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Acquisition and Extinction across Multiple Virtual Reality Contexts: Implications for Specific Phobias and Current Treatment Methods

A Thesis

Presented to

College of Healthcare Sciences

Department of Psychology

James Cook University

In Partial Fulfilment of the Requirements for the degree of

Doctor of Psychology (Clinical Psychology)

by

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Abstract

Treatment for people suffering from Specific Phobias centre on the use of exposure-based approaches to reduce or eliminate the fear response towards the phobic stimuli. Despite the efficacy of this form of therapy, relapse do occur. In order to better understand the mechanisms underlying relapse, we look towards laboratory research focusing on different forms of recovery from extinction. A context driven form of recovery phenomenon is known as Renewal. When testing is done outside of the extinction context, renewal occurs. The shift in context is an important consideration in phobia treatment as it suggests that treatment gains may not benefit from generalization to other contexts outside of the therapists' offices. A form of manipulation to improve the robustness of extinction training is by conducting it across multiple contexts. Although researchers have generally found it to be effective at reducing renewal, a previous study (Gunther et al., 1998, study 2) found that when rats experienced fear acquisition across multiple contexts, it reduced the supposed benefit of extinction in multiple context. This scenario more readily mirrors real world phobia acquisition and have received significantly less attention.

This thesis reviews the definition behind specific phobias, its aetiological models and current treatment methods. Then, focuses on laboratory investigations into recovery of fear phenomena related to phobia relapse and subsequent extinction manipulations seeking to improve extinction robustness. Conducting extinction treatment across multiple contexts has been widely demonstrated to reduce recovery-from-extinction effects such as renewal. Fewer studies, however, have demonstrated that conducting acquisition across multiple contexts results in more renewal and can offset the beneficial effects of extinction in multiple contexts (Gunther et al., 1998). This study sought to replicate these effects in humans using a conditioned expectation paradigm and virtual reality contexts. Sixty-one participants were divided into four groups, half of which received acquisition of a virtual cup-spider association

in one context, and the other half received equivalent acquisition across three contexts. Orthogonal to this, the groups received extinction of the cup-spider association in one or three contexts. All groups were tested for ABC renewal. The results showed less renewal in participants that experienced acquisition in one context and extinction in multiple contexts, which replicates previous demonstrations of the extinction in multiple context effect. Conducting acquisition across multiple contexts, however, resulted in more renewal, regardless of whether extinction was also conducted across multiple contexts. This study demonstrated that learning associations across multiple contexts can have a negative impact on subsequent extinction learning. This is the first demonstration of this effect in humans. These results are important because of the close parallel between extinction treatment and recovery from extinction and exposure therapy and relapse. It highlights the importance of considering the learning history of negative experiences in clinical treatment and more importantly, suggests that the likelihood that most phobias are acquired over multiple contexts may interfere with the effectiveness of subsequent treatment. The study also provided some evidence towards the use of emerging VR technology as a medium for studying human learning across multiple contexts.

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CHAPTER 1

INTRODUCTION

Current treatments for persons with specific phobias mostly focus on the use of Cognitive Behavioural Therapy, with a specific emphasis on exposure therapy. Exposure therapy is the treatment of choice when managing patients with specific phobias (Kaczkurkin & Foa, 2015). A meta-analysis found that exposure-based treatment resulted in larger effect sizes than no treatment, and in-vivo exposure to the phobic stimulus was superior to alternative forms of exposure (e.g., imaginal, virtual reality) (Wolitzky-Taylor, Horowitz, Powers, & Telch, 2008b). While exposure therapy has proven to be extremely effective in reducing fear response to phobic stimulus, the long-term effectiveness are inconclusive and relapse occurs often (Wolitzky-Taylor, Horowitz, Powers, & Telch).

Laboratory studies investigating extinction and recovery-from-extinction have been taken as experimental analogues for exposure therapy and relapse. These studies have suggested that the robustness of the exposure treatment could be increased if exposure treatment is conducted across multiple contexts (e.g., Craske et al., 2014; Shiban et al., 2013b). Increasing the generalization of exposure (extinction) training has been found to reduce renewal or relapse of fear responding (Dunsmoor, Ahs, Zielinski, & LaBar, 2014a; Gunther, Denniston, & Miller, 1998; Shiban, Pauli, & Muhlberger, 2013b; Shiban, Schelhorn, Pauli, & Muhlberger, 2015a). However, this advantage is seemingly negated when fear acquisition also spans over multiple contexts (Gunther et al., 1998, study 2). This may be due to proactive interference, which occurs when previous learning interferes with new learning. In other words, acquiring fear responses across multiple contexts is thought to interfere with subsequent extinction training over multiple contexts (eg., Miguez, Laborda, & Miller, 2014b).

Most research on context effects have been conducted with rats, which allows the researcher to have complete control over the rats' exposure to various and limited environments. Contextual manipulations in human behavioural research are more challenging because the distinctiveness of contexts is generally not as salient due to the broader concept of the environment which humans have. Prior studies have attempted to manipulate contexts by using multiple classrooms or laboratories and varying the audio and/or visual stimuli within these rooms (e.g., MacKillop & Lisman, 2008a; Neumann, 2006; Neumann, Lipp, & Cory, 2007). However, due to logistical reasons, these places are usually located in the same university building, and they have similar layouts or sizes. Others have created multiple contexts by varying the backdrop on computer screens (Glautier, Elgueta, & Nelson, 2013b) or LCD projectors (Hermann, Stark, Milad, & Merz, 2016). But images or videos displayed in this manner are usually stationary and framed within a very limited space (computer screen or wall) in a laboratory or classroom, which does not vary. Context manipulation in human associative learning continues to be challenging.

In order to gain better control of context exposure as well as to improve the overall effectiveness of context manipulations, researchers and clinicians have turned to Virtual Reality (VR) technology. Virtual reality has an advantage over the more rudimentary context manipulations by creating more salient and immersive contexts through the generation of virtual three-dimensional spaces. VR has been used as an adjunct to exposure therapy to help people suffering from specific phobias, post-traumatic stress disorder (PTSD) and anxiety disorders (for a review, see Opriş et al., 2012). Indeed, VR has been used to treat conditions such as Social Anxiety Disorder (Anderson et al., 2013; Bouchard et al., 2017), Animal Phobia (Botella et al., 2010b; Botella et al., 2016), Acrophobia (Levy, Leboucher, Rautureau, & Jouvent, 2016), and Agoraphobia (Malbos, Rapee, & Kavakli, 2013; Meyerbroeker,

Morina, Kerkhof, & Emmelkamp, 2013). However, few studies have taken advantage of VR to investigate the effect of extinction over multiple contexts.

Shiban, Pauli, and Muhlberger (2013a) recruited patients that fulfilled criteria in the DSM-IV for spider phobia and provided them with exposure treatment over multiple virtual reality contexts. They used four virtual contexts with a virtual spider in the middle of the room. After a clinical sample of 40 participants received one session of four exposures over four virtual contexts, the authors observed less renewal (return of fear when extinguished fear stimuli are encountered outside of extinction context) relative to the group that received exposure in only one virtual context. Dunsmoor et al. (2014a) later conducted a similar study using a fear reinstatement paradigm with healthy adult volunteers. Participants acquired a fear association, which was subsequently extinguished in either one or three contexts. The multiple extinction context group showed less return of fear-potentiated startle following independent presentations of the shock unconditioned stimulus (US) (i.e., reinstatement), but this treatment was not effective in reducing spontaneous recovery.

A major advantage of using VR is the ability to control and manipulate the context, and to create an immersive environment that more capably distinguishes between different contexts. Being able to create any kind of 3D space is of particular interest in extinction (or exposure) treatment research (Diemer et al., 2015a; Rothbaum, 2009). A few studies have systematically studied the acquisition of associations in VR (Dunsmoor et al., 2014a; Glotzbach et al., 2012; Huff et al., 2011; Tröger et al., 2012). These studies provide proof of concept that fear conditioning can be done in humans using VR, suggesting this medium has potential for improving context manipulation research. Furthermore, there are many potential applications to experimental psychopathology research for reducing anxiety, such as being used as a visual guide for teaching and practicing mindfulness/relaxation/breathing exercises.

VR may also potentially provide an exposure platform for less accessible environments for people with OCD (e.g., toilets).

The rest of this thesis will discuss what phobias are, theories about how phobias are acquired, and clinical treatments to eliminate phobias (Chapter 2), what extinction means, evidence that extinction is not permanent (i.e., recovery-from-extinction effects), experimental methods to reduce recovery effects, and a theoretical framework for understanding these extinction-related effects (Chapter 4). Chapter 5 will make a case for why studying the conditions of acquisition is important for theoretical and clinical reasons and the advantage of doing this in a VR paradigm. It will end by introducing the empirical part of this thesis. Chapters 6 and 7 will describe the methods and results of the empirical study, respectively, and Chapter 8 will discuss these results and frame them in the wider context of laboratory and clinical research on acquisition and extinction of phobias.

CHAPTER 2

CLINICAL CONCERNS

In this chapter, the clinical relevance of studying phobias will be reviewed in section 2.1. Then some of the dominant theories of aetiology of phobias will be discussed in section 2.2.1, starting with the biological preparedness theory which focuses on the idea of evolutionarily prepared stimuli and an evolved fear module. This section closes by discussing some research that supports the idea of an evolved fear module. Section 2.2.2 covers non-associative pathways to acquiring phobias. This section focuses primarily on Rachman's three pathways theory (1977) and his idea of instructional and vicarious pathways. This section ends by examining some research on these alternative pathways and introduces the idea that all of these pathways are in fact associative. This leads to section 2.2.3, which focuses on an associative learning model for phobia acquisition. This section looks at the research refuting the criticisms of proponents of non-associative pathways, such as the inability to recall a conditioning event and incubation of fear. It ends by introducing a model of associative learning that includes other pathways similar to what was proposed by Rachman but framing them in an associative model. The Diathesis-stress model, which builds on the associative model to include roles for individual differences, that influence the acquisition of a phobia is discussed in section 2.2.4. This section talks about how vulnerabilities from genetics or life experiences, stress, and events that occur after a conditioning event can all lead to individual differences that affect the likelihood of acquiring a phobia. Finally, the aetiology of phobias from a cognitive perspective is discussed in section 2.2.5. This section focuses on Armfield's (2006) cognitive vulnerability model.

2.1 Specific Phobias

Specific phobias are a class of anxiety disorders that present with intense and irrational fear or anxiety about a specific object or situation (APA, 2013). A specific object or situation can be described as the phobic stimulus. The phobic stimulus consists of these categories: Animals, Natural Environment, Blood-injection-injury, Situational and Other (unclassifiable).

Common specific phobias include Arachnophobia (fear of spiders), Agoraphobia (fear of crowded or open spaces), Claustrophobia (fear of enclosed spaces), Hemophobia (fear of blood), Aerophobia (fear of flying) and Acrophobia (fear of heights), while some uncommon phobias include Trisdedekaphobia (fear of the number 13), Hydrophobia (fear of water), and Technophobia (fear of technology). An important aspect for the diagnosis of such a disorder is the marked or intense experience of fear or anxiety in relation to these phobic stimuli. An individual with such a condition would experience markedly more fear in the presence of this stimulus compared to others without this condition. Additionally, the phobic stimuli consistently and persistently trigger the response regardless of context and/or circumstances. The individual may experience significant distress and may experience impairment in their social life, occupation or other areas of important functioning due to their fear, anxiety or avoidance of the phobic stimuli. Some persons suffering from specific phobia may be highly functional as they would often structure their daily lives in a manner that avoids exposure to the trigger. Unfortunately, this avoidance also leads to longer latencies between phobia onset and treatment, which may contribute to higher relapse rates and treatment difficulties.

While demographic statistics can never tell a complete story, they do help to provide context. With that in mind, a World Health Organization World Mental Health Survey (N = 124,902) between 2001 and 2011, cross-national lifetime prevalence of specific phobia was found to be 7.4%, with a 12-month prevalence rate of 5.5% (Wardenaar et al., 2017). The

median age of onset was eight years of age, which suggests that the amount of time an individual suffers from a specific phobia can be quite significant. Slight differences in the 12-month prevalence rates were observed between genders with females at 9.8% and males at 7.7%. Wardernaar et al. also found that of the patients within the 12-month length of experiencing this disorder, 18.7% determined their functional impairment to be severe. However, only 23.1% of patients suffering from a specific phobia sought out treatment. The delay between onset and treatment was found to be at a mean of 18.1 years for specific phobias, which is the longest delay compared to other psychiatric disorders (ten Have, de Graaf, van Dorsselaer, & Beekman, 2013). There may be two reasons for the delay and the lower treatment-seeking statistic. Firstly, due to the early onset of the disorder, children are dependent on their parents for early treatment initiation. Secondly, people with specific phobia may experience less severe impairments compared to other disorders because sufferers may go long periods without triggering their distress by using avoidance strategies (Olfson, Kessler, Berglund, & Lin, 1998). Specific phobia is one of the most common mental health disorders in a population. It occurs early in a person's life and can severely impair a person's day-to-day functionality. Yet, treatment for the disorder is often delayed due to the use of avoidance strategies giving a semblance of functionality. Delays in treatment seeking may lead to increased severity of specific phobia and the development of comorbid disorders (Kessler et al., 2007), complicating treatment efficacy.

The co-morbidity of specific phobia to any mental health disorder was reported as 60.5% (Mood disorders 34.3% and Anxiety disorders 41.2%), with the experience of phobic dysfunction occurring before the onset of other disorders in 72.6% of these cases (Wardenaar et al., 2017). In many cases, individuals have a phobia to more than one object. In these situations, the number of phobic stimuli predicted level of impairment, treatment approach, and co-morbid disorders (Wardenaar et al.). This is of particular importance to clinicians as

specific phobias may underlie clinical presentations of other mental health disorders leading to a perpetuation of dysfunction regardless of treatment for the co-morbid disorders. It is unclear precisely why specific phobias lead to an increase risk of developing other disorders. Trumpf et al. (2010) suggested that the underlying pathological functioning between specific phobias and comorbid disorders may be similar. In addition, the induction of avoidance coping behaviours and the resultant cognitive distortions provide the background for the development of other disorders.

2.2 Models for the Aetiology of Phobias

Descriptions of phobia symptomology have remained relatively constant throughout history. However, theories and models of phobia or fear acquisition have changed over time. As our knowledge of phobias grow, attempts at explaining the complex aetiology of fears and phobias have also evolved. Overall, vast arrays of mechanisms are involved in fear learning. The following section will provide an overview of the different explanations to phobia aetiology.

2.2.1 Biological Preparedness Theory

Early models explaining the aetiology of fear and avoidance are based on biological preparedness and learning theory. For example, taste aversions may be acquired in a single trial (Welzl, D'Adamo, & Lipp, 2001). Evolutionarily, this is adaptive because food that results in illness may be poisonous and should be avoided. This explains why acquiring a conditioned taste aversion occurs with extreme rapidity and strength. Along the same lines, due to the threat certain stimuli posed to existence, organisms evolved a predisposition to acquire fear more easily and rapidly towards threatening stimuli over other stimuli that were not evolutionarily threatening (Ohman & Mineka, 2001; Seligman, 1971). Based on the preparedness theory (Seligman, 1971), stimuli that are evolutionarily threatening are attended to faster, and associations to such stimuli are learned more quickly than associations to

evolutionarily nonthreatening stimuli. As evidence of this, Cook and Mineka (1990) demonstrated that monkeys more readily acquired fear to snakes than flowers, and similarly, Ohman and Dimberg (1978) showed that humans more readily associate electric shock with angry faces than with happy or neutral faces, and these associations between angry faces and shock are slower to extinguish than associations between happy faces and electric shock. These studies support the theory that humans have evolved a special fear mechanism that is more readily activated in the presence of evolutionarily threatening stimuli. Hence, phobias to objects such as snakes, spiders, and heights are more common than phobias to flower or butterflies. However, a review conducted by McNally (1987) found that fear-relevant stimuli are not more likely to be fear conditioned compared to fear-irrelevant stimuli. Nonetheless, there appeared to be some support for this theory as fear-relevant stimuli seemed to be more resistant to extinction. These results are consistent with a later study, which also found no difference in acquisition of fear to fear-relevant stimuli (snakes and spiders) and fear-irrelevant stimuli (flowers and mushrooms). However, greater resistance to extinction was observed to fear-relevant stimuli (Lipp & Edwards, 2002). In addition, not all fear-relevant stimuli appear to be similarly feared. For example, different arthropods (e.g., Spiders, Beetles, Wasps, Bees) elicit different self-reported ratings of fear, danger and disgust (Gerdes, Uhl, & Alpers, 2009). Indeed, more recently, studies have found a differential attention to types of fear stimuli, such as snakes being more preferentially processed than spiders (e.g., Soares & Esteves, 2013; Soares et al., 2017). This suggests that an evolutionary system may underpin human fear acquisition and fear evaluation.

Ohman and Mineka (2001) proposed an evolved module for fear learning and fear elicitation. The module contains four main characteristics: Selectivity, Automaticity, Encapsulation and Specific Neural Circuitry. Selectivity describes that fear-relevant stimuli are prioritised in their activation. These stimuli are likely part of our evolutionary history.

Thus, being aware and learning about them is related to our mammalian survival. Hence, there is a selective sensitivity to such stimuli, which allows the fear module to activate defensive behaviours (i.e., freezing, fight or flight) to increase chances of survival. Examples of such fears include aforementioned dangerous predators (snakes and spiders) and even social rejection (Öhman & Dimberg, 1978). These stimuli are also more likely to acquire conditioned fear facilitated by the fear module. Evidence for such a selectivity come from three lines of evidences: human studies that have consistently demonstrated stronger conditioned fear towards fear-relevant stimuli compared to fear-irrelevant stimuli, differences in fear responses to fear-relevant stimuli, and the lack of preferential conditioning when no aversive outcomes are paired with the fear-relevant stimuli (see Mineka & Ohman, 2002b).

Automaticity describes the activation of the fear module below the threshold of cognitive control. This mean that defensive behaviours are activated before cognitive evaluation of the stimuli. Öhman and Mineka (2001) postulated that these functions originated in lower order organisms with primitive brains since a rapid and automatic activation of defensive behaviours is advantageous to survival. The evolved organisms retained this function of the fear module. Evidence for this underlying mechanism of the fear module was found in studies in which human participants demonstrated increased autonomic responses to backward-masked fear-relevant stimuli (see Esteves & Öhman, 1993; Öhman & Soares, 1994).

Encapsulation describes the fear module's protection against higher cognitive control. For example, people with specific phobia may realise their excessive fear towards the stimulus is irrational but remain helpless against their difficulties. The retrospective threat evaluation is unable to override the automatic activation of defensive behaviours. Lastly, the location of the fear module appears to be in the amygdala. There is substantial evidence that the amygdala is involved in the presentation of fear and the learning of fear (eg., Markram et

al., 2008; Medina, Repa, Mauk, & LeDoux, 2002; Wilensky, Schafe, Kristensen, & LeDoux, 2006). Lesion studies have often resulted in a lack of fearfulness in mammals (Shi & Davis, 1999; Young & Lee, 1998). While electrical stimulations often result in increased fearful behaviours (Inman et al., 2018; Rosen & Davis, 1988). To put it all together, a person that that was almost bitten by a snake may develope a phobia to snakes (Selectivity). That individual may experience fear and panic, recoiling from a coiled rope very quickly before properly identifying if it is a real snake (Automaticity). Despite knowing that not all snakes are venomous (e.g., Rough Green Snake), the individual experiences panic and fear in the presence of non-venomous docile snakes.

