). However, this finding was not present when looking at the avoidance responses only in the self-reported danger and safety ratings and when correlating responses to generalisation stimuli and trait anxiety. Therefore, it could be that the self-report measures are more sensitive at depicting differences between high and low anxiety groups. In this thesis we did not take self-reported measures only behavioural data but we did conducted similar analysis and also used median splits to create high and low anxiety groups and the behavioural data does align with these findings

from (Klein et al., 2020). This potentially highlights an issue of using this method when trying to explore differences in anxiety (see below section for more evaluation of this method).

Future studies can work towards providing a clearer understanding of how anxiety influences the generalisation of avoidance behaviour, by utilising both behavioural and self-report measures, which could influence potential implications for anxiety disorder interventions.

8.4 Contributions to knowledge

This thesis has contributed to the existing literature on avoidance behaviour in several ways. Whilst the findings of the thesis as a whole were not as expected regarding the effect of anxiety on the generalisation of avoidance behaviour, this body of work has nevertheless contributed to the limited literature on the generalisation of avoidance behaviour. Firstly, this thesis was able to develop and modify a task that can investigate many different aspects of avoidance behaviour. It has built on from the work of Flores and collegueas (2018), and the current task allows for the manipulation of warning signals, safety signals and the context. In other words, this task allows researchers to explore many different avenues regarding the generalisation of avoidance behaviour. This research also has contributions of theory and the wider clinical applications.

There are many novel aspects to this thesis which have not been studied with either human studies or within the avoidance paradigm. Firstly, this thesis included a novel design to investigate the generalisation of warning signals by incorporating trace procedures. As outlined in the summary of findings above this was included introduce ambiguity as it has been suggested that ambiguity is needed to assess differences in anxiety (Wong & Lovibond, 2018, 2021).

Moreover, this thesis assed the reinforcing properties of safety signals which has not been investigated in humans before. The research built on the findings from the rodent literature such as (Fernando et al., 2014). It also builds upon the work conducted in relief (Vervliet et al., 2017) and provides behavioural data to support this.

This thesis also investigated the ontology of avoidance acquisition and generalisation. Whilst previous research has investigated age in relation to avoidance behaviour (Glenn et al., 2012) this thesis provided a novel aspect. Firstly, the previous research conducted has used participants who are aged 8 and above whereas this thesis included younger children from age 5 to age 11. Moreover, the previous research had a limitation in that there was age differences present during training which could then carry over into the generalisation test and explain why there were age differences. This thesis was able to produce a task that was able to mitigate these differences during the training stage which allowed the conclusions to be based on generalisation behaviour. Finally, the thesis explored the generalisation of context and the effect on avoidance behaviour. Whilst there has been some work on this (Meulders et al., 2020, 2024) the investigations of this in humans is limited. The experiment included within this chapter provides a first step in investigating the role of the context in avoidance behaviour and has shown that the context could act in similar ways to discrete cues.

Overall, while this thesis may not offer new contributions to the theoretical or clinical fields, it builds upon and reinforces the existing literature. The work presented here provides valuable insights into the generalisation of avoidance behaviour in human participants, the determinants of generalisation and insights into developmental factors. This thesis does provide partial; support for the notion that those with high anxiety avoid more with the evidence from Chapter 6. However, it also shows evidence that anxiety

differences are not always consistent when using similar tasks and that ambiguity could play a key role in this (Wong & Lovibond, 2021).

8.5 Limitations

Whilst this thesis has contributed valuable insights to the avoidance literature it is also important to acknowledge several limitations that may have impacted the scope and validity of the findings. These limitations are primarily due to the methodology and the sampling used within this series of experiments. Within each chapter, the limitations for each set of experiments have been discussed, so this section will cover the overarching limitations of the research. Recognising the limitations adds context to the current findings of this thesis and provides future avenues for research to build and expand on this thesis.

8.5.1 Measurements

8.5.1.1 Measures of Fear and expectancy

Firstly, whilst the main objective of this thesis was to conduct research on avoidance behaviour, we did not collect any measures of fear. This was mainly due to us wanting to focus solely on avoidance behaviour as within many of these projects these phenomena had not been studied in a human avoidance paradigm such as the trace procedures described in *Chapter 2*, or the effect of safety signals described in *Chapter 6*. Due to the fear and particularly the generalisation of fear field being extensive both in healthy and clinical populations we opted not to collect these measures. Neither fear nor avoidance exist in a vacuum in the absence of the other, and there is a benefit in collecting these simultaneously (Vervliet et al., 2017). The caveat to this is that to do so, events presented to participants need to be longer (to allow time for participants to provide for

example a fear rating) and this decreases ecological validity, for it is unclear in which real-world situation individuals are constantly providing numerous ratings. In addition, asking questions in each trial can increase participant's awareness of the goals of the experiment, and therefore increase experimenter demands. This is one reason why we chose to focus on avoidance behaviour at the expense of expectancy measures and other constructs of potential interest. Future work will need to better integrate these different dependent measures and determine whether the results are convergent or divergent. Whilst we have sometimes found that expectancy and behaviour converge (Urcelay et al., 2024) *Chapter* 7 revealed the expected context generalisation at the level of avoidance behaviour but not at that of expectancies. In other words, behaviour and expectancy were not correlated.

We have argued through this thesis that previous findings have revealed dissociations between fear and avoidance measures (Mineka, 1979; Vervliet & Indekeu, 2015). For example, individuals may engage in avoidance without reportedly experiencing fear. Without assessing fear, researchers cannot distinguish between these distinct patterns, potentially oversimplifying the interpretation of avoidance responses and missing critical individual differences. Moreover, sometimes participants report little fear and yet they continue to avoid (Vervliet & Indekeu, 2015). This limitation becomes particularly pronounced in studies examining the generalisation of avoidance behaviour. Fear measures are essential for determining whether fear itself generalises across similar stimuli or whether avoidance generalises for unrelated reasons, such as overgeneralised safety behaviours (Kesim et al., 2024) or conditioned habits (Gillan et al., 2014). For instance, an individual might avoid a stimulus due to a learned association but may not consciously experience fear when encountering that stimulus. In such cases, the

generalisation of avoidance may not accurately reflect the generalisation of fear, leading to a misrepresentation of the underlying processes. Without fear measures, researchers lose the ability to assess whether the avoidance behaviour observed is truly fear-driven or simply a byproduct of another psychological mechanism. Because the relationship between fear and avoidance was not the focus of this thesis, we did not manipulate variables - such as the amount of training, or fear extinction – that are supposed to dissociate these constructs, and instead we focused on avoidance behaviour.

Moreover, the clinical application of the findings of this thesis may be limited due to neglecting measures of fear. This is relevant if the main goal of treatments for anxiety disorders including GAD and phobias is to reduce fear, typically by exposure therapy. Fear reduction has obviously guided the treatment of anxiety disorders and whilst it is not a perfect treatment it has helped individuals deal with their disorders and helped them live their daily lives (Norton & Price, 2007). Without measuring fear in studies avoidance, it becomes difficult to determine whether the patterns observed in experimental studies mirror those seen within treatments. In addition to these practical implications, neglecting to measure fear also obscures the emotional and subjective experiences of participants, which are vital for understanding how fear and avoidance manifest in real-world contexts. Fear is not merely a physiological or behavioural phenomenon; it is also a deeply personal and subjective experience that shapes how individuals perceive and interact with their environment (Le Doux, 2015). Similarly in patients with the same disorder's symptoms can vary, so that some individuals may experience many cognitive symptoms related to overthinking and worrying, whilst other will experience physiological symptoms such as a rapid heartbeat and difficulties breathing, whilst others will experience avoidance as a behavioural manifestation. Without collecting data on all these types of symptoms, it is

difficult to detect relationships between meaningful individual differences, and this can result in a ‘one size fits all’ approach to anxiety disorders and treatments which fails to account for these diverse manifestations of these disorders.

Treatments approaches have adapted to incorporate aspects of avoidance and there is a drive from clinicians to incorporate this more (Treanor & Barry, 2017). Some versions of CBT also include an element called ‘safety behaviour fading’ which aims to reduce and eliminate safety behaviours such as avoidance. They also encourage individuals to come ‘face to face’ with stimuli or events that provoke feelings of anxiety. Findings have found that

By omitting fear measures, researchers fail to capture the participants' emotional distress, potentially misrepresenting the psychological burden associated with avoidance behaviour. This lack of insight into the subjective experience of fear diminishes the ecological validity of the findings, as it overlooks the real-world complexities of how fear influences decision-making, coping strategies, and everyday functioning. In summary, failing to collect fear measures in avoidance studies not only limits the ability to interpret findings accurately but also weakens their theoretical and clinical relevance. To address these limitations, future research should incorporate robust fear measures to ensure a comprehensive understanding of the interplay between fear and avoidance behaviour.

8.5.1.2 Objective and subjective measures

A further limitation regarding measurements within this body of work is the exclusion of self-report measures. This thesis prioritised the collection of objective measures of avoidance behaviour and did not consider using self-reports and scales to assess further cognitive and emotional elements. There were several reasons for doing this, initially we were focused on behavioural and objective measures as some of the

current literature into the topics of generalisation and avoidance such as the early work of Angelakis & Austin (2015) studied these phenomena but did not conduct inferential statistics making the conclusions difficult to draw. Furthermore, a benefit of behavioural measures is that there are no interruptions between the task whereas studies that use subjective measures require participants to constantly answer questions and scales (Vervliet et al., 2017). Whilst this was a decision to optimise the data collection at the initial time of conception of the projects within this thesis, in reflection including other measures such self-reports would have strengthened and complemented the current behavioural findings.

Some of the lines of research within this thesis could have benefitted from also incorporating self-report measures as cognitive measures of the phenomena we were observing. An example of this would be in Chapter 6 which aimed to the role of safety signals in avoidance behaviour. There is previous research conducted on this theme, in terms of assessing the amount of relief people felt after avoiding an aversive event, and in particular which shows that people experienced higher relief pleasantness when they successfully avoided and that participants reported experiencing more relief pleasantness to the CS+ compared to the CS- (Vervliet et al., 2017). Furthermore, there was behavioural research that showed that when a safety signal was presented people seemed to make mor avoidance responses however the sample used was small and no statistical tests were used (Angelakis & Austin, 2015). Due to this we decided we wanted to attempt to demonstrate in humans that safety signals can reinforce behaviour, using the behavioural output as the main dependent measure. Whilst it was shown that safety signals did reinforce avoidance behaviour it would have been interesting to ask participants whether they subjectively felt relief to the safety signal. In unpublished data (not included within

this thesis) we included a question on relief at the end of the experiment. In this experiment we used the same safety signal task but were investigating reinstatement of the safety signal therefore participants underwent acquisition, extinction and then a reinstatement test. Following typical expectancy rating scales, we then included a scale in which the safety signal was presented and we asked participants to rate how much relief they felt when this stimulus was presented. We found that the more safety signals participants received during training was correlated with the amount of relief participants experienced. The inclusion of this type of scale in the experiments in Chapter 6 would have supported the notion that safety signals reinforce behaviour through relief. The behavioural data alone makes it difficult to reach this conclusion as relief is an unobserved (i.e., internal) construct. Of course, the different control procedures used in *Chapter 6* make it difficult to conclude that the effect is not due to relief, anyway it would have been insightful to include a question at the end of the experiment asking participants how much relief they felt when they saw the trained signal vs the novel signal. This would integrate both of these lines of research and allowed us to both observe the behaviour and assess the participants thoughts about the safe and aversive events. Therefore, in future studies, we aim to utilise both of these methodologies to further add to the growing research on avoidance behaviour.