In support of the model, Öhman and Mineka (2003) reviewed findings demonstrating a strong evolutionary predisposition to a fear-relevant stimuli, snakes. Fear responses to snakes were consistent amongst 11 genera of primates, which may correlate to high self-reported prevalence of intense fear towards snakes in humans. In addition, fearful responses to snakes were detected even though conditioning to pictures of snakes occurred below conscious awareness (backward masking paradigm). Snakes were also preferentially processed as detection time for snakes appear to be faster compared to fear-irrelevant stimuli. This suggests that a fear module, consisting of a selective automatic mechanism, manages the fear responses towards an evolutionary fear-relevant stimulus. However, recent research investigating this model has obtained mixed results. Ho and Lipp (2014) conducted an experiment using 40 undergraduate students to observe differentiated fear learning between fear-relevant (pictures of spiders and snakes) and nonfear-relevant conditioned stimulus (CS) (flower and mushrooms) with an aversive US. The authors found initial differentiated learning between the CSs, with the fear-relevant CSs being acquired faster. However, resistence to extinction, as predicted by the model, was not observed, although it should be noted that the number of extinction trials may have been too few to observe a difference. Ahs

et al. (2018) investigated the claim that evolutionary relevent stimuli would be more resistent to fear extinction. Upon reviewing studies that utilised fear-relevant stimuli and tested human autonomic responses resistant to extinction compared to neutral cues, the authors found ten studies (31%) that observed increased resistence while twenty-two studies (69%) did not. While not discounting the possibility of an evolutionary informed predisposition towards fear-relevent stimuli, it was suggested that the effect of preparedness may not be a robust or easily replicated effect. Rather, may be fragile and difficult to observe.

The specificity of the neural pathways may be different for types of fearful stimuli as well. Yang, Bellgowan, and Martin (2012) found that fear-relevant stimuli that are evolutionary (e.g. predatory animals) or modern (e.g., guns, weapons) may differentionally activate parts of the brain. The authors found that evolutionary fear-relevant stimuli activated the amygdala, but non-evolutionary fear-relevant stimuli activated dorsal stream regions. Therefore, two types of fear modules may be present to activate defensive behaviours, the amygdala for evolutionary entities and a cortex-based ciruitry for non-evolutionary entities.

2.2.2 Non-associative pathways

Early studies in fear conditioning led to the associative pathways of phobia acquisition. Watson and Rayner's (1920) study whereby a 9-month old child acquired a conditioned fear towards rats, was the earliest demonstration of traumatic fear conditioning. This led to early psychologists and psychiatrists to believe phobias are acquired fears borne of a transfer of fear towards an unconditioned stimulus (US) (i.e., physical pain) to a neutral conditioned stimulus (CS) (e.g., spider). This led to behavioural therapy as a form of treatment (see Wolpe, 1961). Rachman (1977) pointed out several issues with the associative account of phobia acquisition via the associative learning model. He outlined six specific arguments against associative learning models.

1. Not everyone that goes through a traumatic fearful event acquires a fear.

2. Laboratory observations of fear conditioning in humans is difficult.
3. That associative models assume all stimuli have equipotentiality
4. The distribution of human fears appears inconsistent
5. Recollection of histories from patients with phobia do not match the theory
6. Fears can be acquired through indirect experiences

In the first argument, Rachman pointed to studies that reported that the majority of people that experienced air-raids during the Second World War did not develop psychiatric disorders (Lewis, 1942; Wilson, 1942). The assumption then was that repeated experiences of trauma should result in conditioned fear responses. Next, Rachman argued that conditioning fear is difficult in human laboratory studies, as he had not been successful in pairing a CS with shocks in his laboratory (Hallam & Rachman, 1976). Other researchers encountered similar difficulties (e.g., Bancroft & Marks, 1968; Hallam & Rachman, 1976; Hallam, Rachman, & Falkowski, 1972). In the third and fourth argument against associative learning, Rachman pointed out that not all neutral stimuli are capable of becoming a fear signal. He noted that some stimuli (i.e., predatory animals) are more likely to be associated with phobias than others. However, classical conditioning, as understood at the time, rested on the equipotentiality premise, which appeared inconsistent in the face of studies that had been able to condition fears to some stimuli but not to others (Öhman, Erixon, & Löfberg, 1975). Also, observations that certain phobias of dangerous animals, such as snakes, were more common compared to lambs. More recent assessment of phobia subtypes have found that animal fears are still significantly more common compared to other fears such as heights, flying closed spaces or blood (Eaton, Bienvenu, & Miloyan, 2018) In his fifth criticism, Rachman observed that not all patients recall a specific traumatic event prior to phobia onset (de Silva, Rachman, & Seligman, 1977; Goorney & PJ, 1971). Rachman believed that this meant that an associative event did not even take place for some patients, and yet a phobia had developed.

Finally, Rachman pointed to work by Bandura (1965a, 1965b) as providing evidence that behaviour and emotional responses are learned vicariously. Thus, Rachman proposed that fear may also follow the same pathways of vicarious learning.

Rachman (1977) proposed the Three Pathways Theory to account for the acquisition of most of the common phobias acquired by the population. Fear acquisition is learned through one or a combination of direct conditioning, vicarious learning and information/instructional learning. He acknowledged that direct conditioning is an important process in which fear is acquired, but it insufficiently explains phobia acquisition. Therefore, Rachman suggested that there are at least two other indirect processes (instructional and vicarious) that can lead to phobia acquisition as well. Research into Rachman's model supports the view that there are multiple pathways towards developing a phobia. For example, Ollendick and King (1991) surveyed a large sample of 1092 children aged 9 – 14 years of age on the various pathways of different fears they experience. The surveys used to assess these children allowed more than one pathway to be endorsed. Overall, the authors found that 37% of fears were reported to have been directly experienced, 56% through vicarious learning, and 39% due to negative informational transfer. Unfortunately, this study did not include an option whereby retrospective recall of such fear acquisiton was without explanation (i.e., fear present prior to first contact) and lacked verification of the selected pathways with parents. Another study by King, Clowes-Hollins, and Ollendick (1997) surveyed parents of 30 children, aged 1 to 12 years of age on fear of dogs and included an option for no explanation. In this sample, the researchers found that direct experience made up 27% of the cases, vicarious conditioning accounted for 53%, informational transfer was 7%, and no explanation was 13%. In contrast with Ollendick and King (1991), this study did not have self-report. Instead it relied on parental recall, which may be biased and invalid in terms of actual experiences. More recently, Lin et al. (2014) surveyed 1643 children aged 9 to

12 years on the origins of their dental fears. The authors goal was to assess pathways of dental fear acquisition as a function of non-low and low income groups. The authors reported that for children in the low-income group, vicarious learning followed by direct experience were highly associated with dental fear; no significance was found for informational transfer. For children in the non-low income group, direct experience followed by vicarious and informational transfer was associated with dental fear. They concluded that both vicarious and direct experiences contribute significantly to the acquisition of dental phobia in children from both income groups. More importantly, the authors demonstrated that informational transfer was a pathway for dental fear; a pathway previous studies had not observed.

Empirical data provides support for the three pathways postulated by Rachman (1977). However, much of this support relies on retrospective recall and self-report questionnaires. The latter creates biases that force recalled memories to be categorised into a specific pathway. It also fails to use non-fearful controls to illustrate the importance of vicarious learning. In order to experimentally test vicarious fear acquisiton without use of recall questionnaires, Askew and Field (2007) conducted two experiments on children 7 to 9 years of age. In their first experiment, they sought to demonstrate vicarious learning of fear by presenting animals alongside scared (fear learning group) or happy (non-fear learning group) faces. Children in the fear learning group reported increased fears compared to children in the control group (no pairings of animals and faces) and those in the non-fear learning group, and these elevated scores were sustained over three months. The non-fear learning group, who experienced animals paired with happy faces, reported lower fear scores relative to controls, which was also sustained over three months. Their second experiment replicated this effect using a behavioural avoidance task; children that underwent vicarious fear learning reported increased fear and avoidance compared to the control group and non-fear learning group. Both experiments provide support for vicarious learning as a pathway of

fear acquisition. However, it is unclear if these pathways interact to contribute to fear acquisition. That is, whether one pathway is endorsed more than another, and following the first learned pathway (direct, vicarious or information), other pathways only serve to reinforce the first learned association. Askew, Kessock-Philip, and Field (2008) conducted a series of experiments to investigate the combination of verbal threat information and vicarious learning on fear acquisition. They used procedures similar to Askew and Field (2007) with the addition of verbal threat information. They found that verbal threat information contributed significantly to vicarious learning when it was presented first. However, when simultaneous pathways were activated by presenting the verbal threat information with vicarious learning, no enhanced vicarious learning was observed. Similarly, when revaluation of the US was performed by presenting verbal threat information after vicarious learning occurred, no effet of revaluation was found. Overall, these experiments suggest no evidence for combined pathways of fear acquisition. It does suggest that verbal threat information has a significant impact on negative vicarious learning experiences that follows. However, presenting non-threatening information following vicarious learning does not appear effective at causing a reevaluation of US and a reduction in reported fear.

The source of the threat information has been found to affect fear acquisition in children. Receiving verbal information from an in-person adult (e.g., teacher) produced a greater change in fear beliefs in an object than when it came from watching a video. Additionally, verbal information was more impactful when it came from an adult compared to same-age peer groups (Field, Argyris, & Knowles, 2001). Thus, verbal threat information as a pathway appears to play a significant role in fear acquisiton, especially if it is from an adult. This is not particularly unusual as children look to adults for signals regarding fear information (Muris, Steerneman, Merckelbach, & Meesters, 1996).

Vicarious learning is a important pathway of fear acquisition. Fear towards a neutral stimulus can be acquired after observing the aversive responses of others (Bandura, 1969; Rachman, 1968). Early surveys found vicarious learning to be most endorsed following direct conditioning in patients with phobia (Merckelbach, de Ruiter, van den Hout, & Hoekstra, 1989; Ost & Hugdahl, 1981). Evidence for this pathway was also observed in animal studies. Rhesus monkeys reared in the laboratories displayed no fear of snakes. When they watched a wild monkey react fearfully towards a snake, the laboratory monkeys acquired the same fear (Cook, Mineka, Wolkenstein, & Laitsch, 1985; Mineka, Davidson, Cook, & Keir, 1984). In humans, the vicarious learning of fear were similarly demonstrated. In infant studies using the 'visual cliff' paradigm, mothers stood at the far side of the glass and expressed fear, happiness or anger. Infants that saw fear in their mother's face did not crawl over to them when encountering the visual cliff (Sorce, Emde, Campos, & Klinnert, 1985). Similar experiments using mothers' facial expressions have similarly found that fearful or negative expressions predicted fearful responding in infants (Dubi, Rapee, Emerton, & Schniering, 2008; Gerull & Rapee, 2002; Hornik, Risenhoover, & Gunnar, 1987; Mumme, Fernald, & Herrera, 1996). Hence, learning of the fearful stimuli was influenced by the emotional expression of an adult. More recent studies have found similar impacts of modelling on children's anxious behaviours and cognitions; however, paternal modeling of anxiety had a greater overall impact on the degree of anxiety experienced by the child (Burstein & Ginsburg, 2010). More recently, research has found that positive modelling can be helpful in reducing avoidance and fear responses in children (Reynolds, Field, & Askew, 2018). This suggests that early psychological intervention strategies for children with specific phobias may use positive vicarious learning mechanic as a tool to increase treatment gains.

One could argue that all the pathways suggested by Rachman (1977) are in fact associative learning pathways. Although the vicarious and information pathways are not

experienced in the traditional sense as a direct pairing between a stimulus and an aversive outcome, an association still exists. Field (2006b) pointed out that information learning may constitute a form of associative learning between a stimulus (CS) with negative information (US). For example, being told that all spiders (CS) are venomous and can cause death (US). Vicarious learning also constitutes as a form of condioning where the fearful or anxious behaviour of the model becomes the US of the observer (e.g., Bandura, 1969; Mineka & Cook, 1993). The association thus become a contingent pairing of a CS with the US allowing for an association to be learned. Notably, individual differences play a role in whether the model's response to the CS sufficiently evokes fear and anxiety in the observer (i.e., the unconditioned response, UR) (Askew & Field, 2008).

In addition to Rachman's (1977) three pathways, Poulton and Menzies (2002) suggested a fourth pathway, which is biological non-associative. This pathway accounts for phobias which are the result of biological and evolutionarily innate pathways, not classically conditioned associations (see previous section 2.2.1 on biological preparedness). They asserted that fears may present themselves without any associative learning experiences, and that evolutionary predispositions lead to fear developing to some stimuli (see Menzies & Clarke, 1997; Graham & Gaffan, 1997). However, this view was critiqued by Davey (2002), who asserted that the evolutionary view fails to explain non-evolutionary significant stimuli developing into objects of phobias (e.g. computers), and that the associative account better explains the development and maintenance of phobias through the process of US revaluation, in which evaluation of the US changes CR (see Davey, 1989). A discussion of associative versus non-association models will be further expanded on in the next section: Associative Learning Model

2.2.3 Associative Learning Model

One of the earliest attempts at explaining the acquisition of a phobia comes from associative learning theories. Watson and Rayner (1920) famously demonstrated a fear conditioning experiment whereby a 9-month old child, Little Albert, acquired a conditioned fearful emotional response to rats after repeated presentations of a rat paired with a loud startling noise. Despite showing no significant reactions to the rat initially, the experience caused Little Albert to show extreme distress when the rat was presented. This suggests that Little Albert had acquired a significant fear of the rat akin to a phobic reaction. In an associative learning model of phobia, it is assumed that a phobia is thus acquired through this conditioning route. For example, a person bitten by a spider may acquire a fear of spiders after the traumatic ordeal. The phobic object (e.g., spider) is a conditioned stimulus (i.e., CS) that is associated with an aversive event, unconditioned stimulus (US) (e.g., injury or pain). Repeated intense experiences of this CS – US leads to the development of a phobic reaction to the CS (Grinker & Spiegel, 1945). Indeed, early writings on anxiety and phobia acquisition were greatly influenced by conditioning or associative learning. Mowrer (1939) described anxiety as an adaptive response towards an aversive CS – US association that was learned through repeated experiences. Anxiety thus prepares the organism for the possibility of the US when the CS presents itself. Avoidance as a response helps mitigate the experience of the US and thus becomes reinforcing. This led Mowrer (1951) to propose the two-factor theory of avoidance. It describes the combined effects of classical conditioning, which may explain fear acquisition, and operant conditioning, which maintains the fear. Wolpe and Rachman (1960) also added that any neutral stimulus has the capacity to elicit fear after it has become associated with a fearful experience. Building on the work of preparedness, Eysenck (1976) proposed a conditioning model of anxiety/neurosis that incorporates innate biological predisposition that facilitates the Pavlovian conditioning of fear. It also added that the US in humans may not always be some form of pain or injury, instead may be ‘frustration’.

Criticisms began to emerge on the associative learning theory of phobia aetiology. Field (2006b) reviewed some of these criticisms, which include the lack of memory about aversive events, not all whom have experienced a traumatic event go on to develop phobia, the issue of incubation, an uneven distribution of fears (i.e., fear-relevant versus fear-irrelevant as discussed above), and indirect pathways of fear acquisition. Poulton and Menzies (2002) argued for a non-associative account of fear acquisition by providing evidence towards the lack of retrospective recall of traumatic memories by patients with phobia, and the accounts of people whom have not developed a phobia despite experiencing traumatic events. In their account, they emphasised that some patients with specific phobia do not remember an aversive experience leading to development of their phobia (e.g., Davey, 1991; Menzies & Clarke, 1993a, 1995). Poulton and Menzies argued that the development of such fears is innate to prolong survival of the person from the earliest experience with the stimuli. That is, an innate fear response occurs when a stimulus is presented. This innate protection leads to fewer risky engagement in such activities (e.g., fear of heights leads to less engagement in climbing activities, less risk taking in climbing and less severe experiences if they fall) (see Menzies & Parker, 2001). Hence, consistent with accounts that reported having the fear their whole lives (e.g., Menzies & Clarke, 1995). Poulton and Menzies also highlighted that not people who experience a traumatic event develop a phobia. Specifically, data from studies on acrophobia point towards an inconsistent development of acrophobia despite experiences of injuries from falls (e.g., Menzies & Clarke, 1993b, 1995; Menzies & Parker, 2001). Other phobias with inconsistent developmental histories include fear of flying (Aitken, Lister, & Main, 1981) and fear of thunderstorms (Liddell & Lyons, 1978).

In response to these criticisms, Mineka and Ohman (2002a) pointed out that retrospective recall is not a reliable source of conclusive data. Decay of life events occur rapidly; over a year, about half of one's memories for these events will be forgotten or

inaccurately recalled (Monroe, 1982). A review of major life events also found that accuracy of recall for severe events maintain for a year but reliability declines for less severe events after 5 months (Monroe & Slavich, in press). Retrospective recall depends heavily on age and education of respondents, and omission errors are found to be higher compared to over reporting (Ayhan & Işiksal, 2005). In addition, negative social events have been found to be under reported (Beckett et al., 2001), although this may be affected by cultural differences. These results suggest that the lack of traumatic memories for patients with phobia may not be the absence of the event, but rather the absence of recall. Moreover, a patient would be less likely to recall or report less severe negative stimulus events. Mineka and Öhman pointed out that Poulton and Menzies have neglected to take into account how individual differences play a significant role in affecting the strength and speed of conditioning. Conditioning episodes that are aligned to an individual's vulnerabilities are more likely to lead to phobia development compared to others without the same vulnerabilities (Mineka & Zinbarg, 2006).

In addition to the issues addressed by Mineka and Öhman (2002a), Field (2006b) addressed concerns raised by Eysenck (1979) on the incubation of fear. That is, the phenomenon that unreinforced exposure to a feared stimulus (e.g., a spider without the bite) increases fear instead of decreasing it as in extinction training. Field (2006b) suggested that this effect can be explained through avoidance. The lack of an aversive US outcome does not mean an association did not occur. A mental representation of the traumatic event is experienced, reinforcing both avoidant responses as well as the strength of the CS – US association (see Yule, Udwin, & Murdoch, 1990). In addition, it has been well demonstrated that extinction is not an erasure of learning, as evidenced by recovery from extinction phenomenon like renewal, spontaneous recovery and reinstatement (for a summary, see Bouton, 2017). More recent studies have demonstrated that this "incubation" enhancement may depend on the initial severity of the traumatic event, and the severity impacts the time it

takes to generalise fear across distinct contexts (Poulos et al., 2016). The uneven distribution of fears point towards biological prepardness, which was previously discussed (section 2.2.1). Finally, the indirect pathways of fear are argued to be an example of associative learning and not a criticism for phobia acquisiton via association (Field, 2006b). In such indirect pathways where negative informational transfer (e.g., parents telling children to be careful of something or not to touch something) are USs, this becomes an associative learning mode where a child learns from a parent that the Spider (CS), must not be touched (US). This causal learning is analogus to associative learning as the child learns a CS – US relationship. While fear may not be directly evoked from the US, a parent may tag cautionary information with a probable negative experience (e.g., "Don't touch the spider or it will bite you!"). In other words, negative information transfer is an indirect associative learning pathway to fear acquisiton.