8.5.1.3 Avoidance Measures

As discussed throughout this thesis, a notable strength of the current experiments is the use of a task that allows the frequency of avoidance responses to be assessed. When investigating factors of individual differences, using a continuous variable allows the pattern of responding to be explored rather than the binary data of whether a response was made or not. However, whilst we consider this a strength the current task, there is a

limitation in that it is a low-cost task. In the clinical setting, it has been argued that those with anxiety disorders avoid to high costs, which provide a significant disruption to their daily lives. For example, if a patient has a fear of dogs and on their way to the supermarket there are a number of houses in which dogs are kept in the front gardens, a patient may opt to take a route that is much longer in order to avoid these. Using tasks that are low cost may simplify the behaviour and not properly model avoidance in the real world. There are several reasons why these low-cost tasks are implemented in research. A main factor is that they are practical and in the case of this thesis which utilised online data collection we needed a task that participants could learned quickly and was not overly long and costly as this could increase the dropout rate (Hoerger, 2010). Also using these simple tasks allows the researchers to manipulate variables such as the contiguity between stimuli and outcomes after a successful response. At this stage in the avoidance literature not much is known about these factors and how they influence and effect avoidance behaviour, thereby having a simplified task allows these underlying mechanisms to be studied easier.

Whilst the basic task used throughout this thesis could be argued to be a better measure of avoidance compared to the tasks that require only one press to avoid, they are by no means a high-cost task which opens it up to limitations. As the task is low cost this minimises the effects of real-life avoidance has on those with anxiety, they are considered to have low ecological validity due to as stated above real-life avoidance behaviour having higher stakes which have high impact on people's lives such as daily tasks taking longer, being unable to go to certain places or events. Moreover, low-cost avoidance tasks also risk oversimplifying avoidance, failing to capture the complex decision-making processes that occur in real-world situations. In real life, avoidance often involves weighing long-

term costs and benefits, considering opportunity costs, or grappling with competing goals. For instance, avoiding a feared situation like flying may lead to professional or personal consequences, creating a trade-off that individuals must navigate. Researchers in the field such as Andre Pittig have argues that because real life avoidance has a cost then tasks should also incorporate a cost (Pittig et al., 2021; Pittig & Scherbaum, 2020; Wong & Pittig, 2020).

There has been recent research in which researchers have attempted to use tasks that have higher costs involved. One area is within pain avoidance work, in which there has been research using a robotic arm paradigm (Meulders et al., 2016). In this paradigm, participants have to control a robotic arm from a starting point to a target and have the option of using three possible trajectories, some of which are paired with an electric shock, but each are slightly different. The shortest trajectory has the least amount of effort, but there is a 100% chance of a shock, the longest trajectory requires the most effort as the resistant of the robotic arm is higher but is never paired with an electric shock. The middle trajectory is medium length and a medium effort and is paired with a shock 50% of the time. This paradigm allows participants to avoid the shocks, but it requires efforts and is thus costly. This research has shown that during acquisition participants learn to use the longest trajectory, and report higher pain and fear expectancy ratings to the shortest trajectory (Meulders et al., 2016). This highlights that participants can learn to both avoid and discriminate between the different trajectories. Moreover, other research has used other types of cost within their designs, such as monetary costs. Research from Pittig and Scherbaum (2020) have used monetary rewards within an avoidance programme. In this task, participants have to choose between two options, one which involves high threat but high reward - there is a chance they may receive a shock,

but they will win a larger monetary reward. However, there is also a safe and low reward option, in which there is no chance of being shocked and a lower monetary reward. This influences how much participants could gain from taking part in the study which therefore tries to capture the costs of avoiding. Using this task, they observed that participants avoidance of the high threat/high reward option increased as the chance of being shocked also increased, and notably those with high trait anxiety showed elevated avoidance compared to the low trait anxiety people when the rewards were high. This highlights the complex interplay between avoidance, anxiety and decision making suggesting perhaps that those with high anxiety balance potential rewards and threats more than those with low anxiety. This procedure also suggests that the cost of avoidance is a significant factor and highlights the need to study costly avoidance. These two paradigms show that avoidance can be studied using high-cost tasks and cost does play a factor in avoidance behaviour therefore the implantation of these types of paradigms should be encouraged.

Overall, low-cost tasks are valuable tools for exploring foundational aspects of avoidance behaviour and can serve as a stepping stone for more complex research. However, findings from these tasks should be interpreted with caution, in particular when attempting to generalise results to clinical settings. To address these limitations, researchers can complement low-cost tasks with higher-cost paradigms, more immersive experiments (e.g., virtual reality), or studies involving clinical populations where avoidance is tied to significant fear or distress (Lemmens et al., 2021).

8.5.2 Samples

Firstly, this thesis used two different types of methodology for recruiting participants, one method involved online recruitment from Prolific and the other was using student samples within the laboratory. However, both of these groups were healthy

participants. Whilst it is good that the results observed within chapters were replicated both online and in the lab with different samples, both of these specific methods have limitations. These two methods will both be discussed in turn below.

8.5.2.1 University Student Samples

This study utilised samples of healthy participants whilst this is used throughout the Psychology discipline and within the specific area of anxiety research (Sep et al., 2019). There are many advantages to using this population with one being the practicality of students being accessible and willing to participate in research which ensures the data collection goes smoothly and there is less chance of them dropping out. Additionally, as seen in this thesis, the in-laboratory experiments resulted in much lower proportion of participants excluded based on pre training, or not finishing the task which makes them a more reliable sample. However, there are several limitations that impact the generalisability and ecological validity of findings. The student population is often characterised as 'WEIRD' that is that they are western, educated and less diverse in socioeconomical backgrounds compared to the general population (Henrich et al., 2010). This makes the data less applicable. Furthermore, university students – in particular those studying psychology - may respond differently to experimental manipulations due to their unique developmental stage and life context, which might not accurately reflect the experiences of older adults or individuals in non-academic settings.

8.5.2.2 Online samples

As with all samples there are advantages and disadvantages to using online data collection methods. A significant advantage is the ability to recruit large and diverse samples quickly and cost-effectively, often reaching individuals from different geographic regions, socioeconomic backgrounds, and age groups. This diversity can enhance the

generalizability of findings compared to using undergraduate student samples. Additionally, online methods offer convenience for both researchers and participants, as data collection can occur quickly, and hundreds of participants can participate at once which would not be able to happen in in-person research.

However, there are significant limitations associated with online data collection. One disadvantage is the lack of experimental control, as researchers cannot monitor participants' engagement, adherence to instructions, or environmental distractions during the study. This can lead to greater variability in data quality and potential biases, such as participants multitasking or rushing through tasks. Particularly in the case of this thesis, as the experiments involve aversive stimuli participants could disengage and overt the gaze and not fully experience the US. Moreover, there is a larger dropout rate with participants failing to pass pre training, they experience technical difficulties or do not finish the task completely.

Whilst these limitations exist, in this thesis we did use a mixture of inline and in person experiments and within the chapters that utilised both methods similar results were replicated within the laboratory as was seen online. Therefore, as these findings were consistent across online and in person experiments it validates the use of online samples and suggests that the limitations are not so problematic within this thesis.

8.6 Further Research

This thesis set out to investigate a number of different phenomena within an avoidance paradigm. Whilst many aspects were covered within this thesis there are many different avenues that the research can take. Whilst the research on avoidance behaviour is limited a benefit to this means that there are lots of lines of research that can be

investigated. Both trying to replicate findings from the animal literature in humans, such as we did Chapters 3 and 6 or developing new tasks and ideas to test.

8.6.1 Clinical populations

One of the most anticipated next avenues following on from research in this thesis would be to use these tasks with clinical populations. As stated throughout each chapter and in the above section of this discussion, we did not observe any interactions between trait anxiety and generalisation of avoidance behaviour. We know that the literature on overgeneralization of fear has reported associations with trait anxiety in healthy volunteers, but the averaged effect size is much smaller (Sep et al., 2019) than that seen in people with a diagnosed anxiety disorder (Cooper et al., 2022). Thus, by assessing generalisation with a patient group and comparing it with healthy volunteers may provide a better test of the relationship between avoidance generalisation and anxiety. Depending on the exact criteria it can be difficult to recruit individuals with anxiety disorders, whether we rely on self-reports of diagnoses or have a stricter criterion that involves checking this with a clinical professional. Moreover, that may differ in aetiology, symptomatology, medication and response to experimental groups. It may be better for research to select a particular disorder such as generalised anxiety disorder (GAD) to study although this may also impact the generalisability if the findings, if researchers wanted to assess different disorders this would require a larger sample. This in turn can make recruitment more difficult.

There is also the fact that those with anxiety disorders may be more sensitive to the stimuli used within our experiments. They may experience more distress to the aversive outcomes which could lead to dropouts. These are all factor is that need to be considered future research. Overall, whilst there are some challenges of recruiting clinical

populations, they can offer lots of insights into the underlying mechanisms of anxiety. Even though there is research which has linked trait anxiety scores and the development of anxiety disorders, there may be differences between these populations which are key factors in avoidance behaviour. Moreover, having people with lived experience helps their voices be captured in research which could impact them in the future if changes are made to interventions. Therefore, the eventual goal of research in this field should be to incorporate clinical samples.

8.6.2 Underlying mechanisms

This thesis primarily focused on developing the tasks to assess the generalisation of avoidance behaviour and assess the potential of variables that may alter the generalisation of avoidance behaviour (i.e., for example trace vs. delay procedures). Therefore, a logical next step would be to investigate the underlying mechanisms that explain why these behaviours occur. While establishing the presence of behaviours like avoidance or generalisation has been crucial, exploring the underlying mechanisms driving these patterns is the next essential step. In *Chapter 2* that documented broader generalisation gradients with trace procedure, we speculated that trace procedures result in more generalisation because participants weigh more the common rather than unique elements in the array of stimulation (i.e., warning signals). We speculated this on the basis of a modification of Pearce's (1987) model to account for the effect of trace. An obvious logical step involves seeking evidence for this specific explanation. For example, following avoidance training with delay and trace procedures, we could administer more sensitive tests of the stimuli used during training (for example, an identification test) and better assess the memory content of the stimuli which we speculated should be different on the basis of the training regimen. This deeper understanding can help refine theoretical

models, making them more comprehensive and explanatory. Furthermore, uncovering the "why" behind these behaviours allows researchers to target specific mechanisms, such as biased threat perception, generalised safety behaviours and cognitive processes (such as relief), to develop more effective and tailored interventions.

Other findings in this thesis also require further elucubration. For example, *Chapter 7* documented a clear generalisation pattern based on small variations in a contextual attribute (i.e., the colour). Many have argued that context can except multiple functions over behaviour (Holland & Bouton, 1999; Bouton, 2010; Urcelay & Miller, 2014). Amongst these, two that stand out are: 1) the context functioning like any other conditioned cue, and 2) the context functioning like an occasion setter. The results from *Chapter 7* are silent about which of these functions is determining context generalisation. Transfer tests (for example, training a cue X in context A and cue Y in context B, then testing in the same or different context) would allow to better determine what kind of function is the context serving. There is also evidence suggesting that different parameters (for example, the amount of training, or the spacing of training trials) can determine which function is dominant over behaviour, so these could be manipulated during training before the test on context generalisation.