Field (2006c) and Field and Purkis (2011) described a model of phobia development through the associative learning paradigm. In this model, the CS – US association results in fear responses. Additionally, the model includes other pathways of learning (e.g., direct, negative information, vicarious, self-generated) (Rachman, 1977). This means that the CS (novel stimulus) and US (threat outcome) may not only be a physical stimulus, but also mental representations of threat. Representations allow the model to account for learned fear without direct experiences. This might occur, for example, in negative informational transfer from the individual's social groups. Associative learning through conditioning is therefore assumed to take place across all the pathways (Rachman, 1977). Informational learning is a conditioning experience in which an association between the stimulus (CS) becomes associated with threat information (US). In vicarious learning, the observed responses of the model to the CS is the US (Mineka & Cook, 1993). The authors suggest that these three pathways (direct, vicarious, informational) are capable of creating a CS – US fear association, and any of the pathways are able to strengthen or weaken this link. Observations of severe

fear, such as in patients with specific phobia, is a result of a sustained combination of experience of either or all three pathways. The influence of individual differences such as individual trait anxiety affects the strength and speed of these CS – US associations (Field, 2006a, 2006c). The model also describes factors that affect whether a CS – US association is created. Factors such as learning experiences and current expectations affect the CS – US association. It also includes factors that affect the perception of the US and expression of the conditioned response, such as learning history, presences of inhibitory CSs, experiences of the US without CS and excitatory CSs.

Recent studies have found a combined effect of various pathways of phobia acquisition that may support the Field and Purkis (2011) model. Schindler, Vriends, Margraf, and Stieglitz (2016) investigated the role of associative learning in flying phobia. They compared 30 patients with flying phobia to 30 healthy controls. Participants were interviewed using a questionnaire to assess individual history in flying phobia. One of the questions asked participants if they had experienced a triggering frightening event in a plane. Participants were also asked if family members or other important people in their life experienced fear of flying and if they witnessed this person going through a strong reaction during the flight. Participants with a phobia of flying were also asked if any media information had triggered their phobic reactions. The authors found that 50% of the patients with flying phobia directly experienced a frightening event, 37% witnessed something happening to a family member or important person, and 70% had a reaction through media information. Compared to healthy controls, 53% experienced a frightening event, 23% witnessed a family member or important person going through the event, and 37% had an anxious reaction to media information. These results suggest that while direct conditioning (experiencing a frightful even during flight) may play a part in the development of flying phobia, it does not sufficiently explain the reason why the controls, also with a similar percentage of direct experience, did not

develop a phobia. The authors note that patients with flying phobia also reported higher state anxiety which may result in the susceptibility for fear conditioning. Individual differences may have thus mediated the impact of all three pathways of acquisition of fear.

Overall, while classical conditioning, through direct experiences, plays a role in the development of a specific phobia, the susceptibility towards the event being significant may be mediated by individual differences such as trait anxiety. Acquisition of a phobia may require more than a single pathway of fear acquisition. Research suggests that a combination of multiple vicarious, instructional and direct experiences can result in a strong CS – US association and a conditioned response observed in patients with specific phobia. Criticisms of the associative learning model for phobia aetiology may need to look beyond retrospective studies due to the inaccuracy of human recall.

2.2.4 Diathesis-Stress Model

This contemporary learning theory was proposed by Mineka and Zinbarg (2006) to explain the complexities that are associated with individual differences that lead to the development and maintenance of anxiety disorders. In this theory, they expanded on the traditional learning theory to accommodate some of the criticisms of the learning explanation for phobias (e.g., acquisition of phobias without direct experience, individual differences, the role of prior experience, etc.) that have been made. Three major elements are described in this theory: *Vulnerabilities*, *Stress* and *Post-conditioning* event variables; thus, this is referred to as a diathesis-stress model, which incorporates individual differences into the traditional learning model.

Vulnerabilities

The first element of the model is vulnerability. The authors' diathesis-stress perspective explains two domains of vulnerabilities, genetic/temperament and previous learning experiences. First, vulnerability to phobias were found to have a modest genetic link

(Hettema, Neale, & Kendler, 2001; Van Houtem et al., 2013). This vulnerability may be due to an individual's genetic predisposition to fear conditioning (Garpenstrand et al., 2001; Maren, 2001), which may be mediated by an individual's personality variables, such as high trait anxiety giving rise to a particular vulnerability that affects the rate and intensity of conditioning. An early review by Delprato (1980) attempted to illuminate the arguments surrounding whether fears and phobias are innate or acquired through learned experiences. The author pointed out that the failure of early attempts (e.g., Bregman, 1934; Valentine, 1930) to replicate Watson and Rayner's (1920) study does not necessarily mean that conditioning and learned experiences play no part in the acquisition of fears or phobias. Rather, conditioning is but one of the contributors to the acquisition of phobias, with genetic predisposition and hereditary being the other determinant. Indeed, data from family studies find an overall increased possibility that an individual with a phobia (specific phobia, agoraphobia, social phobia) will likely have a relative with a similar phobia as well (Fyer et al., 1990; Noyes et al., 1986). Twin studies examining the genetics of phobias have estimated that genetic predisposition accounts for 30% to 60% of phobia aetiology (Czajkowski et al., 2011; Kendler, Myers, Prescott, & Neale, 2001; Kendler et al., 1992). Additionally, a more recent meta-analysis of subjects (n = 42585) diagnosed with social phobia found an overall genetic influence of phobia aetiology to be 27%, while non-shared environments contributed to 69% of the differences (Scaini, Belotti, & Ogliari, 2014). Overall, the results from these studies suggest that the argument for innate versus learning in phobia acquisition cannot be completely accounted for by strictly learned associations. The results point towards a general vulnerability towards acquiring a phobia.

Mineka and Zinbarg (2006) stated that individual life experiences can have significant effects on the result of conditioning. There are several individual experiences that affect the learning outcome of aversive events. For example, when an individual is exposed to a CS

before it is paired with an aversive US, the subsequent amount of conditioning between the CS to US is reduced. This phenomenon is known as latent inhibition. For example, Mineka and Cook (1986) found that when monkeys initially watch another monkey behave calmly towards a snake, when tested following exposure to watching fearful monkeys behaving fearfully to a snake, they did not display fear acquisition. This latent inhibition effect was also demonstrated in a human fear conditioning experiment. Vervliet, Kindt, Vansteenwegen, and Hermans (2010) had participants pre-exposed to a CS1 prior to fear conditioning with another similar but different CS2, and then tested with CS1. When compared to controls with no pre-exposure to CS1, the group that experienced non-aversive pre-exposure to CS1 reported lower threat expectancy. This suggests that pre-exposure led to protection against fear generalization from CS2 to CS1. The researchers also found a delay in acquiring a shock expectancy during fear conditioning meaning that the pre-exposure effect also led to a weakened acquisition of fear learning. This prior conditioning experience may thus determine the likelihood of a stimuli gaining a negative associative status, which may lead to phobia development. Prior acquisition of learning to a CS may demonstrate a favourable proactive interference effect (when older memories interfere with retrieval of new memories) (Bjork, 1992). A recent development in latent inhibition research also found that a negative affective state prior to the pre-exposure to the CS disrupted latent inhibition during fear acquisition. That is, latent inhibition was not observed when a negative affective state was experienced before non-aversive CS pre-exposure (De la Casa et al., 2018). This study suggests that the affective conditions leading to certain life event experiences also influences learning of the CS.

In addition to pre-exposure, control of an environment influences fear and anxiety experiences (Mineka, Gunnar, & Champoux, 1986). An individual's history of perceived control over important aspects of their environment can affect the development of a phobia.

Chorpita and Barlow (1998) explained that an individual's early experience of reduced control may lead to developing cognitive thinking patterns that increase interpretation and processing of situations being out of one's control thus leading to a predisposition to experience anxiety and the development of an anxiety disorder. The bias towards perceiving a lack of control leads to an increase in negative emotions (Barlow, 2004; Chorpita & Barlow, 1998). These negative emotions become the core vulnerability towards developing psychopathology especially anxiety disorders (Barlow, 2000). Gallagher, Bentley, and Barlow (2014) investigated the relationship between perceived control and anxiety. In a review of 51 studies (n = 11218), a large negative association was observed between perceived control and anxiety measures. Specifically, the relationship was strongest between a lack of perceived control and trait anxiety in adults compared to children. This is consistent with Chorpita and Barlow's (1998) suggestion that a chronic early life experience of lacking perceived control forms certain cognitive heuristics that eventually develops into personality traits. Some factors relating to perceived control may mitigate the aetiology of anxiety disorders. Hanton and Connaughton (2002) investigated the relationship between self-confidence and performance on anxiety symptomology and found that a strong moderating factor was perceived control. In this study, the authors found that in elite and sub-elite swimmers, those who reported experiencing more control over their anxiety symptoms showed facilitated performance while those who did not feel they had symptoms under control felt debilitated by them. The impact of perceived control was positively related with self-confidence and future improved performance. Thus, this study suggests that an increase in perceived control leads to increased self-confidence, which has been found to be associated with decreased anxiety and depression (Bitsika, Sharpley, & Peters, 2010). Another mitigating factor for anxiety development is increasing predictability of aversive events. Fonteyne et al. (2009) was successful in reducing the experience of anxiety when providing

information towards the predictability of an aversive event (i.e., mild shock). This increase in perceived control led to reduced fear responses and similar to Hanton and Connaughton's study may also provide some evidence for clinicians to make treatment adjustments to increase perceived control for patients suffering from specific phobia or other anxiety-related disorders.

Other individual differences due to individual experiences are vicarious learning and modelling. Vicarious learning refers to the acquisition of a fear response to a stimulus after observing another person behave in a fearful manner towards the stimulus. Recent studies have found evidence for vicarious learning of social phobia. Children that watched a film with a negative social outcome reported greater fear of performing in front of other compared to controls that watched a film that ended in a neutral outcome (Askew, Hagel, & Morgan, 2015). In behavioural modelling, parents play a significant role in relaying information about how a child should react to a stimulus. A child may follow a parent's behaviour to avoid certain creatures or situations thus leading to acquiring a similar fear. Barrett, Rapee, Dadds, and Ryan (1996) found that children with a diagnosed anxiety disorder were more likely to choose avoidant behaviours following discussion of hypothetical situations with their parents. However, some evidence of modelling of anxious behaviours through child/maternal recall methods appear to be mixed as well (Rapee & Melville, 1997).

Stress

In this model, lack of perceived control of stressful events also contributes to aetiology of anxiety disorders (Mineka & Zinbarg, 2006). To clarify, in Mineka and Zinbarg's (2006) model for aetiology of anxiety disorders, the general perceived lack of control is a vulnerability while a lack of perceived control and predictability of stressful events is a stress factor. Studies on the ability to control stressors have suggested that the potential to escape stress influences fear learning and expression (Baratta et al., 2007). For

example, Hartley et al. (2014) randomly assigned human participants into either escapable stressor condition, inescapable condition or control. Participants then experienced fear acquisition, then extinction and were tested a day later. The researchers found that participants who were able to escape from the stress demonstrated more fear extinction and less spontaneous recovery the next day. In contrast, participants who were unable to escape from the stress demonstrated impaired fear extinction and showed significantly more fear expression the following day. Recently, Le et al. (2018) performed a cross-sectional study on refugees and asylum seekers in Zurich, Switzerland. They found a negative correlation between psychopathology and perceived control during torture, which was moderated by the affective state during torture experiences. In other words, having control and having a perception of control both affect fear learning. These studies suggest that an underlying mechanism of controllability also modulates expression and learning of fear and safety associations which influences vulnerabilities to phobia aetiology.

Another factor within the stress factors is traumatic conditioning through direct or vicarious experience. Mineka and Zinbarg (2006) took into account the associative conditioning aspect of anxiety aetiology, which includes both direct and indirect pathways of traumatic conditioning. In the diathesis-stress model of aetiology of anxiety disorders, a conditioning event may occur through various pathways (Rachman, 1990) but is only one of the factors that can lead to the development of an anxiety disorder. Early criticisms of classical conditioning in fear acquisition reported that not everyone who experienced a traumatic experience go on to develop a disorder (Rachman, 1977, 1990). To address this, Laborda and Miller (2011) demonstrated that after initial conditioning, a devalued US was still able to reliably produce conditioned responses. This experiment provides some evidence that fears and phobias may develop without recall of distinct conditioning events. In addition to the unreliability of retrospective recall studies, these results suggest that a direct or indirect

conditioning event may be present, and to assess a definitive occurrence or the lack of one is at this time a difficult task to assess.

Mineka and Zinbarg (2006) postulated that the properties of the conditioned stimulus also influence the development of anxiety disorders. These properties include whether it was fear-relevant or fear-irrelevant, the temporal proximity to stressful events, and if it was interoceptive or exteroceptive. Exteroceptive cues are CSs that are experienced by the senses (e.g., tones), while interoceptive cues occur within an organism (e.g., heart rate, thoughts, breath etc.). Although interoceptive and exteroceptive cues are important in the aetiology of any anxiety disorder (Domschke, Stevens, Pfleiderer, & Gerlach, 2010), they are especially important in panic disorder. Specifically, interoceptive cues, such as breathlessness, can increase as a function of heart rate or sweating and both are capable of eliciting fear if they were experienced in the context of a panic attack (i.e., a CS – US relationship) (Bouton, Mineka, & Barlow, 2001b; De Cort, Griez, Buchler, & Schruers, 2012). Similar to the effect demonstrated by Laborda and Miller (2011), some of these interoceptive associations occur outside of recall or awareness. Pappens, Vandenbossche, Van den Bergh, and Van Diest (2015) induced mild breathlessness (CS) in human participants and paired it with an experience of suffocation (US). This paradigm is analogous to an associative view of panic attacks in the clinical population. The researchers assessed if participants were explicitly aware of the CS – US association and found that more than half of their sample were unaware of the association despite a fear response being observed. This finding suggests that interoceptive cues can undergo fear conditioning without explicit knowledge. This particular property of a potential CS highlights that stress may obstruct the memory formation of associative learning (Mineka & Zinbarg, 2006). Indeed, a recent study has found that acute stress can negatively affect memory consolidation and retrieval, but has no effect on acquisition of associative learning (Nelissen, Prickaerts, & Blokland, 2018). This provides

some explanation towards observations of associative learning without declarative recall, which also calls into question past evidence stating that some patients with phobias do not remember a specific associative memory related to their fears (e.g., Rachman, 1977, 1990).

Post-conditioning

The third element in Mineka and Zinbarg's (2006) model is post-conditioning. In this element, the authors describe factors that affect the quality and intensity of the expression of conditioned anxiety. Two factors described are US inflation and presence of inhibitory CSs (safety cues) or excitatory CSs (summative to conditioned fear).

The US inflation effect refers to a person's experiences immediately after a conditioning event that influence the strength of the fear response (Mineka & Oehlberg, 2008). For example, a child that developed a mild fear of dogs may develop dog phobia if parental physical abuse followed that experience even though no dogs may have been around during the abuse. This effect has been documented in laboratories and in clinical populations. For example, Davey, De Jong, and Tallis (1993) reported several patient case histories of US inflation leading to the aetiology of anxiety disorders (i.e., specific phobia, agoraphobia, PTSD, OCD and panic disorder). For example, the authors reported a patient whom experienced mild social phobia that was accompanied by physical symptoms. However, after a significantly distressing gastrointestinal episode, the patient began interpreting any intestinal unease with catastrophic outcomes. This led to the development of severe agoraphobia symptoms. In another example, Cougle, Resnick, and Kilpatrick (2009) observed that adolescents who did not develop PTSD following their first traumatic event were more likely to develop it after a second traumatic event experience relative to those that developed PTSD following the first traumatic event.

Another post-conditioning event, which can cause a person to re-evaluate the US, is when the individual receives information about the US being more dangerous than originally

experienced. This can trigger a re-evaluation of the US, which results in an inflation of fear to the CS (Davey, 1997; Hosoba, Iwanaga, & Seiwa, 2001). For example, Davey et al. (1993) reported a patient who recounted that at 10 years old, she was awoken one night by a large spider walking on her face. Initially, she did not feel particularly fearful, but when her parents were told of the incident, they reacted with extreme concern and fear. From then on, the patient began feeling severe fear towards spiders and would experience severe spider phobia when witnessing one. Conversely, a deflation of the US was been reported by Leer and Engelhard (2015). They trained healthy student participants to associate a CS and US together (triangle and loud white noise), and then proceeded to gradually decrease the intensity of the US during US exposure. Participants were subsequently extinguished. When compared to controls, the group that experienced gradual US deflation reported lower US expectancy. This reduction was also maintained after context switches.

Overall, Mineka and Zinbarg's (2006) model attempts to explain the array of evidence from three elements, *Vulnerabilities*, *Stress* and *Post-conditioning*, to understand the aetiology of anxiety disorders. *Vulnerabilities* incorporates evidence of genetic predisposition towards anxious traits and behaviours (e.g., Hettema et al., 2001; Van Houtem et al., 2013). It also takes into account different pathways in the history of associative conditioning and individual perceptions of control. *Stress,* takes into account perceived controllability of stressful events, traumatic conditioning events both direct and vicarious, and the properties of the CS. Finally, *Post-conditioning* describes inflation and re-evaluation of the US that may further exacerbate anxiety symptoms leading to anxiety disorder formation.

2.2.5 Cognitive model

The majority of attempts to explain the aetiology of phobias come from the behavioural background. Far fewer models have attempted to explain phobia aetiology through cognitive processes alone. One model by Armfield (2006) stands out as it attempts to

incorporate evidence found in previous models (i.e., biological predisposition, conditioning, vulnerabilities) into one that includes cognitive processes. Armfield (2006) proposed the cognitive vulnerability model in an attempt to explain aetiology of phobias. Armfield stated that a *Vulnerability Schema* is comprised of the individual's perceptions towards the stimuli, which are perceptions of dangerousness, disgustingness, unpredictability and uncontrollability. These perceptions are constructed through an individual's life experiences or knowledge, and a person's individual personality trait or biological predisposition. Upon detection of a stimulus, the Vulnerability Schema is activated unconsciously, automatically, and simultaneously. The author postulated that conscious access to this information is not necessary as activation leads to a general or holistic perception of vulnerability to the stimulus.

Once the schema is activated, two processes occur, which are the activation of an *Automatic Affective Reaction* and a *General Cognitive Evaluation.* The automatic affective reaction describes an unconscious process that comprises of involuntary fear responses that may sometimes be construed as irrational, such as an increase in sweat or heart rate without awareness of the stimulus (Ohman & Soares, 1993; Öhman & Soares, 1994). The next process, the general cognitive evaluation describes a cognitive process that appraises the stimuli and assesses its significance. It is the final process before a person's response is initiated. Armfield (2006) believed that this process comprises of a mix of conscious, subconscious and unconscious threat appraisals. Due to its connection with the vulnerability schema, assessment of the fear stimuli is congruent with the automatic affective reaction. Thus, a fear reaction that appears instantaneous is not without cognitive processes. That is, a person will be able to explain their fear response in a logical and rational manner. Other cognitive factors are also thought to play a role in influencing the general cognitive evaluation process. Factors such as attentional biases, memory biases, negative self-focused

attention, patterns of anxious self-statements, and automatic questioning. These factors may distort the information processing of the stimulus. Specific experience may result in these factors' distortion of the information processing.