8.6.3 Response Generalisation

Whilst this thesis explored three key themes within the avoidance literature warning signals generalisation, safety signals generalisation, and context generalisation, there is one area that it did not explore which is the generalisation of one avoidance response to other responses. In other words, we always trained and tested the same response, except in *Experiment 5* of *Chapter 6* in which we wanted to assess whether the reinforcing properties of a safety signal would also be evident when testing with a new

response that participants had not experienced before (a mouse click) in the context of the avoidance experiment. Transfer is that experiment was reduced by the new response, yet the experiment revealed an effect of the safety signal which was the goal of that experiment. Response generalisation refers to the finding that a stimulus that evoked a particular response can also elicit other responses, as a function of response similarity (Shepard, 1958). This is an interesting aspect of generalisation as it could show how avoidance responses generalise to other, perhaps safe responses. In the context of anxiety, this could involve reassurance seeking behaviour in that an individual with anxiety may look at someone they want to seek assurance from this may then generalise to asking a family member 'will I embarrass myself' and over time this may generalise to them asking other people, asking in safe contexts or checking online forums whether their behaviour would be considered embarrassed. This generalisation represents a shift from the original reassurance-seeking response (eye contact) to engaging in a broader range of reassurance-seeking behaviours (verbally asking) across multiple contexts and social interactions. In avoidance behaviour this could be that participants avoid eye contact with people and this the generalise to other behaviour like avoiding physical contact with people.

There has been some research on response generalisation within the pain avoidance literature. In this experiment, they used a joystick in which participants have to perform different activities which were either gardening or cleaning related (i.e., dusting or pushing a wheel barrow; Glogan et al., 2023). During the task participants could avoid being shocked by using a longer joystick movement which resulted in no shock but less task efficiency. The responses in the safe category were never paired with a shock. The participants were then tested with novel activities (i.e., responses) from each category and

they found that participants generalised their avoidance behaviour to novel activities, from the avoidance category even though they were never paired with the shock and involved a cost. This study highlights that avoidance response behaviour can generalise to other responses.

Moreover, if we wanted to use a design that is similar to other generalisation tasks within this thesis, we could use a modified keyboard in which we replace the letters with colours (from the blue-green continuum). The avoidance task would be the same except two different responses for the CS+ (dark blue) and CSs- (dark green) . These would be positioned on either end of the keyboard and participants would be told that one of the responses will avoid and the other will not. Participants would learn to discriminate and learn that the blue colour is the only one that avoids the aversive outcome and the other does not. In the test phase, we could then instruct the participants that the button they pressed as the CS+ no longer works but they can instead press any of the coloured keys on the sides (a range of colours from the blue-green continuum). These would be randomly arranged. We would then measure the number of avoidance responses participants make and the keys which they use. If they use colours most similar to the CS+ it could show that the avoidance response has generalised to similar responses.

Overall, further research could investigate the generalisation of avoidance responses, and this line of research has started to be explored. but it is in the early stages. Furthermore, using different tasks and designs will allow research to explore different aspects of generalisation and provide insights into how avoidance behaviours can spread in anxiety.

8.7 General Conclusion

The thesis delved into the factors that shape avoidance behaviour and its generalisation in human participants, investigating key elements such as contiguity, stress, development, safety signals, and context. This thesis was able to adapt and develop avoidance protocols to investigate these phenomena online and in the laboratory. This research is driven by avoidance being a core symptom of anxiety disorders, which has received limited attention within the literature – at least much less than fear. The findings of the thesis add to a currently growing literature on avoidance behaviour generalisation. Whilst the main hypothesis that trait anxiety levels will broaden avoidance generalisation did not receive much support, this thesis did demonstrate the reinforcing properties of safety signals and their generalisation, and the effects of contiguity and context on avoidance generalisation. This thesis also explored different factors that can affect generalisation behaviour such as developmental age and stress providing insights into the different factors that can influence generalisation curves.

Whilst this thesis has multiple merits it is not without its limitations including the focus on healthy samples and the types of measures that were and were not used in the experiments. There is a call for future experiments to explore these phenomena in clinical samples and to use a multitude of different measures to try and capture all aspects of avoidance (behavioural and cognitive). Overall, these findings emphasise the complexity of avoidance behaviour and its generalisation, highlighting that multiple factors, including contiguity, age, anxiety, and context, interact in shaping the pattern of responses. This thesis provides first steps in critical areas of the avoidance literature in helping us to understand the underlying mechanisms and the relationship with anxiety. The hope is that

this research has opened up avenues of research which can ultimately have direct implications to the understanding and treatment of anxiety and related disorders.

8.8 References

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9 *Appendix*

9.1 Appendix A1: Aversive Images

For experiments 1-3 and 5 we used IAPS images as the aversive outcome. Participants were shown all six images on the screen and had to rank them from least to the most aversive. Table A1 includes a description of the image, the IAPS number, arousal and valance ratings for each image.

Table 9.1

Description	IAPS	Valance Mean	Valance SD	Arousal Mean	Arousal SD
Vomit	9325	1.89	1.23	6.01	2.54
Spider	1202	3.35	1.77	5.94	2.17
Snake	1050	3.46	2.15	6.87	1.68
Toilet	9301	2.26	1.56	5.28	2.46
Cockroach	7380	2.46	1.42	5.88	2.44
Surgery	3213	2.96	1.94	6.57	1.99

9.2 Appendix A2: Anxiety Analyses for Chapter 2

9.2.1 Experiment 1a

Training

Anxiety was explored within this data to examine if there were differences in those with high and low anxiety levels. During training those with high anxiety made the same number of avoidance responses as those with low anxiety. This was examined with a 3 (CS: CS+, CS-1, CS-2) x 2 (Anxiety: High anxiety and Low anxiety) x 10 (trials) repeated measures ANOVA in which there was no main effect of anxiety, $F(1,49) = .695$, $p = .408$, $\eta_p^2 = .014$. There was a main effect of CS, $F(1.482, 72.622) = 64.205$, $p < .001$, $\eta_p^2 = .567$ and a main effect of trials, $F(6.083, 298.068) = 10.437$, $p < .001$, $\eta_p^2 = .176$. Furthermore, as trials

increased participants made more responses to the CS+ compared to CS-1 and CS-2 shown by a CS by trials interaction, $F(7.738, 379.145) = 185.292$, $p < .001$, $\eta_p^2 = .213$. Furthermore, there was no interaction between anxiety and CS, $F(1.428, 72.622) = .334$, $p = .652$ or between anxiety and trials, $F(6.083, 298.068) = .547$, $p = .775$. Finally, there was no triple interaction between anxiety, cs and trials, $F(7.738, 379.145) = .979$, $p = .45$.

Test

Critically, during test those with high anxiety made the same number of responses to the generalisation stimuli compared to the low anxiety group. A 2 (anxiety levels: high anxiety and low anxiety) x 9 (generalisation stimuli) Repeated measures ANOVA was conducted to examine avoidance responses in test phase and highlighted no main effect of anxiety, $F(1,49) = .349$, $p = .557$. Participants did respond differently to the generalisation stimuli as shown by a main effect of Stimuli, $F(4.387, 214.959) = 24.327$, $p < .001$, $\eta_p^2 = .332$. Finally, there was no interaction between anxiety and stimulus, $F(4.387, 214.959) = 1.28$, $p = .277$. between anxiety and stimulus, $F(4.387, 214.959) = 1.28$, $p = .277$.

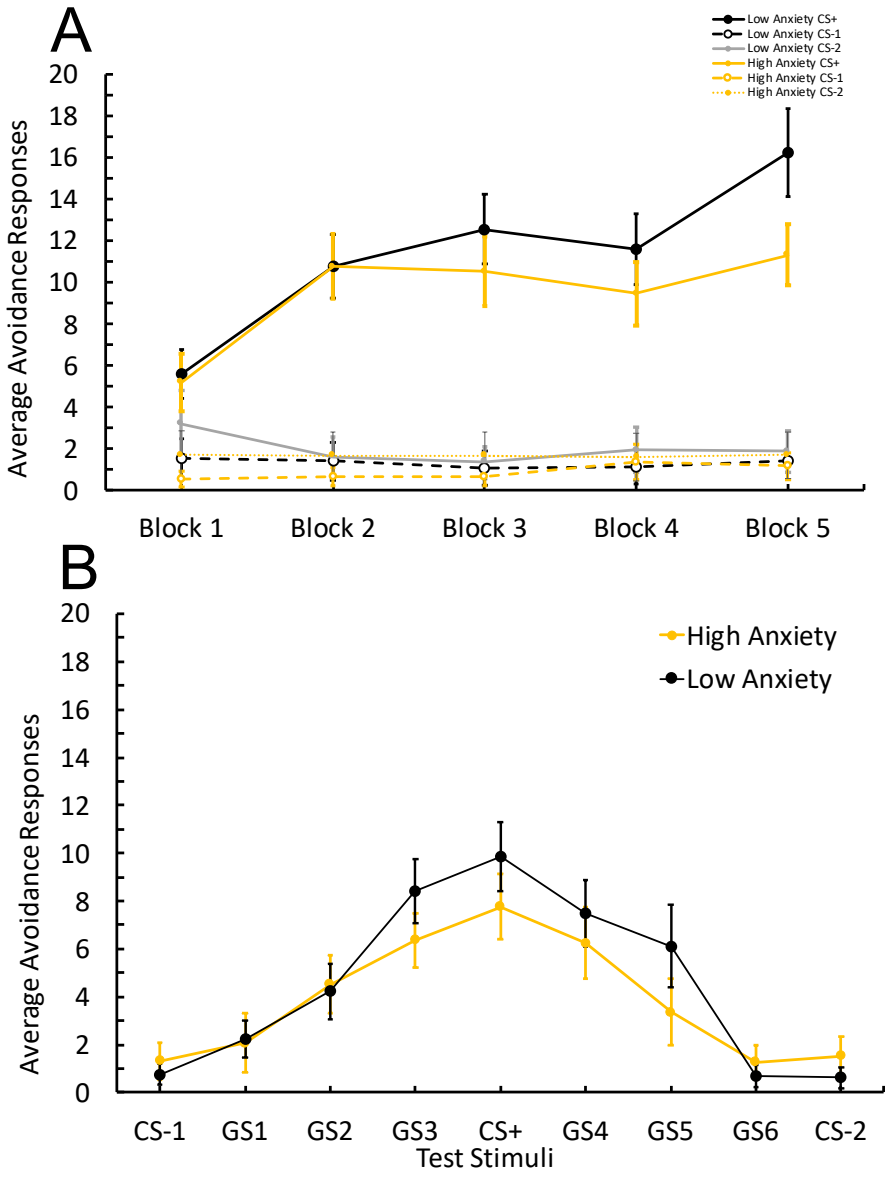

Figure 9.1

Results from Experiment 1a for those with high and low anxiety. (A) depicts the training data in which participants make more avoidance responses to the CS+ compared to the CS-1 and CS-2. (B) depicts the test data showing a generalisation gradient, those with high and low anxiety make a similar number of avoidance responses.

9.2.2 Experiment 1b

Training

Anxiety was explored within this data to examine if there were differences in those with high and low anxiety levels. During training those with high anxiety made the same number of avoidance responses as those with low anxiety. This was examined with a 3 (CS: CS+, CS-1, CS-2) x 2 (Anxiety: High anxiety and Low anxiety) x 10 (trials) repeated measures ANOVA in which there was no main effect of anxiety, $F(1,43) = .719$, $p = .401$, $\eta_p^2 = .016$. There was a main effect of CS, $F(1.129, 48.559) = 64.633$, $p < .001$, $\eta_p^2 = .6$ and a main effect of trials, $F(5.079, 218.38) = 9.161$, $p < .001$, $\eta_p^2 = .176$. Furthermore, as trials increased participants made more responses to the CS+ compared to CS-1 and CS-2 shown by a CS by trials interaction, $F(5.324, 228.937) = 8.995$, $p < .001$, $\eta_p^2 = .173$. Furthermore, there was no interaction between anxiety and CS, $F(1.129, 48.559) = .206$, $p = .682$ or between anxiety and trials, $F(5.079, 218.320) = .1.099$, $p = .362$. Finally, there was no triple interaction between anxiety, cs and trials, $F(5.324, 228.937) = .931$, $p = .466$.

Test

Critically, during test those with high anxiety made the same number of responses to the generalisation stimuli compared to the low anxiety group. A 2 (anxiety levels: high anxiety and low anxiety) x 9 (generalisation stimuli) Repeated measures ANOVA was conducted to examine avoidance responses in test phase and highlighted no main effect of anxiety, $F(1,43) = 1.24$, $p = .272$. Participants did respond differently to the generalisation stimuli as shown by a main effect of Stimuli, $F(3.279, 140.979) = 11.653$, $p < .001$, $\eta_p^2 = .332$. Finally, there was no interaction between anxiety and stimulus, $F(3.279, 140.979) = .433$, $p = .74$.

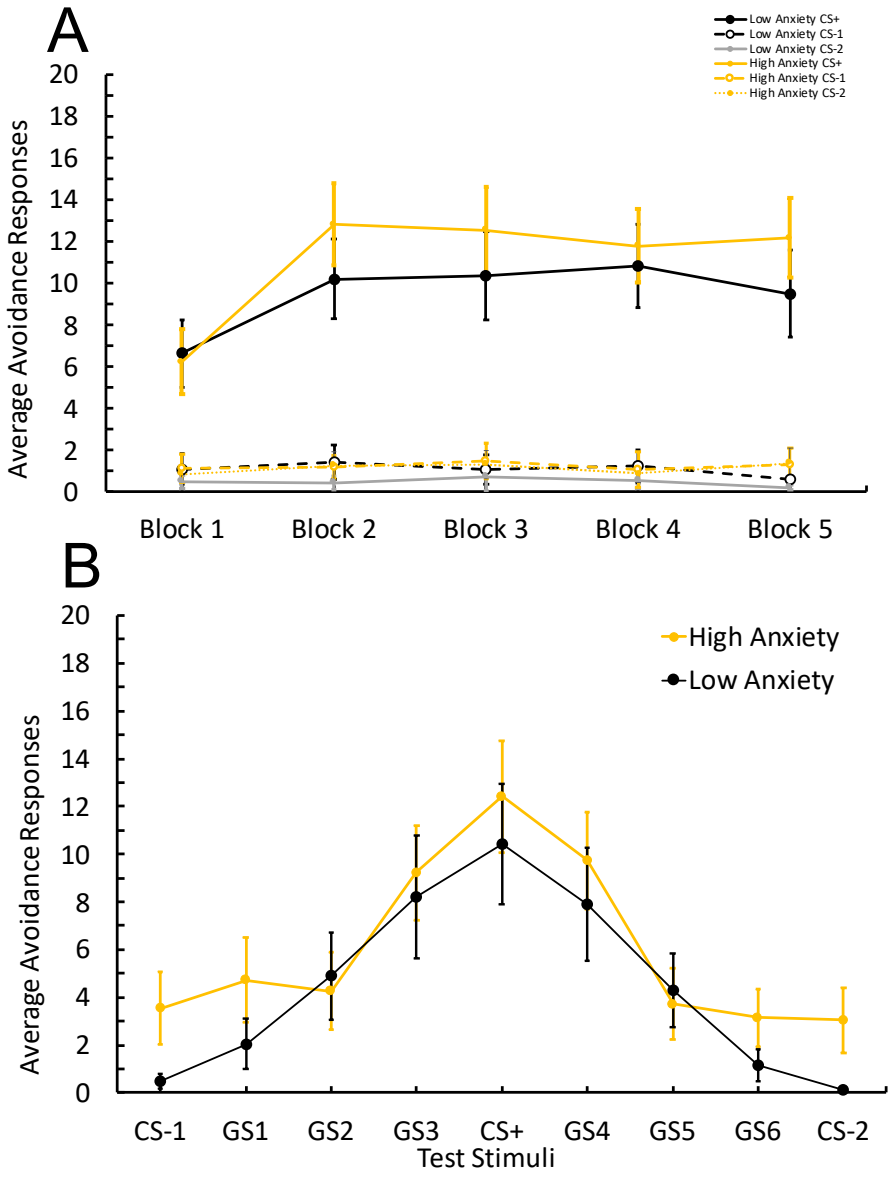

Figure 9.2

Results from Experiment 1b for those with high and low anxiety. (A) depicts the training data in which participants make more avoidance responses to the CS+ compared to the CS-1 and CS-2. (B) depicts the test data showing a generalisation gradient, those with high and low anxiety make a similar number of avoidance responses.

9.2.3 Experiment 2

Training

During training those who had higher anxiety levels made the same number of avoidance responses as those with low anxiety levels. A 2(Group: Trace and Delay) x 3 (CS: CS+, CS-1, CS-2) x 2 (Anxiety: High anxiety and Low anxiety) x 10 (trials) revealed no significant differences between anxiety levels; $F(1,66) = .345$, $p = .559$, $\eta_p^2 = .005$ or groups; $F(1,66) = .007$, $p = .935$, $\eta_p^2 = .000$. Furthermore there was an effect of CS; $F(1.131, 74.651) = 82.015$, $p < .001$, $\eta_p^2 = .554$ and trials; $F(4.773, 315.033) = 3.016$, $p = .013$, $\eta_p^2 = .044$. There was no interaction between CS and anxiety; $F(1.131, 74.651) = .346$, $p = .585$, $\eta_p^2 = .005$ *or* between CS and Group; $F(1.131, 74.651) = 1.858$, $p = .176$, $\eta_p^2 = .027$, or between trials and anxiety; $F(4.773, 315.033) = .819$, $p = .532$, $\eta_p^2 = .012$. There was no interaction between trials and groups; $F(4.773, 315.033) = .597$, $p = .695$, $\eta_p^2 = .009$; *or* between anxiety and group; $F(1,66) = .779$, $p = .381$, $\eta_p^2 = .012$. Avoidance responses to each stimuli did change as the trials progressed as indicated by an interaction between trials and CS; $F(8.642, 570.388) = 7.072$, $p < .001$, $\eta_p^2 = .097$. *There was no triple interaction between CS, Anxiety and group; F(1.1.31, 74.651) = .451,* $p = .528$, $\eta_p^2 = .007$; or between trials, anxiety and group; $F(4.773, 315.033) = .963$, $p = .438$, $\eta_p^2 = .014$. Furthermore there was no triple interaction between CS, trials and anxiety; $F(8.642, 570.388) = .281$, $p = .977$, $\eta_p^2 = .004$; or between CS, trials and group; $F(8.642, 570.388) = .304$, $p = .97$, $\eta_p^2 = .005$. Finally, there was no interaction between CS, trials, anxiety and group; $F(8.642, 570.388) = .592$, $p = .797$, $\eta_p^2 = .009$.

Test

Critically, during test those with high anxiety made the same number of responses to the generalisation stimuli compared to the low anxiety group (see Figure A2.3, panels C and D). A 2 (anxiety levels: high anxiety and low anxiety) x 2(Group: trace and delay) x 9

(generalisation stimuli) Repeated measures ANOVA was conducted to examine avoidance responses in test phase and highlighted no main effect of anxiety, $F(1,66) = .237$, $p = .628$, , $\eta_p^2 = .004$. Participants did respond differently to the generalisation stimuli as shown by a main effect of Stimuli, $F(3.201, 211.253) = 28.643$, $p < .001$, $\eta_p^2 = .303$. There was a difference in avoidance responding depending on group; $F(1,66) = 9.462$, $p = .003$, , $\eta_p^2 = .125$. There was an interaction between stimulus and group; $F(3.201, 211.253) = 3.611$, $p = .01$, , $\eta_p^2 = .052$. There was no interaction between anxiety and group $F(1,66) = .146$, $p = .704$, , $\eta_p^2 = = .002$ or between anxiety and stimulus; $F(3.201, 211.253) = .732$, $p = .542$, , $\eta_p^2 = ,011$. Finally there was o triple interaction between anxiety, group and stimulus; $F(3.201, 211.253) = 1.651$, $p = .176$, , $\eta_p^2 = .024$.

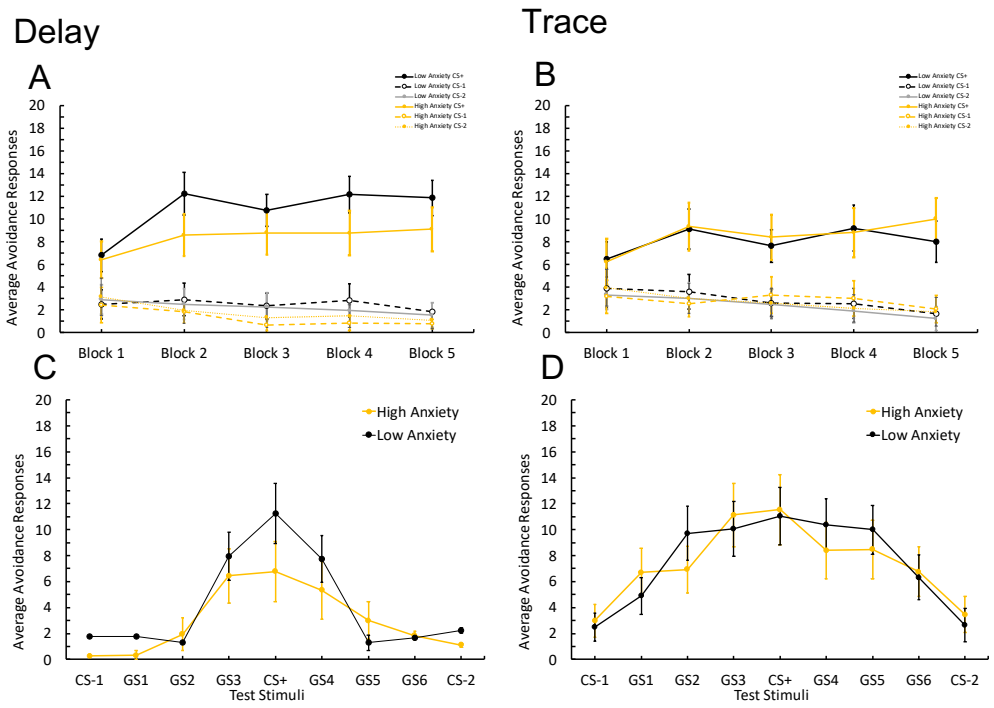

Figure 9.3

Results from Experiment 2 for those with high and low anxiety for the delay and trace groups. in which participants make more avoidance responses to the CS+ compared to the CS-1 and CS-2. (A) depicts the training data for the delay group (B) depicts the training data for the trace group. The test data shows a generalisation gradient that peaks at the CS+ but those in the high and low anxiety groups in both the delay and trace groups made similar number of avoidances responses. (C) test data for the delay group. (D) test data for the trace group.