The model attempts to explain characteristics of specific phobia through the aforementioned processes. The excessive response sometimes observed in patients with specific phobia is postulated to be a response stemming from the automatic affective reaction that is informed by the vulnerability schema, which is informed by personality traits, life experiences and biological predispositions. The pathways of fear acquisition (Rachman, 1977) are merely ways of gathering information related to the stimuli. Any pathway thus adds to perceived vulnerability towards the stimuli. Characteristics of the stimuli such as the uncontrollability, unpredictability, dangerousness and disgustingness help to explain the differential distribution of fear-relevant versus fear-irrelevant type of stimuli. For example, a predatory insect (i.e., spider) would be perceived as being high on uncontrollability, unpredictability, disgustingness and dangerousness as compared to other stimuli with lower perceptions on these characteristics. Fear reactions are therefore thought to be informed by these vulnerability perceptions which explains why some stimuli elicits phobic reactions in some people and none in others.

Overall, the model provides some intriguing elements that attempt to incorporate biopsychosocial elements touched on by all the previous models with cognitive processes. At this time, support for the model's specific processes appear to be minimal. However, the vulnerability schema is conceptually similar to the diathesis-stress model proposed by Mineka and Zinbarg (2006) which describes the interplay between vulnerabilities, stress and post-conditioning variables in phobia aetiology. Associative learning may be viewed by Armfield (2006) as a pathway of information gathering, and it therefore underpins each process described. The automatic affective reaction described is akin to US activations upon

perception of a threatening CS. This is similar to the primary and secondary appraisal theory (Folkman & Lazarus, 1985). Primary appraisal constitutes the automatic affective reaction followed by secondary appraisal which is the general evaluation of the stimuli. Armfield has included other cognitive processes that influence the evaluation of this stimuli which may explain irrationality and how some negative self-beliefs maintain dysfunction in some phobias(e.g., Clark & Wells, 1995). The cognitive vulnerability model may be seen as a macroscopic view of phobia aetiology providing some encapsulation of associative learning and cognitive processes, which would benefit from further research.

2.2.6 Overall summary of models

In looking at the models that attempt to explain the myriad of etiological factors leading to the development of an anxiety disorder, we can appreciate the enormous complexity involved. Variables relating to biological, psychological and sociological/environmental factors interact to contribute to the predisposition and perpetuation of anxiety, and in particular, specific phobias. Although it is acknowledged that cognitive processes and some non-associative processes may be involved in the aetiology of phobias, the present study will be based on contemporary associative learning model as it attempts to explore associative fear acquisition over multiple contexts. Understanding the factors involved in this learning process is essential to providing insight into future clinical implications.

CHAPTER 3

TREATMENT FOR SPECIFIC PHOBIAS

This chapter focuses on treatment models. Section 3.2 covers exposure-based approaches, and section 3.3 reviews cognitive treatment of phobias. The section on exposure-based approaches begins by talking about two proposed mechanisms that underlie the effectiveness of exposure treatments, emotional processing theory and belief disconfirmation theory. Then the goal and process of conducting different forms of exposure-based treatments, including in-vivo (section 3.2.1), systematic desensitization (section 3.2.2), imaginal exposure (section 3.2.3), virtual reality (section 3.2.4), EMDR (section 3.2.5), and applied tension (section 3.2.6) will be described. For each of these approaches, research on the effectiveness of this treatment and some of the pros and cons for each method will be reviewed. The chapter ends by discussing a cognitive-based treatment for specific phobias before ending with a summary and short discussion on relapse.

3.1 Treatment Methods

Treatment for specific phobias have largely utilized exposure therapy as the first line of treatment for people suffering from the disorder. In-vivo exposure is arguably the most effective form of administering this therapy, and it has been the subject of extensive research. Wolitzky-Taylor et al. (2008) conducted a meta-analysis of randomized treatment studies of psychosocial interventions for specific phobia. The authors analyzed 33 studies published between 1977 – 2004. They included exposure approaches (in vivo exposure, systematic desensitization, and imaginal exposure) and non-exposure treatment types (eye movement desensitization and reprocessing, applied tension/relaxation cognitive therapy and progressive muscle relaxation) in their analyses. They found that exposure treatment approaches resulted in large effect sizes compared to no treatment, and it outperformed all non-exposure treatment types. No effect of treatment efficacy was found on type of specific phobia, which

contradicted findings by Choy et al. (2007). In Choy et al.'s review of treatment approaches to specific phobias (e.g. exposure approaches, cognitive therapy, hypnotherapy, supportive psychotherapy), as compared to placebo or wait-list, in-vivo exposure was the most effective at fear and symptom reduction. However, Choy et al. noted that drop out rates of the studies ranged from 0% to 45%. This is underderstandable given the requirement for patients to confront the phobic stimulus. Variations of in-vivo exposure may be more acceptable, such as virtual reality. Garcia-Palacios, Botella, Hoffman, and Fabregat (2007) reported that in their sample of patients with spider phobia (n = 150) the refusal rate for virtual reality exposure was only 3% compared to in-vivo exposure at 27%.

3.2 Exposure Approaches

All exposure approaches essentially require a confrontation of a feared stimulus by the patient. The feared stimulus may take different forms depending on the exposure approach; it may be physical, imaginal, or virtual. For specific phobias, the feared stimulus may be an animal, a situation, an object, an experience or an environment (APA, 2013). However, this may be different depending on the disorder. For example, Post-traumatic Stress Disorder (PTSD) would require exposure to a traumatic memory which may take the form of imaginal exposure. There are two prevailing theories that try to explain the underlying mechanisms of exposure therapy: the emotional processing theory (EPT) (Foa & Kozak, 1986; Foa & McLean, 2016) and the belief disconfirmation theory (Salkovskis et al., 1999).

Firstly, EPT builds on the idea that imagery has a central role in fear and anxiety (Lang, 1977). This fearful imagery of an object or situation is more than a picture in the mind. Rather, it was conceptualized by Lang as a "cognitive structure" or "fear structures" (Foa & Kozak, 1986), which contains components such as the properties of the feared stimulus, affective responses, cognitive responses, behavioural responses, beliefs and

interpretations. As these components are interconnected within the fear structure, inputs that activate any component will activate the entire structure. EPT suggests that there are normal and pathological fear structures (Foa & McLean, 2016). Normal fear structures reflect realistic situations that are dangerous. When activated, adaptive responses (e.g, fight or flight) are engaged, and when the danger is removed, fear dissipates. An abnormal or pathological fear structure is one in which the feared stimulus, response or interpretation of the meaning do not reflect reality and becomes activated by harmless stimuli. In other words, in the absence of any realistic threat, an abnormal fear structure will lead to activation of fear and avoidance responses. Thus, anxiety disorders represent different types of pathological fear structures. For example, in specific phobia, the association between a stimulus and response, such as the association between a spider and its meaning (e.g., venomous, aggressive), or spider and response (e.g., increased sympathetic arousal for flight), is unrealistic and disordered (Foa & Kozak, 1991). For army veterans with PTSD, this might refer to the association between a trash can and its meaning (e.g., contains improvised explosive devices), and trash can and response (e.g., sweating, heartrate). Activation of the structure while incorporating information incompatible with previously stored information (habituation), is thought to lead to the creation of a new non-fear structure, which competes with the previous pathological fear structure. This is consistent with more modern behavioural theories of extinction learning in which original learning is not erased through extinction procedures, but rather, new learning takes place that competes with old learning (Bouton, 2017).

In EPT, emotional processing is the core mechanism for fear reduction in pathological anxiety. Two conditions required for this change are activation of the fear structure for modification and new information incompatible to the current pathological information. Exposure therapy fulfils these conditions by activating said pathological fear structure and

presenting incompatible information about the stimulus. As it is impossible to observe the functioning of such structures and emotional processing, Foa and Kozak (1986) proposed three indicators where emotional processing has been successful. First, fear structure activation would be indicated in subjective and objective measures of fear. Second, reduction of anxiety within treatment session, which indicates habituation to feared stimulus, and third, reduction in overall fear activation between sessions, which lowers peak anxiety. These indicators were later revised as reduction of anxiety during sessions do not predict exposure outcomes (Foa, Huppert, & Cahill, 2006). Overall, according to EPT, reduction in pathological fear and avoidance occurs when pathological fear structures are activated and challenged with information contrary to what was previously stored and integrated into the existing structure.

The other proposed theoretical mechanism underlying exposure therapy is belief disconfirmation theory. Salkovskis et al. (1999) explained that avoidance strategies are common in patients with anxiety disorders as they help avoid the feared consequences brought about by the feared stimulus. This is commonly seen in people with arachnophobia avoiding parks or gardens, people with acrophobia avoiding buildings, and people with claustrophobia avoiding elevators. These are known as "safety-seeking behaviours" by Salkovskis and colleagues. These safety behaviours become ingrained in a patient's behaviours and thought processes that they become convinced the avoidant behaviours are normal. Some of these safety behaviours are observable while others may only occur internally and are not visible to others (Salkovskis et al.). These avoidant behaviours, while serving their primary purpose to avert activation of a perceived negative consequence, have a secondary function of preventing the disconfirmation of the perceived consequence. Thus, these safety behaviours may interfere with exposure therapy as they ultimately prevent the disconfirmation of the maladaptive beliefs.

What both theories have in common that exposure effectiveness is predicated on the reduction of any behaviours that interfere with the presentation of realistic information that is incompatible or disconfirms the currently held maladaptive beliefs of the feared stimulus (Koerner & Fracalanza, 2012). Most treatment of anxiety disorders would recommend the elimination of anxiety control strategies as they interfere with treatment effectiveness (e.g., Barlow, 2014; Craske, Antony, & Barlow, 2006; Steketee, 2011; Storch & McKay, 2013). Some studies have found that anxiety control strategies may not necessarily be detrimental to treatment. For example, in a snake phobia intervention study by Milosevic and Radomsky (2008), snake fearful participants that were allowed to use safety equipment during in-vivo exposure sessions achieved significantly better results in the behavioural approach test compared to controls. Such results have prompted researchers to rethink the impact of safety or avoidance behaviours (e.g., Hood, Antony, Koerner, & Monson, 2010; Parrish, Radomsky, & Dugas, 2008). However, Milosevic and Radomsky's (2008) study operationalized safety behaviours as safety equipment chosen by participants and not internally directed avoidant behaviours. Since it is unlikely that participants have also integrated safety equipment into their fear structures, in the lens of EPT, their fear structures were unlikely to be completely activated. Additionally, snake fearful participants may not be representative of snake phobic patients who may present significantly more dysfunctional fear structures and deeper ingrained avoidant behaviours. Nonetheless, several studies have demonstrated that there may not be a deleterious effect of anxiety control strategies during exposure and may in fact facilitate some (e.g., Craske, Street, & Barlow, 1989; Grayson, Foa, & Steketee, 1982; Piccirillo, Taylor Dryman, & Heimberg, 2016; Rachman, Craske, Tallman, & Solyom, 1986; Sloan & Telch, 2002; Sy et al., 2011). Rachman, Radomsky, and Shafran (2008) even advocated for the "judicious" use of safety behaviours in the early phases of treatment. More recent investigations into the use of anxiety control strategies have generally supported the

formal notion that such strategies are detrimental to the overall treatment effect via exposure therapy, perpetuate negative beliefs/maladaptive beliefs and may even exacerbate the anxiety symptoms (e.g., Blakey & Abramowitz, 2016; Olatunji et al., 2011; Rowa et al., 2015; Taylor & Alden, 2010). Yet others have found no evidence of a deleterious effect and usage remains inconclusive (e.g., Deacon, Sy, Lickel, & Nelson, 2010; Meulders, Van Daele, Volders, & Vlaeyen, 2016).

A more balanced perspective of anxiety control strategies or safety behaviours put forth by Parrish et al. (2008) suggested that such behaviours may be appropriate for patients in treatment if it helps boost self-efficacy, if they do not drain cognitive resources, if engagement provides encouragement to deepen the exposure experience and learning (e.g., approaching the spider), and if safety is not misattributed (i.e., safety due to realistic experience of the stimulus and not safety behaviour). Such circumstances may empower and encourage patients to further engage in exposure treatment and reduce dropout rates (Rachman et al., 2008).

The following section reviews exposure-based interventions used to treat specific phobias, but it should be noted that such interventions are not limited to only specific phobias. Such interventions are applicable to other anxiety disorders such as Obsessive-Compulsive Disorders (OCD), Post-traumatic Stress Disorder (PTSD), Generalized Anxiety Disorder (GAD), panic disorders and social anxiety disorder (social phobia). The interventions covered in the following sections include in-vivo exposure, systematic desensitization, imaginal exposure, virtual reality, eye movement desensitization and reprocessing (EMDR), applied tension and cognitive therapy.

3.2.1 In-vivo exposure

In-vivo exposure therapy involves presenting the phobic stimulus to the patient, such as a live spider for treating Arachnophobia or a live snake for treating Ophidiophobia. During

these sessions, patients are exposed to the object and encouraged to interact with the feared stimulus (e.g., a patient with Claustrophobia getting into an elevator). Before the commencement of in-vivo exposure therapy, a functional assessment may be performed. According to Abramowitz, Deacon, and Whiteside (2019), a functional assessment is required to help therapists develop a treatment plan prior to conducting exposure therapy. In a functional assessment, patient-specific information is collected, such as situations/circumstances that trigger anxiety, responses that follow the experience of anxiety, and thoughts regarding possible consequences. Following identification of primary fears and relevant cues, therapists discuss with patients their level of comfort to experiencing various forms of the phobic stimulus. This leads to the creation of the anxiety hierarchy, a list of phobic situations and/or objects that progresses from the least to the most fear-provoking situation and/or object. This list can be used as a roadmap for future sessions as well as an assessment of progress. For example, an individual with a fear of dogs may be placed in a differentiated proximity to a dog (100m, 50m, 20m, 10m etc), and eventually patting or carrying one.

Regarding in-vivo exposure, Abramowitz et al. (2019) advised several key considerations for therapists. First, ensure each item on the list targets a negative outcome the patient predicts may occur. Second, try to conduct the exposure and confrontation in other contexts. Third, consider varying the intensity of the emotional experience by mixing up the list. This could help with increasing fear tolerance. Fourth, the worst or most feared item should be in the list. Finally, include a measure for subjective units of distress (SUDS) to monitor session-to-session changes in anxiety. Overall, this form of exposure may result in a significant activation of anxiety in the patient. However, it subsides over some time. The duration of exposure can vary depending on the client and level of fear to the phobic stimulus upon commencement of treatment. Typically, exposure may be performed for the duration of

a therapeutic session over several sessions, or over a single session with a much longer duration (Abramowitz et al., 2019; Choy, Fyer, & Lipsitz, 2007b).

A key factor for therapists administering such exposure therapy is to ensure that the patient does not engage in any escape or avoidance coping mechanisms (Abramowitz et al., 2019). Avoiding the feared stimulus by escaping it or distracting oneself does not allow the fear to extinguish. This was demonstrated by Cornwell, Overstreet, Krimsky, and Grillon (2013), who reported that participants' avoidance behaviour was positively correlated with later levels of fear responding after extinction training. Thus, for exposure therapy to be most effective, the patient should fully engage in the therapeutic intervention. Notably, in the associative learning field, this effect is referred to as protection from extinction (McConnell & Miller, 2010; Rescorla, 2003; Soltysik, Wolfe, Nicholas, Wilson, & Garcia-Sanchez, 1983), and it is readily explained by learning theories. This will be discussed further in chapter 4 of this thesis.

One challenging aspect of conducting in-vivo exposure is the difficulty in accessing potential feared stimuli. For example, the expenses, health care and ethical treatment of animals may be significant obstacles for implementing in-vivo exposure for patients with animal phobia. In addition, certain phobias pose logistical difficulties, such as fear of flying or are out of human control, such as fear of thunderstorms. During such times, the therapist will either need to provide the allowance for impromptu sessions or prepare patients to work through these situations. It may be helpful to include printed instructions to facilitate other members of the patient's immediate social group to provide assistance (Abramowitz et al., 2019). Virtual reality exposure therapy may overcome some of these limitations and will be discussed in the following pages.

Efficacy of in-vivo exposure has been extensively researched for treatment of specific phobias, such as spiders (Antony et al., 2001; Michaliszyn et al., 2010a; Wolitzky & Telch,

2009), snakes (Andersson et al., 2013; Hunt & Fenton, 2007), dogs (Craske et al., 2014), blood-injection (Ayala, Meuret, & Ritz, 2009; Olatunji et al., 2007; Oliver & Page, 2003), heights (Emmelkamp et al., 2002), claustrophobia (Ost, Alm, Brandberg, & Breitholtz, 2001), pain-related fear (Vlaeyen et al., 2001), flying (Rothbaum et al., 2006) (for historical evidence, see Choy, Fyer, & Lipsitz, 2007a; Wolitzky-Taylor et al., 2008a). Overall, research has supported the use of in-vivo exposure as a clinical treatment for reducing phobic reactions across a broad population and wide range of stimuli. It is highly effective even when compared to other forms of interventions (e.g., Cognitive Therapy; Öst et al., 2001). When compared to other forms of exposure, such as virtual reality exposure therapy (Emmelkamp et al., 2002), computer aided vicarious exposure (Gilroy et al., 2000; Heading et al., 2001), and imaginal exposure therapy (Rentz et al., 2003), in-vivo was found to be more effective at reducing fear reported post-treatment. However, no difference was observed at follow-up assessments (Wolitzky-Taylor et al., 2008b). Briefly, virtual reality exposure therapy (VRET) is a technique that utilizes computer-rendered virtual environments containing the phobic stimulus to conduct exposure treatment. (This is discussed in more detail below). More recent research comparing in-vivo exposure to VRET also reported findings consistent with previous comparisons. A randomized controlled trial (RCT) conducted by Michaliszyn et al. (2010b) comparing VRET to in-vivo demonstrated similar efficacy at post-treatment. More improvements were observed for in-vivo exposure in the fear beliefs assessed by the Spider Beliefs Questionnaire (SBQ-F) (Arntz, Lavy, Van den Berg, & Van Rijsoort, 1993). However, at follow-up the in-vivo exposure group reported lower scores compared to VRET. A recent review by Wechsler, Kumpers, and Muhlberger (2019) comparing the efficacy of VRET to in-vivo exposure for treatment of specific phobias, such as agoraphobia and social phobia found that in nine RCT studies, no evidence was

present to suggest less overall efficacy of VRET compared to in-vivo exposure. A slight advantage was found for in-vivo for social phobia.

Notably, the process of in-vivo exposure therapy is analogous to behavioural extinction (Bouton & Bolles, 1979; Pavlov, 1927; Rescorla & Heth, 1975) paradigms in laboratories. In extinction training, the excitatory CS is presented repeatedly in the absence of the US leading to a gradual decrease in responding. In exposure therapy for a specific phobia, the feared stimulus is presented until the patient stops exhibiting a fear response. As such, extinction studies in the laboratory are used to study the mechanisms of exposure therapy (e.g., Bouton, 1988; Craske, & Mystkowski, 2006; Craske et al., 2008). The fact that exposure therapy is so highly effective in reducing phobic response suggests that associative learning does contribute to the aetiology of phobias.

3.2.2 Systematic desensitization.

Systematic desensitization (SD) was developed by Wolpe (1958). SD seeks to reduce the association between the phobic stimulus and anxiety by pairing it with a physiological state that is in opposition to anxiety. Similar to what was described above, patients and therapists first engage in discussions to establish an anxiety (fear) hierarchy. This list may contain phobic situations and/or objects and starts from the least fear provoking to the most. Therapists then begin to teach relaxation strategies to the patient. This takes the form of progressive muscle relaxation first developed by Edmund Jacobson in 1934 (see McCallie, Blum, & Hood, 2006), although other forms of relaxation such as deep breathing and visualization may also be taught (Baker, 2009). Next, the therapist facilitates the visualized confrontation, based on the selected stimuli in the anxiety hierarchy, while the patient is in the state of relaxation. These encounters are gradually increased based on their level of fear on the hierarchy all while the patient is in a relaxed state. This procedure is believed to result

in the relaxation experience to dominating and overriding the experience of anxiety at each level.

Wolpe (1958) explained that the goal of SD is to initiate "reciprocal inhibition", in which anxiety becomes inhibited by a response incompatible with anxiety (i.e., relaxation response). In other words, the sympathetic response to the aversive situation can be inhibited through muscular relaxation. This training needs to be done gradually through visualization or in-vivo exposure. A conditioned inhibition response is trained for every stimulus listed on the anxiety hierarchy until the most aversive phobic stimuli becomes a conditioned inhibitor of the anxious response through relaxation. Initial studies reported that relaxation was an essential component for systematic desensitization to be effective (e.g., Johnson & Sechrest, 1968; Kass & Gilner, 1974; Rachman, 1965), but others have found that relaxation alone is effective (e.g., Freeling & Shemberg, 1970; Laxer & Walker, 1970; Waters, McDonald, & Koresko, 1972), and yet others have found graduated imaginal exposure to be as effective with or without relaxation (e.g., Dawson & McMurray, 1978; McGlynn, Solomon, & Barrios, 1979). Imagery also appears not to be an essential component to SD (Aponte & Aponte, 1971).

Another challenge to reciprocal inhibition comes from research on the effectiveness of flooding therapy (Boudewyns, 2012), which elicits high levels of distress and anxiety while using relaxation. Reciprocal inhibition had stated that anxiety needs to be minimized in order for counterconditioning of antagonistic responses, such as relaxation, to occur. This led researchers to conclude that while SD appeared to be an effective therapeutic paradigm for treating anxiety disorders, the reciprocal inhibition explanation postulated by Wolpe was not supported, and not all components may be necessary to elicit change (Kazdin & Wilson, 1978; Yates, 1975). The conceptual basis from which Wolpe formulated reciprocal inhibition has been criticised as an extreme extension of past studies on reactive inhibition (Hull, 1943)

and an extrapolation of competing muscular reflexes as a complex neural and behavioural explanations of the functional components of SD (Wilson & Davison, 1971).

Counterconditioning was used as a concept to explain the sustained impact of SD (Wolpe, 1958). Relaxation was viewed as the replacement of the previous anxious response to the fear stimulus. Comparing groups experiencing SD, relaxation alone, exposure alone and no treatment control, Davison (1968) found strong support for SD in anxiety reduction. The author also noted that Wolpe's description of reciprocal inhibition is fundamentally similar to counterconditioning. However, Nawas, Mealiea Jr, and Fishman (1971) strongly disputed Davison's results on grounds of lacking an adequate control group. As a component of SD, support for counterconditioning as an effective anxiety reduction technique has not been well supported (Van Egeren, 1971; Van Egeren, Feather, & Hein, 1971). Similarly, Spiegler et al. (1976) found no support for the efficacy of counterconditioning. Instead, superior reduction in anxiety was found in cue-controlled relaxation (known as self-control paradigm of systematic desensitization in this article). Spiegler et al. defined the tension experienced during anxiety as the cue to practice relaxation.

Habituation was also put forth as an explanation of SD. Watts (1979) explained that the gradual reduction in autonomic response to the repeated presentations of the phobic stimulus is a habituation process. Relaxation helps to further reduce arousal, maximising the habituation procedure. However, inconsistencies such as habituated responses lead to recovery when the stimulus is not present, increases in response strength when a stronger stimulus is present, and the longer lasting fear reduction experienced from exposure, means that habituation may not accurately account for all the processes of SD (Craske, Liao, Brown, & Vervliet, 2012; Tryon, 2005).

Research on the efficacy of SD in treating anxiety related disorders and specific phobias began in the early 1960s and declined in the 1970s (McGlynn, Smitherman, &

Gothard, 2004). More recently, researchers have investigated the efficacy of SD compared to other treatment types such as Acceptance and Commitment Therapy (ACT) (Zettle, 2003), Benson's relaxation (Sajadi et al., 2017) and in combination with other treatment types. For example, Zettle (2003) treated college students with math anxiety with ACT or SD. Both treatments demonstrated comparable efficacy in reducing self-reported anxiety with math and test taking. Only SD demonstrated reduction in trait anxiety. Neither treatment predicted improvements in math ability. Both interventions also maintained at the two-month follow-up. While general effectiveness of both interventions was established for reducing math anxiety, the processes of change may be different. Specifically, participants that reported higher experiential avoidance responded better to ACT, and negatively to SD. This suggests that SD as a first-order change strategy (Wolpe, 1958) may not be suitable for patients with higher levels of experiential avoidance, and ACT should be considered instead. In another study, Sajadi et al. (2017) compared Benson's relaxation technique (van Dixhoorn & White, 2005) to SD in decreasing self-reported anxiety in highly anxious nurses. The RCT found general support for the effectiveness of both techniques in reducing state and trait anxiety. Although no significant differences were found between the two intervention strategies, SD reported a higher mean change score.

For combined treatments, Coldwell et al. (2007) investigated if benzodiazepine would facilitate the treatment effectiveness of SD in patients with dental injection phobia. While the authors found no evidence for the advantage of drug combination with SD, as measured by self-reported anxiety, heart rate and a behavioural avoidance test, dental fear was overall reduced and maintained after one year, which suggested that SD did produce significant results on dental fear treatment. Iglesias, Iglesias, and Iglesias (2013) conducted a case study on a patient with driving-related phobia, or amaxophobia. They combined SD with hypnosis and treatment outcome was measured by reduction in distress signals from the patient as well

as completion of the treatment plan. The patient received one assessment session, four hypnosis sessions, and one treatment termination session plus 14 independent in-vivo exposure sessions. The authors reported that the patient overcame the driving phobia and remained symptom free during a six-month follow-up.

In a multi-technique combination intervention, Triscari et al. (2011) compared the combination of CBT + SD to CBT + Eye Movement Desensitization and Reprocessing (EMDR) in treating patients with fear of flying. (Briefly, EMDR is a psychotherapy technique in which the patient is asked to recall distressing imageries and then asked to follow a bilateral stimulation such as moving the eyes side to side. This is discussed in more detail below). Using the Flight Anxiety Situations Questionnaire and the Flight Anxiety Modality Questionnaire (Van Gerwen, Spinhoven, Van Dyck, & Diekstra, 1999), results indicated that both treatment types (CBT-SD and CBT-EMDR) were effective at reducing self-reported anxiety. In addition, more than 90% of participants in both groups (CBT-SD: n=31, CBT-EMDR: n=21) were able to experience an actual flight post-treatment. In a similar follow-up study, Triscari et al. (2015) included CBT + VRET, in addition to CBT-SD and CBT-EMDR. Using similar procedures and measures to Triscari et al. (2011), the researchers found that all three interventions were effective at reducing self-reported fear of flying. Similar to the previous study, more than 90% of the participants in all groups completed an actual flight post-treatment. Notably, CBT-VRET resulted in 100% participants flying after treatment. Although efficacy for the combination of treatment types were observed in this sample, the authors did not have a single treatment control group to compare the effectiveness of individual treatment compared to combined treatment. Hence, this makes conclusions about the effectiveness of each treatment type difficult.

It is notable that much of the research on SD, particularly the early studies, lack validity and contain severe methodological flaws such as the lack of subjective fear (Lang &

Lazovik, 1963), poor control of experimental demand effects (e.g., Orne, 1962), lack of detailed explanation of how treatment was administered, assessment procedures, (see, Kazdin & Wilcoxon, 1976; cf. McGlynn, Mealiea Jr, & Landau, 1981; McGlynn et al., 2004; Wilkins, 1971). Overall, there is a drastic decline in interest in SD due to the emergence of competing treatments, such as flooding (Malleson, 1959), implosive therapy (Stampfl & Levis, 1967), participant modelling (Bandura, 1971), and the shift to cognitive behaviour therapy (Beck & Dozois, 2011).

3.2.3 Imaginal Exposure

Imaginal exposure (IE) is a procedure in which patients use their imagination as a medium to experience their feared stimulus. Wolpe (1958) was the first to incorporate such a technique as a clinical component in systematic desensitization (SD). IE is often a component of a treatment intervention that requires exposure treatment but where in-vivo exposure might not be realistic or accessible. Treatment types that have incorporated IE as a component of treatment include Prolonged Exposure treatment (e.g., Foa, Hembree, & Rothbaum, 2007; Hagenaars, van Minnen, & Hoogduin, 2010), Dialectical Behavioural Therapy – Prolonged Exposure protocol (e.g., Harned, 2013), CBT (e.g., Kaur, Murphy, & Smith, 2016; Levinson, Rapp, & Riley, 2014), Schema Therapy (e.g., Jacob & Arntz, 2012), EMDR (e.g., Shapiro, 1995) and Acceptance and Commitment Therapy (e.g., Orsillo & Batten, 2005).

Implementing IE does not necessarily require relaxation training prior to implementation. A significant advantage to using IE compared to in-vivo may be logistical. It can be challenging and inconvenient to conduct in-vivo exposure due to the availability of certain feared stimuli. For example, animal phobias can be challenging for therapists to provide in-vivo exposure because of housing, care and, possibly, ethical handling of animals. In addition, the flexibility of use means that patients and therapists may work together to construct detailed idiosyncratic situations that otherwise might be, logistically impossible or

ethically unsound, to provide in-vivo. (e.g., exposure therapy for people suffering from blood-injection-injury phobia).

Although exposure occurs in the patient's imagination, these benefits translate successfully to real-world scenarios. Richards (1988) treated one patient with snake phobia using IE. Interestingly, the author audio-taped the sessions to facilitate the patient's self-administered IE homework. After 10 sessions, self-reported fears on questionnaires reduced significantly. The patient was also able to attempt an in-vivo exposure to a live snake and managed to hold and carry a moving snake post-treatment. Although the study is a single case study, it lends some evidence of translational effectiveness of IE in reducing anxiety and aiding faster habituation towards a real-world experience. In a comparison between in-vivo exposure and IE, Hecker (1990) recruited 36 highly snake-fearful participants and allocated them to either condition for treatment. Over 10 exposure trials, self-reported fear and heartrates declined for both exposure treatments. Outcome rating on the snake phobia questionnaire recorded a decline in both treatments as well. However, this study does not accurately compare both treatments as the imaginal scenes used were inconsistent; the first scene depicted the snake further and another much closer. This elicited a difference in initial fear during a scene change which may be observed as a renewal of fear (see Bouton 1993). Nonetheless, the decline in overall self-reported fear and recorded heartrates provides some evidence for IE's effectiveness for treating specific phobia. Other studies have also found similar positive treatment effects as compared to virtual reality,

Integrating IE with coping skills, Rentz et al. (2003) sought to investigate the utility of in-vivo coping skills with IE in treating patients with dog phobia. For the sample of 82 participants, when compared to IE alone, and in-vivo exposure, no differences were observed, all treatment interventions found decreased self-reported fear and increased behavioural approach post-treatment. At follow-up, in-vivo exposure was found to have the highest

relapse rate (21.4% of participants in this group) followed by IE with active coping (4.8%) and IE alone (0%). However, this follow-up result may not be an accurate measurement due to participant dropouts. Although this study did not specify what coping skills are used, the utility of adding some form of anxiety management strategy may serve to reduce relapse and a protection from relapse. An earlier study comparing the use of benzodiazepine, with psychological treatment (single session stress management skills with IE) and no treatment, found superior effectiveness for IE at reducing relapse of dental phobia (Thom, Sartory, & Jöhren, 2000). Up to 70% of patients in the IE group returned for follow-up treatment, while only 20% returned for the benzodiazepine group and 10% for the no treatment group.

Studies comparing IE to virtual reality in treating phobias have found mixed results. Some have found little difference between virtual reality exposure to IE (e.g., Rus-Calafell, Gutierrez-Maldonado, Botella, & Banos, 2013) while other studies have found the opposite (e.g., Wiederhold et al., 2002). More recently, Reger et al. (2016) conducted a RCT comparing prolonged IE (PE), to virtual reality exposure (VRE) and wait-list controls. Hypothesizing that VRE would be the superior treatment of choice, the authors recruited 162 active-duty soldiers with PTSD, and randomly assigned them to one of the three groups. Conducted over 10 sessions, the authors measured treatment efficacy using structured clinical interview as the primary measure. The results found significant improvements in both PE and VRE compared to waitlist. No superiority was found for VRE over PE. Instead, at three- and six-months follow-up, larger symptom reductions of PTSD were observed for the PE group compared to VRE. Interestingly, a case study used PE during a VRE procedure to treat a PTSD patient with multiple severe traumas. Posttreatment reductions in the clinical interview similar to Reger et al. were large and maintained over 6 months. Some advantages of IE over VRE include lower setup cost and simpler implementation. Disadvantages include a lack of therapist control, and subjective efficacy due to the use of imagination (Bush, 2008). A

teething problem with using technological advances in treatment may be due to a therapist's lack of confidence and familiarity with it leading to reluctance. Increasing training and education regarding use of VR may eventually reduce therapist reluctance.

Although in current years, the primary use of IE has been for treating post-traumatic stress disorder (PTSD) (e.g., Arntz, Tiesema, & Kindt, 2007; Bryant et al., 2003; Powers et al., 2010), it has been shown to be effective with other anxiety disorders including generalized anxiety disorder (GAD) (e.g., Craske, 1999; Dugas & Robichaud, 2012), obsessive-compulsive disorder (OCD) (e.g., Foa, Steketee, & Grayson, 1985; Foa, Steketee, Turner, & Fischer, 1980), animal phobias (e.g., Rentz et al., 2003) and fear of flying (e.g., Rus-Calafell et al., 2013). Particularly, in treatment of PTSD, Arntz et al. (2007) combined IE with imagery rescripting. They hypothesized that IE with imagery rescripting provides more corrective information relating to the trauma. Results were favourable for the combination treatment compared to IE alone. Interestingly, therapists in the study preferred the combined treatment paradigm as they were able to provide corrective information through rescripting. There is a need to clarify that IE and imagery rescripting are different forms of treatment. IE, as explained, is a form of exposure to an imagine stimulus that can take the form of events, objects or situations. Imagery rescripting is a technique used to modify the patient's subjective relationship with the recollected memory of events, objects or situations. The modification is the key to extinguishing the learned relationship between, for example, heights (CS) and frightening images (US). IE leads to habituation towards the US (Hunt & Fenton, 2007).

Comparing in-vivo exposure to IE, the data appears mixed. When both are compared in treating spider fear, IE was found to be less effective at reducing fear (Armfield, 2008). A review of exposure approaches for treating phobias concurs with such a finding, that in-vivo exposure is superior to IE (Wolitzky-Taylor et al., 2008b). However, some studies have

reported no difference between both approaches (James, 1986), and other researchers have noted that combining both approaches yielded better overall reduction in fear responses (Kaloupek, 1983). Instead, it may be the active engagement in therapy related to in-vivo or imaginal exposure homework (i.e., self-administered exposure activities outside of therapy hours) that would aid in overall fear reduction (Mathews et al., 1976). However, it may not be the modality of exposure that is important but rather which approach is capable of eliciting a stronger state of emotional processing (Hecker, 1990). Hence, IE's capability of eliciting emotional states (Gerrards-Hesse, Spies, & Hesse, 1994; Holmes, Mathews, Mackintosh, & Dalgleish, 2008) is an important precursor to reducing overall anxiety through exposure learning. Through the lens of EPT (Foa et al., 2006; Foa & Kozak, 1986), the most effective type of exposure treatment is one that effectively and reliably activates fear structures and presents incompatible results.

Although the fundamental methods of exposure between in-vivo and imaginal are similar in that the patient confronts the feared stimulus, there are several important differences which can influence the effectiveness of the treatment. In-vivo exposure requires confrontation with the object or situation to be conducted external to the individual. In contrast, imaginal exposure conducts confrontation to objects or situations internally, in the mind's eye. This means that the quality of the exposure depends entirely on the mental image constructed by the patient and is thus out of the control of the therapist. Indeed, Lang, Melamed, and Hart (1970) reported that imagined feared stimuli are less vividly imagined by phobic patients compared to neutral ones. In addition, anxiety reduction, via imaginal exposure, was found to be affected by the level of details in imagined scenes (Watts, 1974). This would suggest that for imaginal exposure to be effective in treating patients with specific phobia, they would need to be capable of constructing a vivid and detailed mental imagery of their feared stimulus. Watts, Sharrock, and Trezise (1986) found that imaginal details from

participants with spider phobia are not necessarily less detailed compared to controls. But the authors found that coping imagery was significantly poorer for these participants compared to controls (e.g., describing how they would get a spider out of a bathtub). Phobic individuals may be experiencing significant difficulties visualizing how they will cope with the phobic stimulus, perhaps due to over utilization of anxiety control strategies, which therefore leads to the lack of disconfirmation experiences. Phobic imagery has also been found to generate internal sensations (e.g., discomfort on the skin and in the body). These images appear to induce more anxiety, increase negative self and other's maladaptive beliefs (Pratt, Cooper, & Hackmann, 2004). This may result in further engagement in anxiety control strategies without the knowledge of the therapist during imaginal exposure, resulting in poorer treatment outcomes. Foa et al. (2007) noted that disengagement from exposure interventions occur during the beginning of the treatment implementation. Foa et al. advised therapists to elicit details that are sensory and affective (e.g., "What do you see in this scene?", "What kind of emotions are you experiencing in this scene?"). Additionally, therapists should discuss with patients any issues relating to disengagement, under engagement or avoidance of IE. Addressing such concerns may provide more insight into maladaptive beliefs and thought processes (e.g., "What if I am unable to control myself?"). Hence, as previously mentioned, in some circumstances initial use of anxiety control strategies may provide some sense of control and boost self-esteem which may help patients feel better prepared for more challenging exposures (Parrish et al., 2008).