9.2.4 Experiment 3

Training

During training those who had higher anxiety levels made the same number of avoidance responses as those with low anxiety levels. A 2(Group: Trace and Delay) x 3 (CS: CS+, CS-1, CS-2) x 2 (Anxiety: High anxiety and Low anxiety) x 10 (trials) revealed no significant differences between anxiety levels; $F(1,66) = .117$, $p = .733$, $\eta_p^2 = .002$ or groups; $F(1,66) = .944$, $p = .335$, $\eta_p^2 = .014$. Furthermore, there was an effect of CS; $F(1.080, 71.253) = 88.805$, $p < .001$, $\eta_p^2 = .574$ and trials; $F(6.274, 414.081) = 20.543$, $p < .001$, $\eta_p^2 =$

.237. There was no interaction between CS and anxiety; *F(*1.080, 71.253) = 7.972, *p* = .005, η_p^2 = *.108;* or between CS and Group; *F(*1.080, 71.253) = .266, *p* = .626, η_p^2 = .004. There was no interaction trials and anxiety; *F(*6.274, 414.081) = .1.416, *p* = .204, η_p^2 = .021; or between trials and groups; *F(*6.274, 414.081) = .971, *p* = .447, η_p^2 = *.014; or* between anxiety and group; *F(*1,66) = 2.613, *p* = .111, η_p^2 = *.038*. However, there was an interaction between trials and CS; *F(*8.161, 538.615) = 17.407, *p* <.001, η_p^2 = *.209. Moreover, there was no triple interaction between CS, Anxiety and group; F(1.080, 71.253)* = *.451, p* = .528, η_p^2 = .007; or between trials, anxiety and group; *F(*4.773, 315.033) = .230, *p* = .651, η_p^2 = .003. There was a marginal triple interaction between CS, trials and anxiety; *F(*8.161, 538.615) = 2.0121, *p* = .042, η_p^2 = .030; but there was no triple interaction between CS, trials and group; *F(*8.161, 538.615) = .942, *p* = .493, η_p^2 = .014. Finally, there was no interaction between CS, trials, anxiety and group; *F(*8.161, 538.615) = .885, *p* = .530, η_p^2 = .013.

Test

Critically, during test those with high anxiety made the same number of responses to the generalisation stimuli compared to the low anxiety group. A 2 (anxiety levels: high anxiety and low anxiety) x 2 (Group: trace and delay) x 9 (generalisation stimuli) Repeated measures ANOVA was conducted to examine avoidance responses in test phase and highlighted no main effect of anxiety, *F(*1,66) = .082, *p* = .775, , η_p^2 = .001 . Participants did respond differently to the generalisation stimuli as shown by a main effect of Stimuli, *F(*3.262, 215.266) = 29.99, *p* <.001, η_p^2 = .312. There was a difference in avoidance responding depending on group; *F(*1,66) = 9.291, *p* = .003, , η_p^2 = .123. There was an interaction between stimulus and group; *F(*3.262, 215.266) = 1.732, *p* = .157, , η_p^2 =.026. There was no interaction between anxiety and group *F(*1,66) = .123, *p* = .727, , η_p^2 = .002 or between anxiety and stimulus; *F(*3.262, 215.266) = 2.97, *p* = .029, , η_p^2 = .043. Finally there

was no triple interaction between anxiety, group and stimulus; $F(3.262, 215.266) = .582$, $p = .642$, , $\eta_p^2 = .009$.

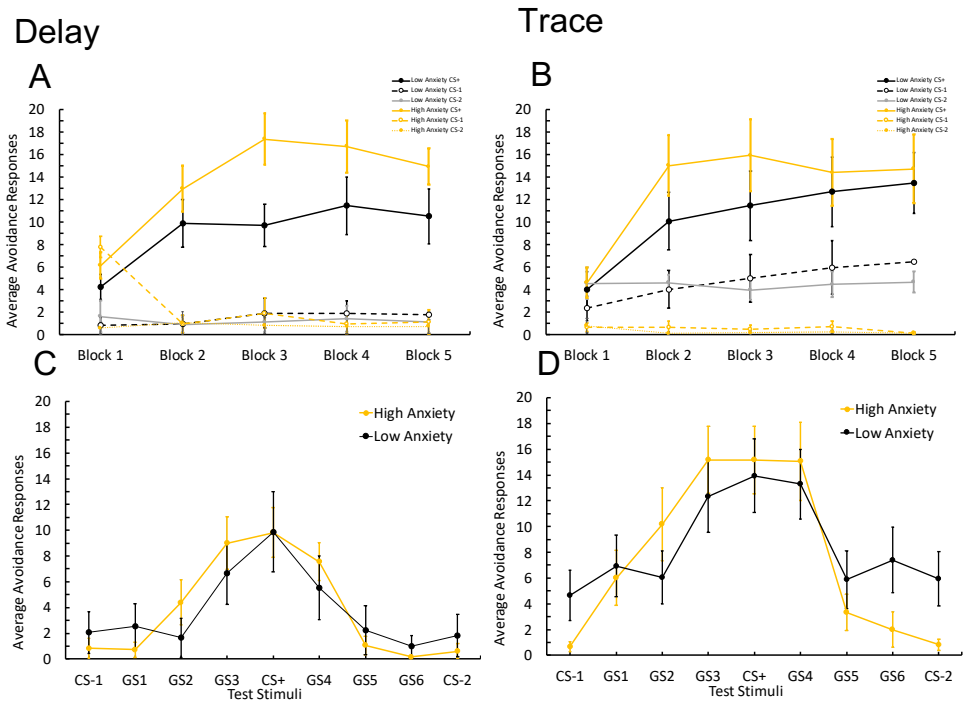

Figure 9.4

Results from Experiment 3 for those with high and low anxiety for the delay and trace groups. in which participants make more avoidance responses to the CS+ compared to the CS-1 and CS-2. (A) depicts the training data for the delay group (B) depicts the training data for the trace group. The test data shows a generalisation gradient that peaks at the CS+ but those in the high and low anxiety groups in both the delay and trace groups made similar number of avoidances responses. (C) test data for the delay group. (D) test data for the trace group.

9.2.5 Experiment 4

Training

Participants made the same amount of avoidance responses regardless of group and anxiety levels. A 2(Group: Trace and Delay) x 3 (CS: CS+, CS-1, CS-2) x 2 (Anxiety: High anxiety and Low anxiety) x 10 (trials) revealed no main effect of Anxiety, $F(1,38) = 2.336$ $p = .135$, $\eta_p^2 = .058$ and no main effect of groups $F(1,36) = .166$, $p = .686$, $\eta_p^2 = .004$. However, there were effects of CS; $F(1.01, 38.368) = 59.225$, $p < .001$, $\eta_p^2 = .609$ and effect of trials $F(3.602, 136.873) = 5.568$, $p < .001$, $\eta_p^2 = .128$. There was an interaction between CS and

Trials, $F(4.848, 184.239) = 19.845$, $p < .001$, $\eta_p^2 = .343$ and between CS and Group, $F(1.865, 70.852) = 3.317$, $p = .045$, $\eta_p^2 = .08$. Avoidance responses also changed for each CS as trials increased as shown by an interaction between trials and groups $F(5.332, 202.63) = 1.742$, $p = .122$, $\eta_p^2 = .044$.

There was no interaction between CS and Anxiety, $F(1.01, 38.368) = .231$, $p = .636$, $\eta_p^2 = .006$ or between Anxiety and trials, $F(3.602, 136.873) = .538$, $p = .690$, $\eta_p^2 = .014$; or between Anxiety and group, $F(1,38) = .69$, $p = .808$, $\eta_p^2 = .002$. There was no triple interaction between group, cs and anxiety, $F(1.865, 70.852) = .573$, $p = .555$, $\eta_p^2 = .015$ or between group, trials and anxiety, $F(5.332, 5.332) = 1.732$, $p = .124$, $\eta_p^2 = .044$. Furthermore, there was no triple interaction between cs, trials and anxiety, $F(4.848, 184.239) = 1.227$, $p = .299$, $\eta_p^2 = .031$ or between group, cs, trials $F(5.781, 219.684) = .716$, $p = .632$, $\eta_p^2 = .019$. Finally, there was no interaction between group, cs, trials and anxiety, $F(5.781, 219.684) = .682$, $p = .659$, $\eta_p^2 = .018$.

Test

A 2(group: trace and delay) x 2(Anxiety: high and low) x 9(stimuli) revealed that there was no effect of anxiety, $F(1,38) = 2.32$, $p = .136$, $\eta_p^2 = .058$. There was an effect of stimulus, $F(1.914, 68.894) = 21.786$, $p < .001$, $\eta_p^2 = .377$ and an effect of group, $F(1,38) = 18.602$, $p < .001$, $\eta_p^2 = .329$. There was no interaction between CS and group, $F(4.031, 153.162) = 1.559$, $p = .188$, $\eta_p^2 = .039$; there was also no interaction between group and anxiety, $F(1,38) = .041$, $p = .840$, $\eta_p^2 = .001$. Furthermore, there was no interaction between Cs and anxiety, $F(1.898, 72.105) = .665$, $p = .501$, $\eta_p^2 = .017$ nor was there a triple interaction between anxiety, group and stimulus, $F(4.031, 153.162) = 1.197$, $p = .314$, $\eta_p^2 = .031$.

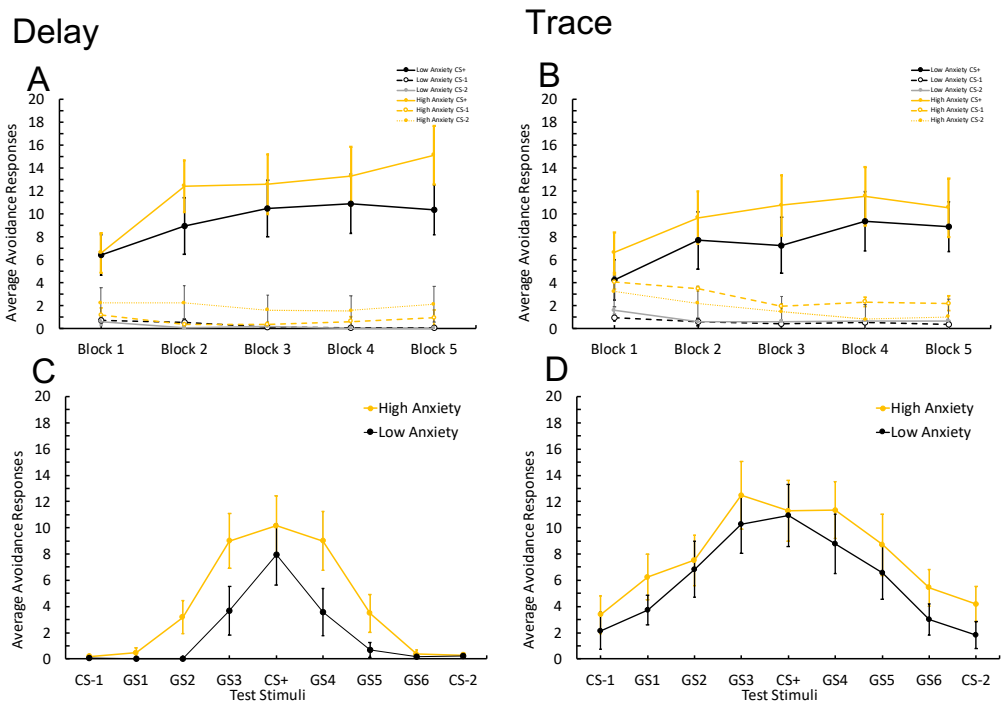

Figure 9.5

Results from Experiment 4 for those with high and low anxiety for the delay and trace groups. in which participants make more avoidance responses to the CS+ compared to the CS-1 and CS-2. (A) depicts the training data for the delay group (B) depicts the training data for the trace group. The test data shows a generalisation gradient that peaks at the CS+ but those in the high and low anxiety groups in both the delay and trace groups made similar number of avoidances responses. (C) test data for the delay group. (D) test data for the trace group.