An interesting variant of IE is written exposure therapy (Sloan et al., 2013), which is mostly used for PTSD patients. This treatment requires patients to write about their traumatic experience. Preliminary studies suggest that this treatment shows promising effectiveness (e.g., Sloan et al., 2012) on levels comparable or better than other cognitive-based therapies (e.g., Neuner et al., 2004) in treating PTSD. Written exposure therapy is hypothesized to

operate using the same or similar underlying mechanisms as other exposure-based treatments (Sloan, Marx, & Epstein, 2005).

Another interesting development is using writing as a form of assessment. While in-vivo exposures usually assess treatment effectiveness using a Behavioural Approach Test (BAT), a new method has emerged known as the Behavioural Approach Test using Imaginal Exposure (BATIE), which is an alternative to the traditional BAT (Davis III et al. (2013). Patients with specific phobia were asked to perform a BATIE followed by an in-vivo BAT. The BATIE began with a piece of paper depicting the drawing of a room, with a person standing outside the room and a star (representing the fear stimulus) inside the room. Patients were then asked to circle the distance they were willing to approach the star if they imagined themselves as the figure. Differences in scores were found between patients and controls and demonstrated predictability of BAT scores. Therapists may therefore consider the use of BATIE in imaginal exposure sessions as it has the potential of being a helpful assessment tool to chart progress between sessions.

3.2.4 Virtual reality (VR)

Another form of exposure therapy is by virtual reality (e.g., Opdyke, Williford, & North, 1995; Opris et al., 2012; Strickland, Hodges, North, & Weghorst, 1997). This technique utilizes computer-rendered environments containing the phobic stimulus. As a tool for psychological treatment, its strength lies in its dynamic versatility to provide a tailored simulated environment that is safe for the patient to interact with. It can be considered as a vicarious exposure technique in which the patient is physically situated in a safe space, while providing the patient with a multi-sensorial exposure through digital representations of the phobic stimulus. VR potentially mitigates some of the logistical difficulties found in in-vivo exposure methods. Environments can be created to provide exposure for situations that may be more challenging. For example, fear of flying (e.g., Rothbaum, Hodges, Smith, Lee, &

Price, 2000), agoraphobia (e.g., Botella, Garcia-Palacios, Villa, Banos, Quero, Alcaniz, & Riva, 2007) and height phobia (e.g., Emmelkamp, Krijn, Hulsbosch, Vries, Schuemie, & van der Mast, 2002). The use of VR in psychotherapy has been on a rise, particularly for treating phobias. In general, studies have shown positive effects for this type of treatment across a broad range of phobias (Parsons & Rizzo, 2008).

In general, the efficacy of VR exposure therapy for patients with anxiety disorder has received wide support from several meta-analytic studies (e.g., McCann et al., 2014; Morina, Ijntema, Meyerbröker, & Emmelkamp, 2015; Opriş et al., 2012; Parsons & Rizzo, 2008; Powers & Emmelkamp, 2008). Anxiety disorders that were found to respond well to this therapy included fear of flying, panic disorder, social anxiety disorder, spider phobia, height phobia and PTSD. Opriş et al.'s analyses found that when compared to other evidence-based interventions (CBT, in-vivo exposure and imaginal exposure), VRET performed similarly.

One of the key components to the effectiveness of VR is the sense of presence. Presence adds to the immersiveness of VR and can be understood as transportation, where individuals feel "present" in the VR space (Schuemie, Van Der Straaten, Krijn & Van Der Mast, 2001). These experiences are more salient within a VR environment than in imaginal environments or environments created through images on a computer screen (Heeter, 1992; Lombard & Ditton, 1997; Slater & Wilbur, 1997). The therapist has significantly more control over the exposure treatment as it does not rely on the patient's imagination. In addition, the therapist would be able to observe both the patient's virtual interaction (i.e., through a monitor) as well as physiological reactions that may result from it. This way, treatment does not depend on patient self-reported engagements with an imagined feared stimulus. Instead, maybe observed real-time by the therapist. Diemer et al. (2015b) stated that theories attempting to conceptualize the sense of presence can be broken into descriptive models or structural models. Descriptive models attempt to represent presence as different

components. For example, Schubert, Friedmann, and Regenbrecht (2001) identified three components of presence: spatial presence, involvement and "realness". Structural models explain that the sense of presence is a direct result of cognitive processes such as selective attention to the VR space, and generating a mental representation of the VR environment are important factors that contribute to the experience of presence (Schuemie, van der Straaten, Krijn, & van der Mast, 2001; Witmer & Singer, 1998).

Since VR may be able to provide superior immersion into an environment compared to imaginal exposure (IE), one may assume that VR treatment is superior in treatment effectiveness for phobia. However, empirical data appear to be mixed. In a treatment comparison between VR and IE, Wiederhold et al. (2002) recruited 30 participants with a diagnosis of specific phobia for fear of flying. They were randomly allocated to either VR with physiological feedback, VR without physiological feedback and IE treatment groups. At the end of treatment, all groups reported a reduction in self-reported fear and anxiety. However, 18 participants that experienced VR exposure were able to fly without medication or alcohol at a three-month follow-up, only one participant from IE was able to achieve this. The authors noted that self-reported fear during exposure treatment was significantly less for groups that experienced IE compared to VR. As previously discussed, emotional processing theory states that fear structures need to be activated during exposure so that incompatible information may provide disconfirmation of anticipated danger. Differences between elicited anxiety during treatment were also observed in another study that combined VR and IE for treatment of fear of flying. Hoffman (2009) found that anxious behaviour of participants in VR treatment decreased over treatment sessions but not for participants in IE treatment. There was also a stronger congruency between observed anxiety and subjective anxiety compared to IE. This suggests that VR more naturally and organically elicits fear and anxiety compared to IE. Although all participants were able to fly post-treatment, more reduction in

subjective anxiety and anxiety related behaviours after VR treatment was found compared to after IE treatment. Overall, more symptom reduction was observed after VR treatment as compared to IE.

In another comparison study, 88 participants with social phobia were randomly allocated to CBT with IE, CBT with VR exposure or wait-list control. Both treatment interventions successfully reduced overall self-reported anxiety compared to control, but no differences were observed between them (Wallach, Safir, & Bar-Zvi, 2009). Thus, the data is mixed on which treatment option is superior for treating phobias. Some studies comparing IE and VR for treating PTSD appear to reflect similar mixed results. In a study comparing VR, IE and wait-list control in treating elderly war veterans for PTSD, both VR and IE were found to be superior to control, but no differences on PTSD symptomology were observed between VR and IE post treatment. Conversely, another study found that prolonged IE was superior to VR exposure for treating PTSD in active-duty soldiers (Reger et al., 2016). Differences between these two studies are the type of veterans suffering from PTSD. Older post-war veterans may benefit better from either treatment since trauma memories are not as fresh compared to active-duty soldiers which may have an advantage in recalling events for IE.

Treatment effectiveness between VR and in-vivo appear to be largely similar in treating anxiety disorders. For example, comparing VR with in-vivo exposure and wait-list controls, 37 patients suffering from panic disorder with agoraphobia were found to equally benefit from both treatment interventions compared to controls. That is, patients experienced symptom reduction, and self-reported improvements in anxiety, panic, depressive symptoms and a reduction in avoidance and negative beliefs of the phobic stimuli. No differences were found between VR and in-vivo suggesting that VR was as effective as in-vivo in this study (Botella et al., 2007). In a treatment study, patients experiencing acrophobia (fear of heights)

were assigned to either VR exposure or in-vivo exposure treatment. Over the course of three exposure sessions, the researchers found that both interventions resulted in reduced self-reported acrophobia symptoms and improvements in the behavioural approach. Results were also maintained at a six month follow-up (Emmelkamp et al., 2002). However, a later study found that treatment times for VR were faster compared to in-vivo for acrophobia (Coelho et al., 2008).

Comparisons between VR and in-vivo for treating arachnophobia also appear to reflect similar results. In a RCT study, Michaliszyn et al. (2010b) found that although both treatments were found to be effective and no differences between them were found across the battery of assessments, one particular result stood out. A significant difference was found in post-treatment beliefs of spiders for patients that experienced in-vivo exposure but not those that experienced VR exposure. This suggests a slight advantage of in-vivo for changing beliefs in treating arachnophobia. Both treatment types also appear to have similar effectiveness for treating children diagnosed with arachnophobia (St-Jacques, Bouchard, & Bélanger, 2010). A recent large scale RCT comparing VR to in-vivo using consumer grade VR equipment also found similar levels of effectiveness between VR and in-vivo (Carlbring, 2017). Other phobias such as social phobia (e.g., Robillard et al., 2010) and fear of flying (e.g., Rothbaum et al., 2006) also found similar levels of effectiveness between VR and in-vivo exposure, with no significant treatment differences between them.

Despite the encouraging union between VR technology and clinical treatment, there are several drawbacks and limitations to using VR exposure. Firstly, therapists hoping to implement VR exposure will need to be familiar with both the program and hardware used to conduct treatment. This will require therapists to be adept at computer technology for successful delivery. Such a skill not only ensures a smoother delivery of treatment, it also ensures simple troubleshooting can be performed without incurring additional costs of hiring

professional technicians. Next, costs of hardware and custom-built software may become a barrier to implementation in real-world treatment centres. Although costs of VR hardware has decreased over the last few years allowing for recent research to utilize consumer grade VR technology for various research fields (e.g., Carlbring, 2017; Chessa, Maiello, Borsari, & Bex, 2019; Seo et al., 2016), high costs for custom VR programs remain a significant barrier. Nonetheless, recent commercially available VR programs such as Turtle Rock Studios' " Face Your Fears" game published by Oculus Studios (Oculus Studios, 2016) may aide clinical VR exposure implementations. In addition, it is important for the therapists implementing such an exposure paradigm to be just as proficient at conducting other types of exposure like in-vivo or imaginal as this provides patients with more options in their therapeutic choice.

3.2.5 Eye movement desensitization and reprocessing (EMDR)

Shapiro (1989) developed EMDR to treat post-traumatic stress disorder (PTSD). Originally, Shapiro thought that eye-movement was unique in eliciting desensitization. Both systematic desensitization (SD) and EMDR seek to diminish the emotional responsiveness to anxiety. However, the methods to elicit desensitization are different. EMDR elicits desensitization to traumatic memories through repeated eye movements (Shapiro, 1989), whereas SD elicits desensitization through gradual repeated exposure of fear from least feared to most feared stimuli (Wolpe, 1958). Both techniques utilize interoceptive exposure either that of imaginal exposure in SD or recalled traumatic memories in EMDR.

EMDR therapy focuses on processing unresolved traumatic memories which is hypothesized to contain images, sounds thoughts and feelings from the original event. Negative emotions and beliefs of self are associated with these traumatic memories. EMDR works by reducing the physiological effects brought on by these memories and then integrate positive/adaptive self-assessments. In other words, negative cognitions connected to the

traumatic memories are replaced by positive cognitions (e.g., from “I am powerless.” to “I am in control.”). A “connection” between the desensitized traumatic memory and the positive cognition is made. This ensures that the next time the memory of the event is triggered, it is associated with the positive cognition and not the previously maladaptive cognition about themselves (Shapiro, 2001, p. 74).

In EMDR, a traumatic memory is first elicited and an image that represents the most distressing part of the incident is chosen as the focus. Next, the patient is asked to identify a negative self-belief that is associated with the image. Shapiro (2001) calls this the “negative cognition”. Following this, the patient identifies a desired positive cognition. This allows a direction to be set for therapy and a manner in which to initiate the adaptive memory networks. This is followed by desensitization. The patient tries to focus on the distressing image while experiencing desensitisation through rapid left-right eye movement until self-reported levels of distress are low. Following this, the patient is asked to simultaneously hold on to the desensitized traumatic image and the positive cognition while engaging in the same desensitizing process.

Shapiro (Shapiro, 1995, 2001; Shapiro, 2002) developed the Adaptive Information Processing (AIP) model as the theoretical foundation for EMDR. The AIP model posits that within individuals, an information processing system exists that integrates new experiences into current memory networks. These memory networks make up an individual’s perception, attitudes and behaviours. Perceptions of a given event automatically trigger associated memory networks. In other words, useful information is learned and stored in memory networks encoded with appropriate emotions. This provides the individual with a frame of reference and guides future thoughts, feelings and behaviours. In AIP, psychopathology is explained by inadequately processed experiences. These traumatic experiences may be stored in their own memory network that is isolated and does not connect to other adaptive networks

(Solomon & Shapiro, 2008). This particular memory is encoded with all its associated psychological and physiological experiences (i.e., distress, anxiety, self-perceptions), and can be triggered by internal and external stimuli, resulting in the manifestations of pathological symptoms. Thus, negative behaviours and personality traits are the result of storing inappropriate information (e.g., negative beliefs of self). Unlike CBT, current psychological distress is a result of unprocessed negative life experiences and not negative self-beliefs. Hence, EMDR postulates that resolution is only achieved through accessing the dysfunctional memory, initiating the processing system and establish links to adaptive memory networks. Support for the hypothesis comes from various neurobiological sources. For example, Buchanan (2007) reviewed neurological research suggesting that the brain regions associated with emotional processing are also involved with emotional memory retrieval. In other words, a person reexperiences emotions during retrieval of memories. The AIP's hypothesized mechanism of reconsolidation of memories by integrating positive cognitions to desensitized traumatic memories is consistent with some theories of memory reconsolidation (Cahill & McGaugh, 1998; Suzuki et al., 2004). Other studies have also found that unprocessed memories of possibly traumatic experiences are associated with the development and maintenance of psychopathology (Afifi et al., 2012; Felitti et al., 1998; Mol et al., 2005; Teicher et al., 2010).

There is wide support for EMDR as an effective psychotherapy for trauma-related disorders. It is recognized by organizations such as the American Psychiatric Association (Ursano et al., 2004), National Institute of Health and Clinical Excellence (Bisson et al., 2005; INSERM, 2004) and the International Society for Traumatic Stress studies (Foa, Keane, Friedman, & Cohen, 2008). In addition to trauma-related disorders, clinicians and researchers have begun exploring the use of EMDR as treatment for depression (Hase et al., 2015; Hofmann et al., 2014; Uribe, Ramírez, & Mena, 2010), specific phobias (Barker &

Barker, 2007; Muris, Merckelbach, Holdrinet, & Sijsenaar, 1998), generalized anxiety disorders and panic disorders (de Jongh & Broeke, 2009; Gauvreau & Bouchard, 2008), obsessive compulsive disorder (Marr, 2012), conduct problems (Soberman, Greenwald, & Rule, 2002), borderline personality disorder (Brown & Shapiro, 2006) and medically unexplained symptoms (van Rood & de Roos, 2009).

Treatment for specific phobias follows the "EMDR Protocol for Phobias" (Shapiro, 2001). Although largely similar to the protocol for PTSD, Shapiro pays special attention to teaching self-control strategies to help patients with specific phobia manage "fear of fear". It was noted that many traumatic events may underlie the development of a phobia. Thus, the overall protocol is applicable for treatment. Indeed, phobias have been found to be segregated to trauma-related phobias and those without trauma history (De Jongh & ten Broeke, 2007; De Jongh, van den Oord, & ten Broeke, 2002). A more detailed treatment manual was later described and expanded upon (De Jongh, 2015), but has not received much attention.

Early studies using EMDR to treat phobia found encouraging results in choking phobia (De Jongh & Ten Broeke, 1998; De Roos & de Jongh, 2008). This is because patients with choking phobia often have past traumatic near-choking experiences although all pathways of fear acquisition are also possible (Rachman, 1977). Hence, these traumatic near-choking experiences respond well to EMDR's technique since it is primarily a trauma processing technique. In addition to choking phobia, EMDR was also found to be effective in treating childhood arachnophobia. Compared to in-vivo treatment, spider phobic children reported lower anxiety post-treatment (Muris et al., 1998; Muris, Merckelbach, Van Haaften, & Mayer, 1997); however, in-vivo was more effective at reducing overall avoidance of spiders. A later case study report of treatment of spider phobia through EMDR by Gupta, Gupta, and Choudhary (2014) was reported to "end with a positive response by the child".

However, no subjective assessment was administered and thus, no empirical data was reported.

When EMDR was compared to wait-list and placebo groups for treatment of Panic disorder with agoraphobia (Goldstein, de Beurs, Chambless, & Wilson, 2000), EMDR was found to be similar to the placebo group on post-treatment reduction in symptom severity, and frequency of anxious thoughts and frequency of panic attacks. EMDR was more effective at symptom reduction compared to wait-list, but they were similar on frequency on anxious thoughts and panic attacks. EMDR was also reported to have successfully treated dental phobia. In a case study report, four adult patients age 24 to 39 reported decrease in dental phobia related symptoms and there were improvements in self-reported anxiety following two to three sessions of EMDR treatment. Treatment gains were reported to be maintained two weeks and six weeks post treatment (De Jongh et al., 2002). In another study, EMDR was compared to trauma-focused CBT (TFCBT) in treating patients with travel phobia (i.e., a fear of travel often resulting from past experience of road traffic accidents) (de Jongh, Holmshaw, Carswell, & van Wijk, 2011). A sample of 184 patients underwent either EMDR or TFCBT over an average of eight one-hour sessions. Outcome measures included the general health questionnaire, impact of event scale and the hospital anxiety and depression scale. Overall results found no difference between treatment groups. Both groups reported significant reductions across all measures. This suggests that for the treatment of trauma-related travel phobia, EMDR is comparable to TFCBT in its effectiveness.

Research into the effectiveness of EMDR on treating specific phobias still appear to be limited at this time. However, more recent research has found some effectiveness at reducing social anxiety (Qorbanpoor Lafmejani, Samady Biniaz, & Rezaei, 2020; Sagaltici & Demirci, 2019) and Blood Injection Injury phobia (BII) (Meentken et al., 2020). The latter is most interesting as treatment for BII phobia has largely focused on the use of applied tension

due to the unique presentation of biphasic vasovagal symptoms (see 2.3.1.6 Applied Tension for more).

EMDR's unique approach to treatment uses dual attention tasks of asking patients to focus on their distressing traumatic memory while focusing on the repetitive left-right movement of the therapist's fingers. Some studies have found that the eye movement exercise contributes significantly to the treatment effectiveness (Kavanagh, Freese, Andrade, & May, 2001; Lee & Drummond, 2008; van den Hout, Muris, Salemink, & Kindt, 2001), while others have found success omitting the exercise (Cahill, Carrigan, & Frueh, 1999; Davidson & Parker, 2001). However, more recent reviews have reported that the eye movement exercise contributes to the processing of emotional memories (Lee & Cuijpers, 2013), suggesting that the overall impact of eye movement is critical to the success of EMDR. Three mechanisms were proposed to explain its effectiveness. Schubert, Lee, and Drummond (2011) hypothesized that the rapid bilateral visual stimulation taxes working memory, activates parasympathetic responses because of an orienting response and taps into the same processes of memory consolidation as rapid eye movement sleep.

Although overall effectiveness of EMDR is good, it is a treatment focused on trauma-related disorders, and while some studies have found success at treating some phobias, results are, at this time, limited but encouraging.

3.2.6 Applied tension (AT)

Applied tension (AT) was a technique first used by Ost, Lindahl, Sterner, and Jerremalm (1984) using a tension technique adapted from Kozak and Miller (1985). It is a technique used for treating blood phobia or blood-injection-injury (BII) phobia (Ost & Sterner, 1987). There are two main components of AT therapy: (1) muscle tension practice, in which the patient tenses the muscles of the buttocks, stomach, buttocks, arms, neck, fists and jaw repeatedly for 10 – 15 seconds followed by 20 seconds of rest; (2) repeated in vivo

exposure to the phobic stimulus while using the muscle tension practice (Öst, Salkovskis, & Hellström, 1991; Ost, 1989).

Patients with BII phobia tend to experience a unique biphasic physiological response characterized by an increase in blood pressure and heart rate representative of anxiety, and then followed by a drop in blood pressure and heart rate (Marks, 1988). Consequently, many BII patients faint upon seeing blood. AT combines muscle tension and in vivo exposure. Patients learn to identify early symptoms of blood pressure decrease and then practice tensing and releasing their muscles so that the drop in blood pressure is reversed, preventing fainting (Öst, 1989; Öst et al., 1991). AT has been found to increase the velocity of cerebral blood flow in patients with phobia as well as non-phobic people (Foulds, Wiedmann, Patterson, & Brooks, 1990)

Ditto, France, Albert, and Byrne (2007) investigated what they believed to be components of AT. The authors hypothesized that AT is made up of several components: lower-body tension, upper-body tension, expectation of positive effect, and distraction. Lower-body tension describes the repeated muscle tension of lower body muscles which includes legs and abdomen. Upper-body tension describes repeated muscle tension of both arms. Expectation of positive effect is a possible placebo effect from learning AT. Distraction describes paying attention to other stimuli during AT (i.e., paying attention to the arm not getting an injection). Ditto et al. randomly allocated 1209 blood-donors into six groups which includes the no treatment group, full AT, and each of the four hypothesized components. Results were supportive of AT in reducing pre-post self-reported anxiety and request for assistance (i.e., chair reclining to assist with blood flow). Only two components resulted in significant decreases in self-reported anxiety and chair reclining, lower-body tension and distraction. Participants in these groups also reported significantly more reduction compared to no treatment controls and were comparable to the full AT group. This study supports the

idea that the effectiveness of AT is driven by lower tension of large muscles in the legs and abdomen and active distraction.

However, this study did not use patients with specific phobia related to BII; participants were regular blood donors and therefore may not be representative of BII patients. Additionally, the components are not well defined nor are they supported by empirical evidence prior to the investigation. They were merely hypothesized by the authors to be components of AT. Nonetheless, the evidence provides an early investigation into refining components of AT. It had also been proposed that rhythmic muscle tension may be more effective at eliciting the rise in blood pressure compared to constant muscle tension (Bodycoat, Grauaug, Olson, & Page, 2000).

Compared to in-vivo exposure for BII phobia, AT appear to be superior. Ost, Fellenius, and Sterner (1991) found that patients with BII phobia responded better to AT than to in-vivo. Significant improvements in blood pressure were observed for the AT group relative to the in-vivo group. Pre-Post-test behavioural avoidance was also significantly reduced compared to the in-vivo group, with gains observed still at a one-year follow-up. Total self-reported fainting spells also reduced for the AT group as compared to in-vivo at post-test and at follow-up. Another study compared multiple sessions of AT to one prolonged AT session (Öst, Hellström, & Kåver, 1992). The authors reported comparable effectiveness for both manipulations in reducing BII anxiety. This suggests that a three-hour, one-session exposure treatment with AT is just as effective as five one-hour sessions. Treatment studies for BII phobia have only explored the use of AT as a treatment paradigm and all have demonstrated effectiveness in reducing overall anxiety, reducing fainting spells and increasing blood pressure (Hellstrom, Fellenius, & Ost, 1996; Öst et al., 1992; Ost et al., 1991; Ost et al., 1984; Ost, Sterner, & Fellenius, 1989). A review of the historical literature surrounding BII phobia and AT treatment found that all the previously available research

supporting AT's use for BII come from a single research team. Their results had not yet been replicated by other independent research teams (Ayala et al., 2009). However, more recent research has found evidence that AT is effective for treating adolescents with diagnosed BII phobia (Mednick & Claar, 2012), and AT may be performed through self-arranged in-vivo exposure through blood donation (Pitkin & Malouff, 2014). More recent research focuses on the use of AT to reduce anxiety in blood donors (e.g., Holly, Balegh, & Ditto, 2011; Holly, Torbit, & Ditto, 2012).

An interesting advancement in our understanding of the psychophysiology of BII has emerged. Ritz, Meuret, and Ayala (2010) proposed that the reduced carbon dioxide observed in the blood of BII patients during attacks leads to reduced blood flow to the cerebral cortex. The authors suggested that respiration focused treatment methods may be an effective treatment method. This was tested by Mennitto et al. (2019), who found that respiration control technique using slow and shallow breaths was as effective as AT in reducing self-reported anxiety and controlling vasovagal symptoms in a population of 547 blood donors. AT has not been used as a technique to treat other phobias as the vasovagal symptoms are unique to BII phobia, which are specifically targeted by AT treatment techniques. Nonetheless, in-vivo exposure to blood or experiencing the procedure (i.e., injection) is necessary for overcoming BII phobia. AT provides the physiological stability for the behavioural exposure to be successful.

3.3 Cognitive Therapy (CT)

Aside from the more behavioural-based approaches described above, phobias have also been treated using other clinical paradigms, such as cognitive therapy, and acceptance and commitment therapy. As this study is focused primarily on the associative learning and behavioural aspects of phobia acquisition and their treatment, these other types of therapy will only be briefly discussed.

CT aims to target distorted and irrational thoughts that are associated with the phobic stimulus or situation as well as misinterpreting physiological symptoms that occur and misappraisal of the degree of risk the object or situation poses despite relative safety (Beck, Emery, & Greenberg, 2005). For example, a person with arachnophobia might see a spider and immediately think "That spider is venomous and will definitely bite me and I will die from the venom" or "That spider will bite me, and it will be extremely painful". This imagined threat may range from mild anxiety to activating a full-blown panic attack. Unique to phobias is that danger or perceived threat is dormant until in the presence of the feared stimulus. Generally, thoughts such as not being able to cope if the phobic stimuli appear or that catastrophic events will occur in its presence are the main targets for change in CT. Through cognitive restructuring, the patient works towards active confrontation of their own maladaptive thoughts, resulting in decreased anxiety and avoidance (Beck et al., 2005). Cognitive therapy has been found to be effective in treatment anxiety disorders and other psychopathologies (For a review, see Butler, Chapman, Forman, & Beck, 2006).

CT is usually used in combination with behavioural strategies (i.e., CBT), incorporating the cognitive components as adjunctive to exposure therapy. However, as a solo treatment modality, evidence has been largely mixed with efficacy found for claustrophobia (Booth & Rachman, 1992; Ost et al., 2001), generalized anxiety disorder (Öst & Breitholtz, 2000) , social phobia (Clark et al., 2006), dental phobia (Willumsen & Vassend, 2003) but mixed results for fear of flying (Capafóns, Sosa, & Viña, 1999; Muhlberger, Wiedemann, & Pauli, 2003). The current literature has significant research data for the use of CBT (or some variation of it) for treating anxiety-related disorders. However, as suggested by Choy et al. (2007a), it may be unclear how the behavioural related components, which incorporate some form of exposure, contributes to the treatment gains compared to just cognitive therapy alone.

Acceptance and commitment therapy (ACT) is known as one of the third wave of cognitive behavioural therapies (Hayes, 2016). ACT focuses on reducing cognitive fusion and experiential avoidance. Cognitive fusion takes the form of distorted thoughts about the self, people around them, and the world. It is similar to CT's view of maladaptive beliefs. Experiential avoidance are the individual's attempts to escape or evade privately experienced events (Hayes, 2016). They are essentially anxiety control strategies to mitigate experiences of psychological pain. ACT's main goal is to achieve cognitive defusion and reduce experiential avoidance. This would require patients to reduce control strategies and observe thoughts as mental phenomenon, an ongoing process. Mindfulness exercises play a large role in ACT treatment, which aims to help patients achieve cognitive defusion (Hayes, Strosahl, & Wilson, 2009). Generally, there is a key interest in helping the patient gain insight. ACT's view of specific phobias is similar to CT in the sense that catastrophic beliefs and inaccurate assessments of situations inform the thought patterns leading to avoidance or panic. ACT also focuses on empowering patients through an evaluation of intrinsic subjective values. These values can be seen as general reasons for wanting to change, and eventually serve as motivations to engage in exposure exercises. Eventually, through cognitive defusion and values clarification, a person may more willingly engage in an in-vivo or imaginal exposure exercise without engaging in any anxiety control strategies or experiential avoidance. Ideally, patients are motivated to perform because of adherence to internal values. (Hayes, 2005).

An early meta-analytic review of ACT's effectiveness on mental health disorders (e.g., anxiety, depression, smoking cessation, substance abuse) generally favoured ACT over wait-list controls across all studies. However, ACT was not found to be more effective than CT or CBT (Powers, Zum Vorde Sive Vording, & Emmelkamp, 2009). Unfortunately, this early review did not include any studies investigating specific phobias or subtypes such as social phobia or agoraphobia, likely due to the lack of such research. Herbert and Cardaciotto

(2005) proposed an acceptance-based model for treating social phobia. The author postulated that components in ACT such as mindfulness, acceptance, cognitive defusion and reducing experiential control suits the treatment of patients with social anxiety due to their tendency for self-focused attention (Clark & Wells, 1995). Since then, a significant number of intervention studies have found ACT to be effective at treating social phobia (e.g., Molavi, Mikaeili, Rahimi, & Mehri, 2014; Ossman, Wilson, Storaasli, & McNeill, 2006; Pourfarj, 2011). These studies often include self-directed in-vivo exposure (i.e., attending social events) as part of the treatment paradigm. Data for ACT's effectiveness for specific phobia is at this time very limited. Recently, Hacker, Stone, and MacBeth (2016) conducted a meta-analysis of intervention studies specifically using ACT for treatment of anxiety and depression. Out of the 67 identified studies, only 28 studies focused on anxiety, and subsequently only one study included a sample of patients with specific phobia. Unfortunately, in that study only 4.7% of the sample (6 of 127) had a diagnosis of specific phobia, and only two patients received ACT as intervention (Arch et al., 2012). Just one unpublished dissertation of a case study regarding treatment of choking phobia with ACT was found (Stein, 2010). Other studies have investigated components of ACT such as defusion (Ritzert et al., 2015) and mindfulness (Hooper, Davies, Davies, & McHugh, 2011) for spider phobic patients.

3.4 Overall summary of specific phobia treatment

Overall, a significant body of research into treatment methods for anxiety-related disorders, and specifically phobias, seem to agree on the efficacy of exposure therapy. However, the overall effectiveness of any given treatment may depend on a number of variables, such as the delivery of the exposure (e.g., imaginal, VR, in-vivo).

Theories on the effectiveness of exposure therapy, such as EPT and belief disconfirmation theory, focus on the presentation of realistic information incompatible to

maladaptive beliefs currently held. During treatment, anxiety control strategies are generally not endorsed as they interfere with the treatment effectiveness as they reinforce negative/maladaptive beliefs, perpetuating the anxiety disorder. Treatment for specific phobia via in-vivo and VR exposure have found significant support over the years and are endorsed as primary treatment methods. Other exposure-based approaches such as systematic desensitization, EMDR, and AT have demonstrated effectiveness for specific types of phobias or anxiety disorders and may not readily be used as a primary treatment type for all phobias. Nonetheless, exposure is a core component of the intervention whether in-vivo, imaginal or virtual.

3.5 Relapse after treatment

Exposure based treatments for specific phobias have generally yielded successful results. Post-treatment follow-up studies found that treatment effects maintain between six months to one year (Choy et al., 2007a). However, there is a high risk of relapse of anxiety related symptomology beyond one year. Lipsitz et al. (1999) followed up with post-treatment patients and found that clinically significant symptoms exist 10 – 16 years after treatment regardless of phobia subtypes. Relapse remains to be a significant issue with between 30% to 60% reporting a return of fear (Mavissakalian, 1995; Yonkers, Bruce, Dyck, & Keller, 2003) Indeed, historically, the relapse or return of fear has been documented (see Rachman, 1989). Grey, Sartory, and Rachman (1979) conducted in-vivo exposure to 27 subjects with different types of animal phobia (spiders, snakes, mice, snakes, worm and toads). They obtained significant reduction in fear in a session but observed a significant return of fear the next session. In another study, Barlow, Mavissakalian, and Schofield (1980) provided three participants with agoraphobia a combination of cognitive restructuring and in-vivo exposure. After reporting being free from anxiety, one subject relapsed after a month. Similarly, Mystkowski, Mineka, Vernon, and Zinbarg (2003) provided exposure therapy for 43

participants who reported being highly fearful of spiders. After exposure was performed, significant reduction of reported fear was found. However, return of spider fear was observed after 1 week. These examples indicate that treatment for specific phobias may present successful post-treatment results, however, follow-ups are important as relapse may occur. This problem undoubtedly poses a significant challenge to clinicians and therapists as relapse may lead patients to lose faith in themselves or in psychotherapy.

Successful treatment paradigms all involve an exposure component, whether via in-vivo, imaginal or virtual they appear to be successful at reducing reported fears. However, this fear reduction is transient, and relapse occurs. The present challenge for treatment of specific phobias is not only to achieve fear reduction, but more importantly, maintain fear reduction (Vervliet, Craske, & Hermans, 2013).

Researchers have sought to understand the underlying mechanisms for the return of fear. Bouton (2002b) proposed that all forms of relapse are driven by the same underlying mechanism of interference and dissimilarity of the "testing" context to the extinction (or exposure therapy) context. This will be discussed in more detail in Chapter 4. Research utilizing animals, humans, and clinical analogue methods indicates that recovery from extinction is most often observed when the fear inducing stimulus (phobic stimulus) is presented in a context different from the treatment context (Alvarez, Johnson, & Grillon, 2007; Bouton, 1994). It has been suggested that a multi-contextual treatment paradigm might attenuate the recovery effect, thereby increasing the organism's cognitive generalization of the fear stimulus. The mechanisms underlying relapse will be further discussed in the following chapter, which will focus on laboratory investigations into the acquisition and extinction of fear.

CHAPTER 4

LABORATORY INVESTIGATIONS

In this chapter acquisition and extinction in associative learning will be briefly explained in section 4.1. Then, some factors that influence the effectiveness of extinction such as attention, presence of other stimuli and temporal aspect are explained in section 4.1.1. This is be followed by a discussion of the relevance of extinction research on clinical treatment in section 4.1.2. In section 4.2 the focus is on clinically relevant recovery from extinction phenomena. This is followed by a discussion of renewal in section 4.2.1, spontaneous recovery in section 4.2.2 and reinstatement in section 4.2.3. I will then introduce and briefly review Bouton's (1993) retrieval model in section 4.3.

The second part of this chapter begins at section 4.4, where various laboratory techniques that have been used to mitigate recovery from extinction will be discussed. The first method is massive extinction, in section 4.4.1, where extinction is carried out over a significant number of trials. Next, retrieval cues from extinction, in section 4.4.2, where an additional cue may be introduced during extinction to facilitate retrieval of the extinction memory. In section 4.4.3 spaced learning paradigms are discussed. This includes spacing of trials, sessions and retrieval practices that are conducted across uniformly spaced intervals, or in gradual expanding intervals. Finally, extinction in multiple contexts will be discussed in section 4.4.4. This would also include studies that have combined massive extinction with extinction in multiple contexts to augment recovery reduction. Section 4.5 will close with a summary.

4.1 Acquisition and Extinction

Within the field of associative learning, acquisition refers to the increase in an anticipatory response to a stimulus following repeated parings of that stimulus with an outcome (e.g., food or electric shock). This was first reported by Pavlov (1927) who reported

that dogs began to salivate in response to the presence of the research assistant walking to them with food. Importantly, this salivation behaviour occurred before they were given the food. The dogs learned to anticipate the food because this was frequently paired with the research assistant. Thus, the appearance of the research assistant became a signal for food, and naturally, the dogs began to salivate in expectation of the food.

In this example, the salivation behaviour is called an unconditioned response (UR), which is an innate behaviour that does not require prior training. The UR is elicited in the presence of an unconditioned stimulus (US), which is a stimulus that will naturally evoke a response. Although initially the sight of the research assistant did not elicit a response, that is, it was associatively neutral, repeated pairing of the research assistant with food resulted in the research assistant becoming a signal for impending food. This is known as a conditioned stimulus (CS), and the dogs' salivation to the CS is called a conditioned response (CR). Subsequent studies showed that dogs were able to learn the predictive value of all sorts of stimuli, such as the proverbial bell.

This basic learning forms the foundation for acquiring more complicated behaviour, such as emotional responses, like fear. This was famously demonstrated by Watson and Rayner (1920) who conditioned baby Albert to associate a white rat with an upsetting loud noise. Consequently, Albert exhibited a conditioned emotional response of fear when presented with the rat, even in the absence of the noise (see also Pittig, Treanor, LeBeau, & Craske, 2018).

4.1.1 Factors that influence the effectiveness of extinction

Pavlov (1927) also showed that CR can be reduced, or extinguished, following repeated presentations of the previously excitatory CS in the absence of the expected outcome. That is, a CS – noUS presentation. Since then, there has been considerable research examining the parameters and moderators of extinction. One such factor influencing

extinction is attention. Pavlov (1927) believed that extinction leads to the decrease in attention towards the CS. This was later supported by research from Robbins (1990) who concluded that extinction is the result of a decrease in an organism's attention towards the CS as it no longer reliably predicts the US. This modulation of responding to the CS through attentional processes was also thought to influence decreases of CRs within-sessions and increases in CRs between session (i.e. recovery of responding). Kehoe (2002) suggested that decreases in attention towards the CS during extinction may protect the loss of associative strength between the CS and the US. Hence, increasing attention towards the CS again provides it with full control again (i.e. rapid reacquisition). However, studies designed to maintain attention to the CS during extinction did not support this idea (e.g., Delamater, 1996; Peck & Bouton, 1990). More recent neurological evidence has also found that the increased sustained visual attention towards a threat predicting CS was resistant to extinction, stable and maintained (Panitz, Keil, & Mueller, 2019). Therefore attention appears to play a more complex role in extinction than previously thought. Specifically, attention may be bias towards threatening CSs.

The presence of other stimuli during extinction treatment can also influence the rate of extinction. Rescorla (2006) demonstrated a deepened extinction effect, when two separately trained excitatory CSs were extinguished in compound relative to only one being extinguished. This was observed in less spontaneous recovery, reinstatement and slower reacquisition. This effect was replicated by McConnell, Miguez, and Miller (2013) who reported similarly deepened extinction effect (i.e., less ABC renewal) when two excitatory CSs were extinguished in compound relative to only one being extinguished. Interestingly, the addition of a third excitor in compound did not further augment extinction. Instead, extinction of three excitors in compound resulted in less extinction relative to two excitors in compound. The presence of a conditioned inhibitor can also negatively impact extinction

learning leading to a protection from extinction. This is observed when the conditioned excitor is extinguished in the presence of a conditioned inhibitor (McConnell & Miller, 2010; Rescorla, 2003; Soltysik et al., 1983). In these studies, a conditioned excitor that undergoes extinction training in the presence of a conditioned inhibitor results in stronger retention of associative strength compared to a conditioned excitor that was extinguished alone. Thus, the presence of other cues during extinction can facilitate or hinder the rate of extinction learning.