Correlation data with Experiments 1-3

A Pearson correlation was conducted to examine the relationships between Trait anxiety score, Width+, Width-, and Height. The analysis revealed that Trait score was not significantly correlated with SD+ (r = -.076, p = .244), SD- (r = .016, p = .803), or Height (r = -.029, p = .660).SD+ was strongly and positively correlated with SD- (r = .788, p < .001) and negatively correlated with Height (r = -.531, p < .001). Similarly, SD- showed a strong negative correlation with Height (r = -.511, p < .001).

9.3 Appendix A3: Anxiety Analyses for Chapter 6

9.3.1 Experiment 1

Training

There was no difference in avoidance responses for the CS+ and the CS- (see Figure S2A) $F(1, 70) = .019$, $p = .89$. Furthermore those with high and low anxiety made a similar amount of avoidance responses, $F(1,70) = 2.23$, $p = .140$. There was a main effect of trials $F(3.664, 256.481) = 10.01$, $p < .001$, $\eta p^2 = .125$. There was no interaction between anxiety and trials $F(3.664, 256.48) = .603$, $p = .646$; or between CS and anxiety $F(1, 70) = .044$, $p = .834$. Finally, there was no triple interaction between anxiety, CS and trials $F(8.091, 566.341) = 1.103$, $p = .139$.

Number of safety signals produced

As the trials increased participants produced more safety signals, $F(10.59, 741.59) = 7.256$, $p < .001$, $\eta p^2 = .094$. However, there was no difference between those with high and low anxiety scores, $F(1,70) = .002$, $p = .926$. Furthermore, there was no interaction between anxiety and number of safety signals produced $F(10.594, 741.59) = 1.043$, $p = .304$.

Test

Those with high anxiety scores made more avoidance response than those with low anxiety scores, $F(1,70) = 3.963$, $p = .05$, $\eta p^2 = .054$ (see Figure S2B). Also participants with made more responses to the Gabor that produced the safety signal compared to the Gabor that produced nothing, $F(1,70) = 6.312$, $p = .014$, $\eta p^2 = .083$. Also as the trials increased the participants made fewer avoidance responses, $F(3.499, 244.922) = 4.916$, $p < .001$, $\eta p^2 = .066$. Furthermore, there was and no interactions between signal and trials $F(4.788, 335.141) = 1.431$, $p = .215$, $\eta p^2 = .020$; or between trial and anxiety $F(3.499,$

244.922) = 1.431, p = .215 or signal and anxiety $F(1,70)$ = .846, p = .356. Finally, there was also no triple interaction $F(4.788, 335.141)$ = 1.45, p = .208.

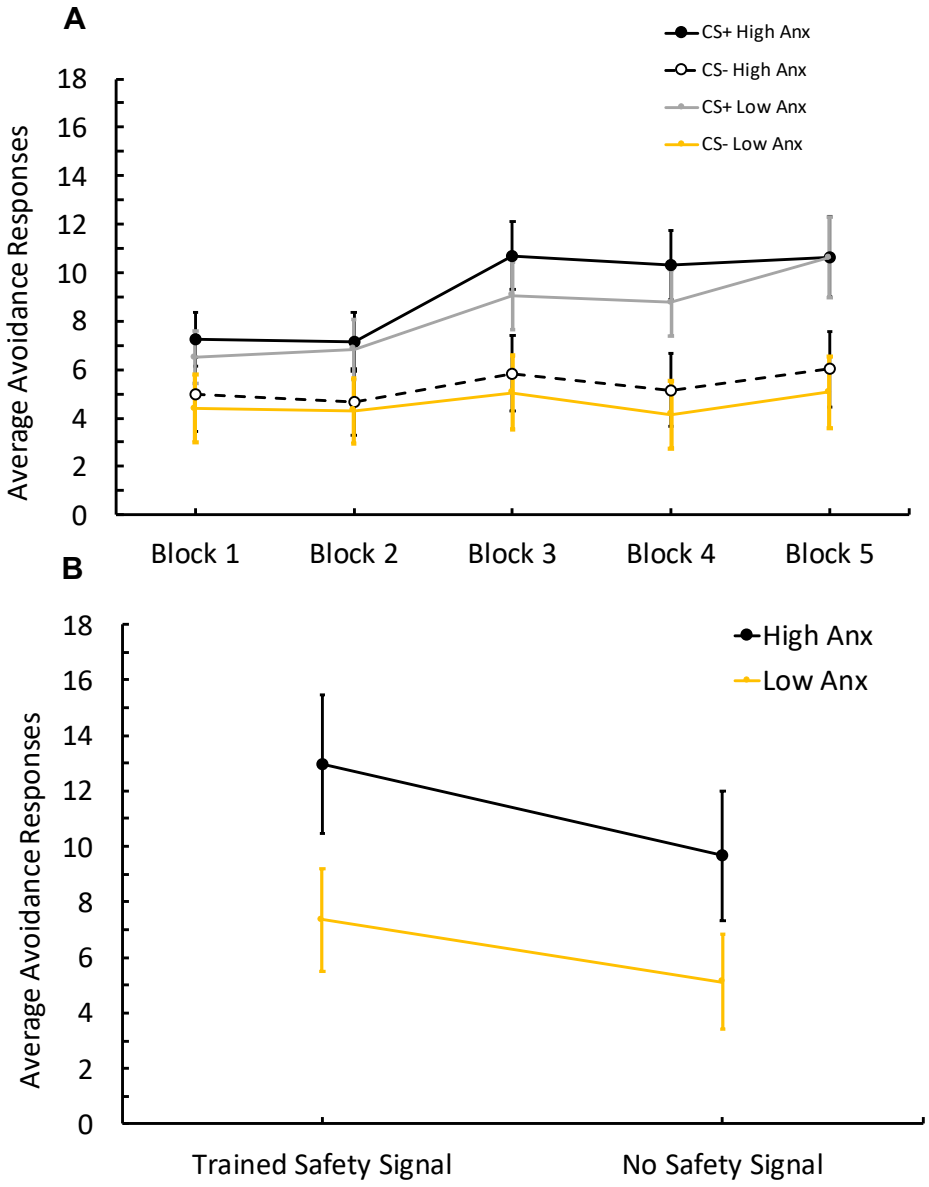

Figure 9.6
Results from Experiment 1 for high and low anxiety scorers (A) Training data depicting avoidance responses to the CS+ and CS-. Each block contains 3 trials. (B) Test data comparing the trained signal to no signal.

9.3.2 Experiment 2

Training

In Experiment 2 a mixed ANOVA revealed that there was no difference in avoidance responses during training for high and low anxiety scorers, $F(1,53) = 1.303$, $p = .259$, $\eta p^2 = .795$ (see Figure S3a). Participants made more responses to the CS+ compared to the CS-, $F(1, 53) = 7.312$, $p = .009$, $\eta p^2 = .121$. There was also a main effect of trials $F(7.05, 373.591) = 5.602$, $p < .001$. Furthermore, participants made more responses to the CS+ compared to the Cs_ as trials progressed which was shown through an interaction, $F(8.66, 459.305) = 3.225$, $p < .001$, $\eta p^2 = .057$. However there was no interaction between anxiety and trials $F(7.05) = .713$, $p = .762$, $\eta p^2 = .013$, or between CS and anxiety scores $F(1,53) = .762$, $p = .387$, $\eta p^2 = .014$. Finally, there was also no triple interaction between anxiety scores, CS and trials $F(8.66, 459.305) = .515$, $p = .858$, $\eta p^2 = .01$.

Number of signals produced

As the trials increased participants produced more safety signals, $F(10.344, 548.221) = 8.646$, $p < .001$, $\eta p^2 = .140$. However, there was no difference between high and low anxiety scorers in the number of safety signals they produced, $F(1,53) = .001$, $p = .972$. Also there was no interaction between trials and anxiety $F(10.344, 548.221) = .575$, $p = .840$, $\eta p^2 = .011$.

Test

There was no difference in avoidance behaviour between the Gabor that produced the trained safety signal and the Gabor that produced a new signal, $F(1,53) = .093$, $p = .757$, $\eta p^2 = .002$ (see Figure S3B). Critically, those with high anxiety and low anxiety made the same number of responses during the test $F(1,53) = .000$, $p = .985$, $\eta p^2 = .000$. Participants did make less responses as the trials increased suggesting extinction $F(3.793, 178.049) = 3.793$, $p = .009$, $\eta p^2 = .067$. Furthermore there was no interaction

between safety signal and anxiety $F(1,53) = .352$, $p = .556$, $\eta p^2 = .007$. or anxiety and trials $F(3.359, 178.049) = 1.487$, $p = .216$, $\eta p^2 = .027$. Furthermore, there was no interaction between Signal and trials $F(5.194, 275.296) = 1.447$, $p = .205$, $\eta p^2 = .027$ and there was no interaction between anxiety, signal and trials $F(5.194, 275.296) = 1.935$, $p = .086$, $\eta p^2 = .035$.

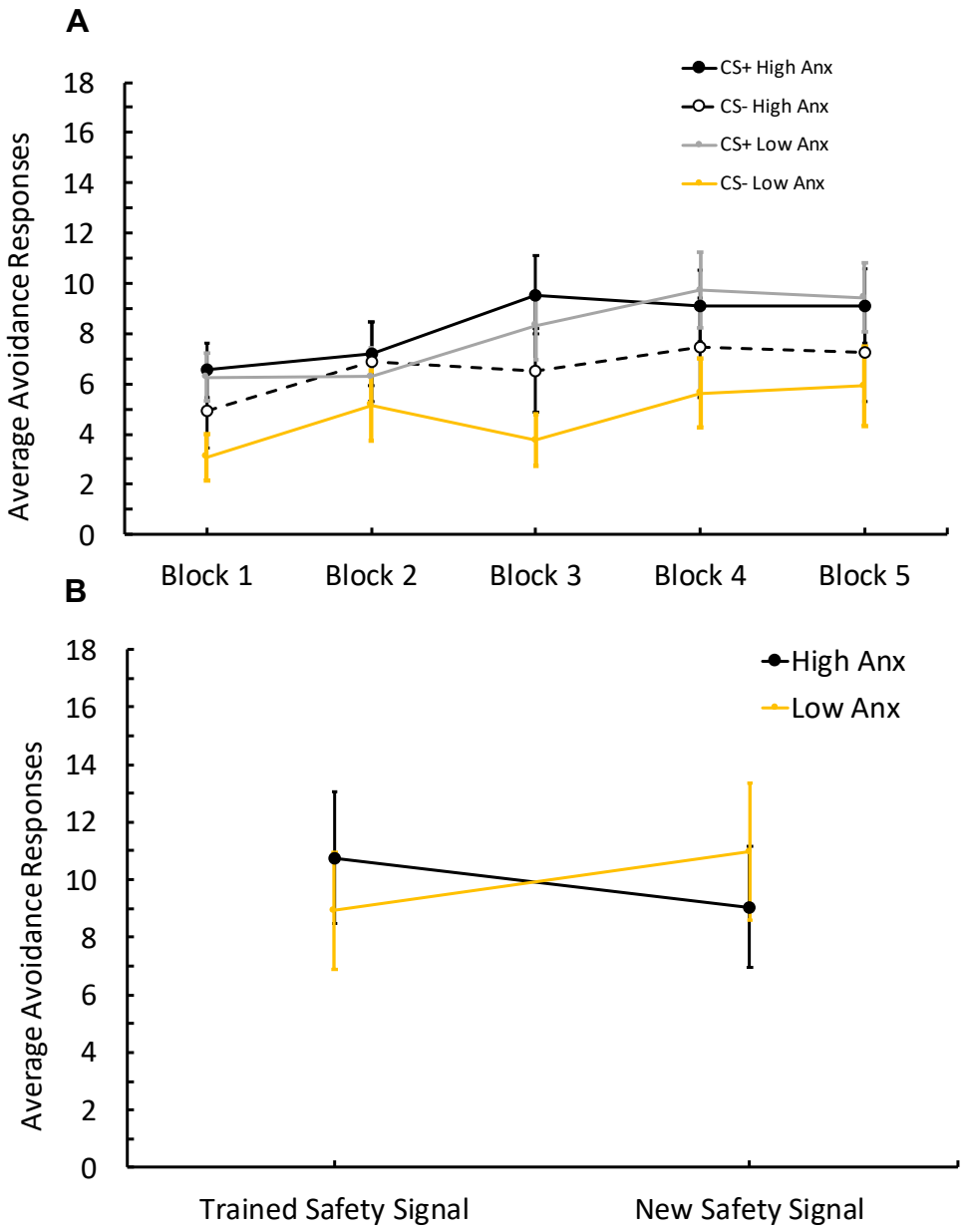

Figure 9.7
Results from Experiment 2 for high and low anxiety scorers (A) Training data depicting avoidance responses to the CS+ and CS-. Each block contains 3 trials. (B) Test data comparing the trained signal to a new signal.

9.3.3 Experiment 3

Training

Those with high anxiety made more responses compared to those with low anxiety scores, $F(1,72) = 5.461$, $p = .022$, $\eta p^2 = .07$ (see Figure S4A). Participants made more responses to the CS+ compared to the CS- as trials increased as shown by an interaction between trials and signal $F(7.885, 567.742) = 5.360$, $p < .001$, $\eta p^2 = .069$. Furthermore this was highlighted with main effects of CS, $F(1,72) = 31.342$, $p < .001$, $\eta p^2 = .303$ and trials $F(7.975, 574.223) = 9.153$, $p < .001$, $\eta p^2 = .113$. However, there was no interaction between signal and anxiety $F(1,72) = .104$, $p = .748$, .001. or between trials and anxiety $F(7.975,574.223) = 2.067$, $p = .037$, $\eta p^2 = .028$. There was also no interaction between signal, anxiety and trial $F(7.885, 567.742) = 1.492$, $p = .158$, $\eta p^2 = .02$.

Number of signals produced

Participants produced more safety signals as the trials increased, $F(9.166,659.950) = 12.637$, $p < .001$, $\eta p^2 = .149$. However, there was no difference in number of safety signals produced for high and low anxiety scorers, $F(1,72) = .587$, $p = .446$, $\eta p^2 = .008$. Moreover there was no interaction between anxiety and trials $F(9.166,659.950) = .892$, $p = .533$, $\eta p^2 = .012$.

Test

Critically, there was no difference in avoidance responses for the Gabor that produced the trained safety signal compared to the Gabor that produced the new novel safety signal, $F(1,72) = 1.385$, $p = .243$, ηp^2 .019 (see Figure S4B). Furthermore, there was no difference between high and low anxiety scorers, $F(1,72) = .815$, $p = .37$, $\eta p^2 = .011$. As trials increased participants made fewer avoidance responses as shown by a main effects of trials, $F(3.901, 280.899) = 4.763$, $p < .001$. There was no interaction between anxiety and signal $F(1,72) = .053$, $p = .819$, $\eta p^2 = .019$; or between signal and trials $F(5.058, 364.202) =$

.836, p = .558, ηp^2 = .011. Moreover, there was no interaction between anxiety and trials $F(3.901, 280.899)$ = .800, p = .531, .011; and there was no interaction between anxiety, signal and trials $F(5.058,364.202)$ = 2.02, p = .074, ηp^2 = .027.

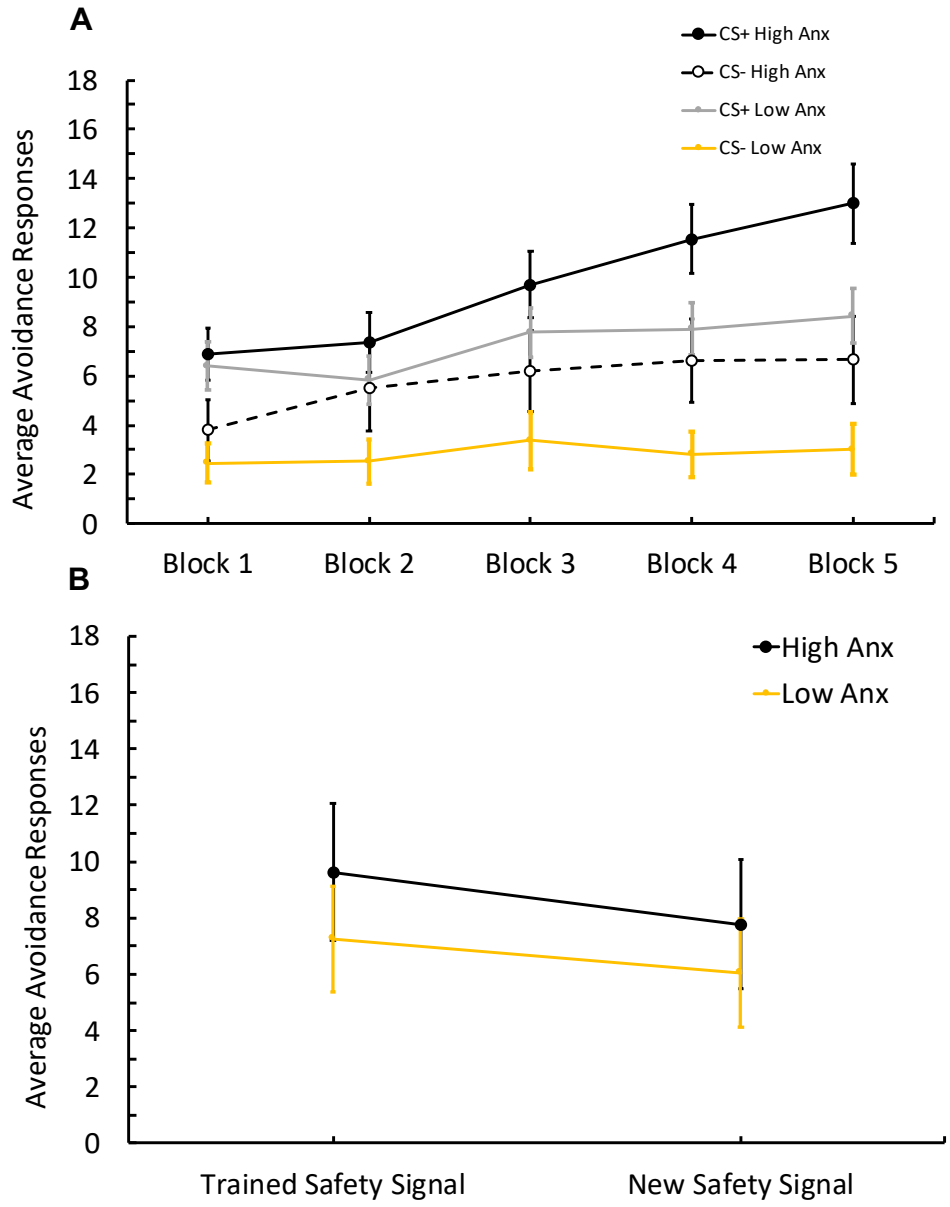

Figure 9.8
Results from Experiment 3 for high and low anxiety scorers (A) Training data depicting avoidance responses to the CS+ and CS-. Each block contains 3 trials. (B) Test data comparing the trained signal to a new signal.

9.3.4 Experiment 4

Training

There were no differences in avoidance behaviour for the CS+ compared to the CS- $F(1,39) = 2.788$, $p = .103$ (see Figure S5A). Furthermore, there was no difference in avoidance behaviour for high and low anxiety scorers, $F(1,39) = 2.31$, $p = .137$. As the trials increased the participants made more responses to the CS+ compared to the CS- as revealed by interaction, $F(4.866, 189.787) = 5.347$, $p < .001$, $\eta p^2 = .121$. Moreover, there was an effect of trials $F(3.349, 130.61) = 8.232$, $p < .001$, $\eta p^2 = .174$. Furthermore, there was no interaction between CS and anxiety scores, $F(1,39) = .015$, $p = .903$; or between trials and anxiety $F(3.349, 130.61) = 1.124$, $p = .344$. Finally, there was no interaction between anxiety, CS and trials, $F(4.866, 189.787) = 1.23$, $p = .280$.

Number of safety signals produced

As the trials increased the participants produced more safety signals, $F(5.624, 219.341)$. Those with high and low anxiety produced the same amount of safety signals $F(1,39) = .609$, $p = .44$. Furthermore there was no interaction between anxiety and number of safety signals produced $F(5.624,219.34) = 1.9$, $p = .087$.

Test

Those with low anxiety made more avoidance responses than the high anxiety people $F(1,39) = 5.076$, $p = .03$, $\eta p^2 = .115$ (see figure S5B). Participants also made less avoidance responses as the trials increased, $F(2.763, 107.767) = 6.599$, $p < .001$, $\eta p^2 = .145$. Participants made the same amount of avoidance responses to the Gabor that produced the safety signal and the Gabor that produced nothing, $F(1,39) = 1.962$, $p = .169$. Furthermore, there was no interaction between trials and signal, $F(4.447, 173.44) = .722$, $p = .592$; or between trials and anxiety, $F(2.763, 107.767) = 6.599$, $p = .063$. Moreover, there

was no interaction between signal and anxiety, $F(1,39) = .949$, $p = .336$; finally, there was no triple interaction, $F(4.447, 173.44) = .447$, $p = .794$.

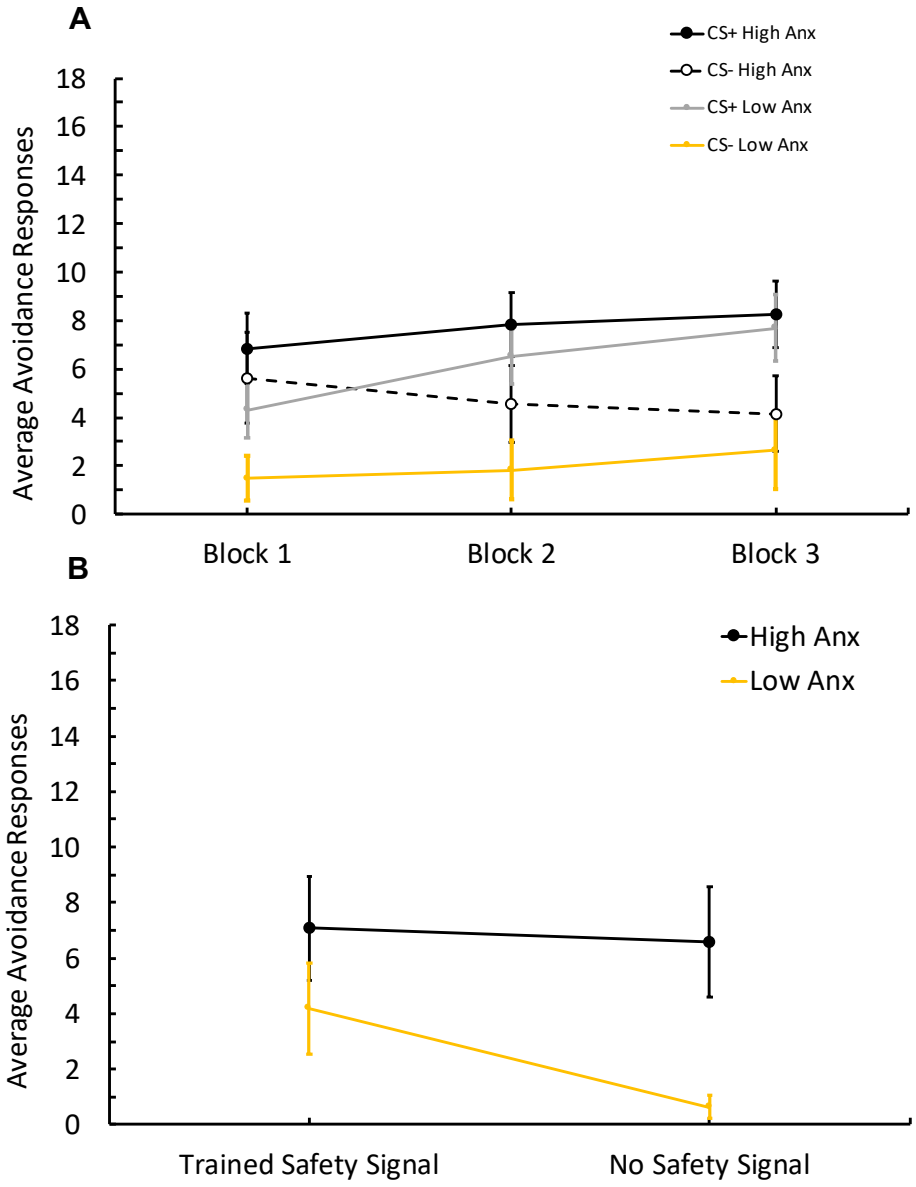

Figure 9.9
Results from Experiment 4 for high and low anxiety scorers (A) Training data depicting avoidance responses to the CS+ and CS-. Each block contains 3 trials. (B) Test data comparing the trained signal to no signal.

9.3.5 Experiment 5

Training

Those with high anxiety made the same responses as those with low anxiety scores, $F(1,54) = .038$, $p = .846$ (see Figure S6A). Participants made more responses to the CS+ compared to the CS- as trials increased as shown by an interaction between trials and signal $F(8.781, 456.624) = 5.384$, $p < .001$, $\eta p^2 = .094$. Furthermore, this was highlighted with main effects of CS, $F(1,54) = 39.01$, $p < .001$, $\eta p^2 = .429$ and trials $F(7.452, 387.51) = 2.536$, $p = .013$, $\eta p^2 = .047$. There was an interaction between signal and anxiety $F(1,52) = 4.51$, $p = .038$, .08. But there was no interaction between trials and anxiety $F(7.452, 387.513) = 1.027$, $p = .423$. There was also no interaction between signal, anxiety and trial $F(8.781, 456.63) = 1.75$, $p = .078$.

Number of safety signals produced

As the trials increased the participants produced more safety signals, $F(9.14, 475.48) = 3.94$, $p < .001$. Those with high and low anxiety produced the same amount of safety signals $F(1,52) = 2.74$, $p = .104$. Furthermore, there was no interaction between anxiety and number of safety signals produced $F(9.14, 475.48) = .905$, $p = .522$.

Test

Critically, there was no difference in avoidance responses for the Gabor that produced the trained safety signal compared to the Gabor that produced the new novel safety signal, $F(1,52) = 3.01$ $p = .089$ (see Figure S6B). Furthermore, there was no difference between high and low anxiety scorers, $F(1,52) = 2.877$, $p = .096$. As trials increased participants made the same number of avoidance responses as there was no main effect of trials, $F(3.537, 183.93) = .682$, $p = .587$. There was no interaction between anxiety and signal $F(1,52) = 1.01$, $p = .320$, $\eta p^2 = .019$; or between signal and trials $F(3.8623, 200.845) = .554$, $p = .690$. Moreover, there was no interaction between anxiety

and trials *F(3.54, 183.931)* = 1.409, *p* = .237; and there was no interaction between anxiety, signal and trials *F(*3.682,200.845) = 1.873, *p* = .119.

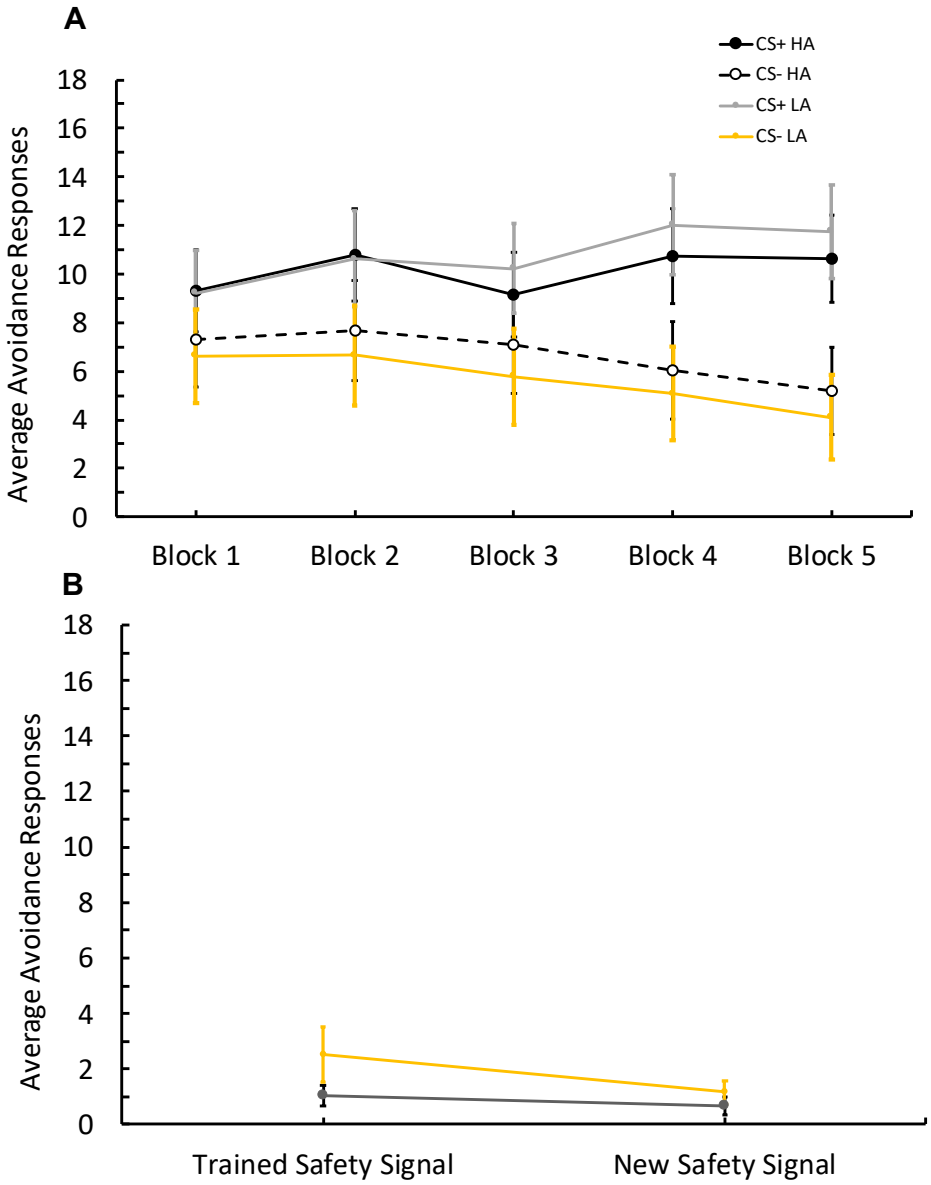

Figure 9.10
Results from Experiment 5 for high and low anxiety scorers (A) Training data depicting avoidance responses to the CS+ and CS-. Each block contains 3 trials. (B) Test data comparing the trained signal to a new signal.

Training Data for the online Experiments 1, 2, 3 and 5

When assessing all of the training data together for participants in Experiments 1, 2, 3 and 5, they make more responses to the CS+ than the CS- as the trials increase,

F(10.944, 2781.59) = 12.716, $p < .001$, $\eta p^2 = .048$ (*see Figure S7*). Furthermore, those with high anxiety made the same amount of avoidance responses as those with low anxiety, *F*(1,253) = 3.405, $p = .066$ although there was a tendency for higher responding in participants with high anxiety. Furthermore, there were main effects of CS, *F*(1,253) = 85.605, $p < .001$, $\eta p^2 = .253$; and trials, *F*(8.837, 2235.88) = 14.122, $p < .001$, $\eta p^2 = .053$. Moreover, there was no interaction between anxiety and trials, *F*(8.837, 2235.88) = .959, $p = .471$. However, there was no interaction between anxiety and CS, *F*(1,253) = .496, $p = .482$; and there was no triple interaction between CS, trials, and anxiety *F*(10.944, 2781.59) = .743, $p = .697$.

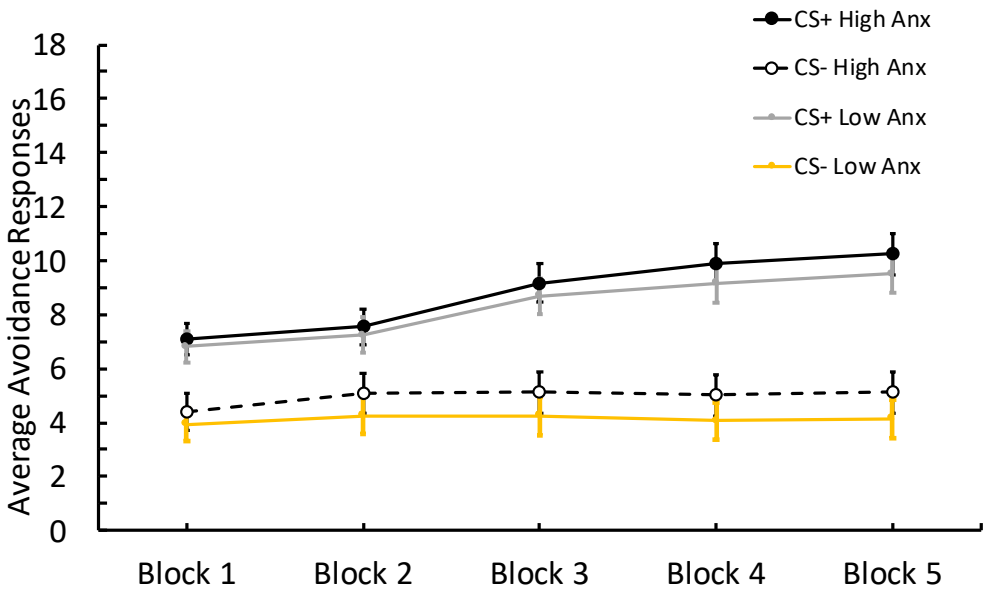

Figure 9.11
Results from the training data for Experiment 1-3 and 5 for high and low anxiety scorers (A) Training data depicting avoidance responses to the CS+ and CS-. Each block contains 3 trials. Participants respond more to the CS+ compared to the CS- and those with high anxiety make more avoidance responses to both the CSs compared to the low anxiety scorers.