The temporal aspects of the extinction procedure also influence its effectiveness. Several researchers have investigated the effect of varying the length of CS duration in extinction by lengthening, shortening or equating the length of the CS used during acquisition learning. Using a differential human fear conditioning paradigm, Prenoveau, Craske, Liao, and Ornitz (2013) varied the number of extinction trials and the CS duration. The total exposure to the CS was equated across groups while holding constant intertrial intervals (ITI) and total session duration. The final test CS used the original acquisition duration. The authors reported more fear was attenuated in groups that received more trials with shorter CSs as compared to groups that received fewer trials with longer CSs. This points towards the critical role of trial numbers in producing stronger extinction learning. This is consistent with Drew, Yang, Ohyama, and Balsam's (2004) conclusion as well. However, faster reduction in fear did not translate to less recovery of fear when tested 24 hours later. Prenoveau et al. reported no differences between groups at the final test, which suggests that equating overall CS exposure during extinction led to similar levels of performance on the final test. These findings are consistent with the results of Shipley (1974) who also reported that regardless of CS duration or trial numbers, conditioned fear suppression in rats was directly related to total CS exposure during extinction. Contrasting with this observation, Drew et al. (2004) found that final test performance was a function of similarity between the acquisition and extinction

CSs, not overall non-reinforced CS exposure (see also Drew, Walsh, & Balsam, 2017). Thus, while it is clear that CS duration and overall CS exposure are both important aspects at determining the presentation of the final behaviour at test, more research is required to ascertain how these variables interact.

Importantly, the ITI was kept constant in the aforementioned CS-duration studies. This is important because studies have demonstrated that the rate and durability of learning are influenced by spacing or massing trials. In the past, researchers had investigated the effect of massing or spacing trials during extinction. The results of this research were mixed with some finding better extinction with massed trials relative to spaced (e.g., Edmonson, 1954; Reynolds, 1945), others reported the opposite (e.g., Howat & Grant, 1958; Sheffeld, 1950) and some reporting no differences between groups extinguished with massed and spaced trials (e.g., Reynolds, 1945). Research on the effect of varying the ITI was revived a few decades later. Across four experiments, Cain, Blouin and Barad (2003) provided evidence that massed extinction trials led to greater short-term (within-session) and long-term (final test after 24 hours) extinction than spaced trials. Additionally, better extinction was observed when massed extinction trials were temporally spaced (i.e., multiple sessions of extinction trials) compared to a single session of massed trials. Cain et al. suggested that massed extinction is superior for inducing extinction, but spaced extinction yields stronger extinction learning.

Similar findings were also concurred by Li and Westbrook (2008) who observed faster extinction with massed trials compared to spaced trials but better extinction performance at a final test following spaced extinction (see also Urcelay, Wheeler, & Miller, 2009a). However, these findings were contested by Moody, Sunsay, and Bouton (2006b). Although they replicated the pattern of faster extinction with massed trials relative to spaced, they did not observe a difference in spontaneous recovery. It is worth noting that the Moody

et al. study was conducted in appetitive conditioning, whereas the Cain et al. and Li and Westbrook studies were done in fear conditioning.

Taken together, these studies suggest that extinction is not determined by a single variable. Rather, extinction behaviour is determined by an interaction of multiple variables related to the acquisition and extinction CS.

4.1.2 Clinical relevance of extinction research

Extinction is of particular importance to researchers because there are obvious parallels between laboratory extinction and exposure therapy. Extinction, in fact, underlies all exposure therapy modalities. The key role of exposure therapy is to demonstrate that the feared stimulus (i.e., CS) does not always result in the feared outcome (i.e., US) (Bouton, 2002a). This is done by repeatedly presenting the fearful stimulus in a safe environment, which helps the client learn a new association between the CS and a noUS representation. For example, a therapist for patients with Post-Traumatic Stress Disorder (PTSD) might ask them to talk about their traumatic experiences with greater detail. This allows patients to associate cues and stimuli in those traumatic memories with safety, creating a CS-noUS association. This is true for behavioural treatments, imagery-based treatments and treatments focused on distress tolerance (Cukor, Olden, Lee, & Difede, 2010; Cukor et al., 2009). An even closer analogue to laboratory extinction is exposure therapy for Specific Phobias. This treatment typically entails a form of graduated in-vivo exposure towards the fearful stimuli (e.g., a spider, heights, enclosed areas etc.). In this component of treatment, patients are gradually exposed to the fearful stimulus. Öst (2012) described a Cognitive-Behavioural model of treatment for specific phobias using a one-session treatment paradigm. While cognitive components such as challenging thought patterns, reducing safety behaviours and testing beliefs are present, core changes occur through in-vivo exposure. Patients will try to commit to experiencing a certain stimulus and remaining in the exposure situation until anxiety

slowly fades (CS-noUS). As described in the previous chapter, Bouton et al. (2001b) explains the importance of how anxiety becomes a cue towards augmenting conditioned and unconditioned responses that may lead to a panic attack. Thus, in essence, an in-vivo exposure to a fearful stimulus may allow the patient to learn at least two extinction signals: first, that a spider does not necessarily mean being bitten (CS-noUS) and second, that anxiety does not necessarily lead to panic attacks (CS-noUS).

Indeed, one of the strongest change processes (i.e., clinical gains) appear to be extinction training. For example, Twohig, Whittal, Cox, and Gunter (2010) investigated the types of processes of change in acceptance and commitment therapy (ACT), cognitive therapy, and exposure and response prevention (ERP). Amongst these processes were psychological flexibility, cognitive reappraisal and extinction. The scores for extinction processes were apparent in all modalities and was reported as having the highest overall raw score. This suggests that a significant change process in many therapeutic paradigms is extinction training. In addition to in-vivo exposure, another example of laboratory-to-clinic translation of extinction is the treatment for Obsessive-compulsive disorder (OCD) known as ERP (see Olatunji, Cisler, & Deacon, 2010). This treatment requires a collaborative effort to create a fear hierarchy ranking stimuli in order of most to least feared. Patients are then asked to confront each of these stimuli with progressive efforts while preventing safety or avoidance behaviours that alleviate the anxiety. The process of extinction takes place through these repeated exposures to CS (e.g. things that stimulate the fear of becoming ill) without occurrences of the US (e.g. becoming ill).

Given the clear parallels between laboratory extinction and clinical exposure therapy, there have been several studies in translational research, which focus on applying principles from the laboratory to the clinic. For example, extinction to multiple cues can lead to a reduction in recovery (e.g., Glautier & Elgueta, 2009). In clinical terms, cues may be

associated with drug urges and approach behaviours. Hence, in the field of smoking cessation, cue exposure treatment aims to reduce relapse in smokers by exposure to cues previously associated with smoking (e.g., Collins, Nair, & Komaroff, 2011; Unrod et al., 2014). Another manipulation found to significantly reduce recovery of fear was extinction in multiple contexts (e.g., Bouton, 1991; Gunther et al., 1998). When such a manipulation was used to treat patients with specific phobia, clear clinical gains were also observed (e.g., Bandarian-Balooch, Neumann, & Boschen, 2015; Olatunji, Tomarken, Wentworth, & Fritzsche, 2017a; Shiban et al., 2013b; Shiban et al., 2015a).

4.2 Recovery from extinction

While early researchers theorized that extinction erases the original excitatory association (e.g., Rescorla & Wagner, 1972), there is now considerable research demonstrating that the decline in behaviour observed during extinction training is not permanent (e.g., Bouton & King, 1983a; Hermans et al., 2005a; Moody et al., 2006b; Napier, Macrae, & Kehoe, 1992; Rescorla & Heth, 1975; Robbins, 1990; Rosas & Bouton, 1996; Shaham, Adamson, Grocki, & Corrigall, 1997). This is true even if responding is completely abolished by extinction (Bouton, 1986; Leung, Bailey, Laurent, & Westbrook, 2007; Quirk, 2002). There is broad consensus amongst researchers that extinction results in new learning of an inhibitory association, which competes with the excitatory association for expression at the time of testing (Alfei et al., 2015; Eisenberg, Kobilo, Berman, & Dudai, 2003). According to Bouton (1993), when a CS has a history of both reinforcement and extinction, it becomes ambiguous. In such circumstances, the organism turns to contextual information to help resolve this ambiguity. Thus, the similarity of the test context to the extinction context is the primary determinant of whether behaviour indicative of acquisition or behaviour indicative of extinction will be observed. In this manner, the extinction context acts like a negative occasion setter (Trask, Thrailkill, & Bouton, 2017). Consequently, if testing occurs outside of

the extinction context, then recovery from extinction (i.e., excitatory responding) should be observed. Importantly, these recovery effects are observed without further training of the CS and US together.

Just as experimental extinction is taken to be the laboratory analogue to exposure therapy, recovery from extinction can be considered an analogue to relapse from exposure therapy. Consequently, research on recovery from extinction effects is especially important for clinical procedures that utilize exposure therapy. As evidence of this, researchers have investigated the underlying mechanism of the return of fear in translational research seeking to improve clinical practices through controlled laboratory findings (e.g., Bouton & Nelson, 1998; Gillihan & Foa, 2011).

Recovery from extinction effects comes in many forms. Briefly, these include *renewal*, which refers to an increase in responding to an extinguished CS when tested outside of the extinction context relative to being tested in the extinction context (e.g., Bouton & King, 1983b; Bouton, Todd, Vurbic, & Winterbauer, 2011b), *spontaneous recovery*, which refers to an increase in responding to an extinguished CS after a period of time has passed since extinction training relative to when tested immediately after extinction training (e.g., Leung, Reeks, & Westbrook, 2012; Pavlov, 1927) and *reinstatement*, which refers to an increase in responding to an extinguished CS after being exposed to the US alone again relative to not experiencing more US alone trials (e.g., Bouton & Bolles, 1979b; Crombag, Bossert, Koya, & Shaham, 2008; Marchant, Kaganovsky, Shaham, & Bossert, 2015). These three tend to be considered and researched most often, but other forms of recovery from extinction include *resurgence*, which refers to an increase in producing an extinguished instrumental response following extinction of a second instrumental response (e.g., Leitenberg, Rawson, & Bath, 1970; Winterbauer & Bouton, 2010), and *concurrent recovery*, which refers to an increase in responding to an extinguished CS following training of another

CS (e.g., Kehoe, Morrow, & Holt, 1984; Weidemann & Kehoe, 2005). Lastly, evidence for the temporary effect of extinction training comes from observations of *facilitated reacquisition* of excitatory behavioural control by an extinguished CS relative to a novel CS being trained for the first time (e.g., Bouton, Woods, & Pineño, 2004; Napier et al., 1992). While all of these phenomena are of theoretical and applied interest in their own right, spontaneous recovery, renewal, and reinstatement are most commonly looked at when considering the translational value of recovery from extinction effects. Hence, these will be the focus of more in-depth discussions for the remainder of this paper.

4.2.1 Renewal

The renewal phenomenon was first discovered by Bouton and colleagues (Bouton & Bolles, 1979a; Bouton & King, 1983b). They found that when the contextual cues relevant to the extinction context changes, the extinguished response reappears. This recovery of responding is known as renewal. This is typically studied in a three-phase experiment in which acquisition of a CR occurs in one context (Context A), and extinction of that CR occurs in a different context (Context B). In the third phase, the organism is returned to the acquisition context (Context A) for the final test in which the CS is presented but without the US. This tends to result in an increase in excitatory responding to the CS relative to when the organism is tested in the extinction context. That is, when tested back in the acquisition context, the organism responds as if the US will be presented again, even though extinction training eliminated this response previously. This is referred to as ABA renewal (see Bouton & Bolles, 1979a; Bouton & King, 1983a). Remarkably, responding in Context A sometimes reached levels similar to groups that have not received any extinction (see Bouton, Todd, Vurbic, & Winterbauer, 2011a). Another type of renewal is known as ABC renewal. In ABC renewal, acquisition occurs in Context A, extinction in Context B and testing in a novel context, known as Context C (eg., Bouton & Bolles, 1979a; Craig et al., 2020). The key

difference between ABA and ABC renewal is the context of testing. The final renewal type provides acquisition and extinction in Context A and extinction in Context B, known as AAB renewal (e.g., Bouton & Ricker, 1994; Cohenour, Volkert, & Allen, 2018; Nakajima, Tanaka, Urushihara, & Imada, 2000).

Renewal demonstrates that shifting out of the extinction context leads to a recovery of extinguished responses. This effect is very robust and prevalent; it has been observed in multiple experimental procedures. For example, fear conditioning in humans (Dibbets, Poort, & Arntz, 2012; Leer & Engelhard, 2015) and non-human animals (Chan, Leung, Westbrook, & McNally, 2010; Elias, Gulick, Wilkinson, & Gould, 2010), taste aversion (Bernal-Gamboa et al., 2012; Revillo, Castello, Paglini, & Arias, 2014), appetitive conditioning (Bernal-Gamboa, Carrasco-Lopez, & Nieto, 2014; Carranza-Jasso, Urcelay, Nieto, & Sanchez-Carrasco, 2014), causal association tasks in humans (Cobos, González-Martín, Varona-Moya, & López, 2013; Nelson et al., 2011). It has also been investigated as treatment relapse in a clinical populations with severe intellectual disability (see Pritchard et al., 2016). These studies have helped us establish that extinction does not lead to erasure of the original acquisition learning. The return of conditioned behaviour helps provide evidence that the memory of the original association remains in the organism.

Several researchers have observed different degrees of renewal when comparing between ABA, ABC, and AAB renewal. ABC and ABA renewal are often reported to be stronger than AAB renewal, which some studies were unable to detect (Crombag & Shaham, 2002; Nakajima et al., 2000; Thomas, Larsen, & Ayres, 2003; Üngör & Lachnit, 2008). Relative to ABA renewal, ABC renewal has been reported to be weaker (Berry, Sweeney, & Odum, 2014; Harris, Jones, Bailey, & Westbrook, 2000). Conversely, Bernal-Gamboa et al. (2012) reported no differences in magnitude between the three forms of renewal. Interestingly, Bouton's model (2000) predicts no difference in the size of the three types of

renewal, as all three involve tests outside of the context of extinction. To fill this explanatory gap, various suggestions have been offered, such as differences in sensitivity to extinction. In a study by Rauhut, Thomas, and Ayres (2001), there were no differences in ABA renewal following 20 or 100 extinction trials. Tamai and Nakajima (2000) administered 72 or 112 extinction trials and similarly observed no effect of increasing extinction on ABA renewal, however, AAB renewal was eliminated by overtraining. Together, these results suggest an unequal impact of increasing extinction training for ABA and AAB renewal, with the former being less impacted by increasing extinction trials. However, there is certainly a limit to the impervious nature of ABA renewal. Denniston, Chang, and Miller (2003) tested the effect of massive extinction treatment (800 trials) on ABA and ABC renewal. Similar to Rauhut et al., 2001 and Tamai and Nakajima 2000, groups that received moderate extinction (160 trials) demonstrated significant ABA renewal. However, both ABA and ABC renewal were completely abolished after 800 extinction trials.

Miller and his colleagues have conducted multiple studies to investigate the associative status of the context to explain the differences in ABA, ABC, and AAB renewal strength. Laborda, Witnauer, and Miller (2011b) highlighted the role of the acquisition context on extinction. They found that when extinction is conducted in the same context as acquisition (e.g., AAB renewal), stronger extinction learning is observed compared to if extinction was conducted in a neutral context (e.g., ABC renewal). This is predicted in the mechanisms that deepen extinction (see section 4.1.1). Assuming that the target CS and the acquisition context both acquire excitatory associative strength during conditioning, extinction in the acquisition context is therefore similar to a compounded stimuli extinction that results in deepen extinction. The authors explained that those in the AAB condition have greater expectation for the US and when it is not presented during extinction, a greater expectancy violation was experienced by the AAB condition, resulting in deeper extinction.

In another study, Polack, Laborda, and Miller (2012) demonstrated that massed extinction in a neutral context (e.g., ABC renewal) can result in the neutral context acquiring the properties of a conditioned inhibitor, passing both a negative summation and retardation test. This means that the excitatory associative strength of the CS may be partially protected from extinction. A later study by the same authors replicated the deepened extinction contributed by an extinction context that had excitatory associative status (e.g., AAB renewal), resulting in less AAB renewal (Polack, Laborda, & Miller, 2013). They also showed that ABA renewal was larger compared to ABC renewal because of the summation of the excitatory associative status of the acquisition context and the residual excitatory associative status of the extinguished CS. Post-extinction exposure to the acquisition context decreased ABA renewal but had no effect on ABC renewal, supporting the summative account of the acquisition context with the extinguished CS. Taken together, these studies suggest that associative summation of the CS with the contexts offers at least a partial explanation for the differences in ABA, ABC, and AAB renewal.

It is worth mentioning that in the scope of learning literature, the term *context* is not limited to a physical setting or environment. A context is generally made up of a multitude of stimuli, which are represented as a configured stimulus. There is a complexity in understanding the organism's experience of a context. A physical context is often multisensory, encompasses a wider area and is continuously present in the experience. Yet this only describes a physical context experience. There are other forms of context that provide information to the organism. Indeed, it has been demonstrated that renewal may occur in contexts other than spatial ones. Interoceptive contexts have been found to have an influence on renewal as well. Examples of interoceptive contexts that have successfully observed renewal following extinction are, alcohol influence (Troisi II & Craig, 2015), hunger (Schepers & Bouton, 2017), stress (Schepers & Bouton, 2019) and drug states

(Saunders, O'Donnell, Aurbach, & Robinson, 2014). Another context with consistent demonstrations of renewal is temporal context. That is the passage of time serving as different contexts (Brooks & Bouton, 1994; Luck et al., 2018; Urcelay et al., 2009a). Maren, Phan, and Liberzon (2013b) broke down the representation of contexts into five categories: spatial, temporal, interoceptive, cognitive, and social and cultural contexts.

Spatial contexts describe the physical presence of a context or place. Spatial contexts are defined by the features of items, their relative configuration to each other and events that occur in the place (Li, Gong, & Xiang, 2012). Next, temporal contexts describe memories and behaviours that occur in time and become encoded with a time reference. Occurrences of events are often encoded with properties such as frequency, which serve as a form of context (Li et al., 2012). Another type of context is known as the interoceptive contexts. This is the internal state experienced by the organism such as hunger, stress and emotions that serve as a contextual reference (Bouton, Kenney, & Rosengard, 1990). Following that, the cognitive context can be described as the thoughts that arise from external or internal experiences that set the context for retrieval or encoding of information (Javanbakht et al., 2017; Miller, Sadler, Mohl, & Melchiode, 1991). Finally, the social and cultural contexts describe experiences of life events in relation to individuals, and their larger cultural aspects. It helps us to define these experiences. They become a significant influence on how we understand ourselves and the world (Chen & French, 2008; Jarvis, 2011).

It is important to consider the wider definition of a context given that renewal is of great importance in understanding clinical treatment models for human psychopathology. For exposure-based approaches to be more successful, contexts need to more accurately retrieve memories of extinction to prevent renewal. Several studies have mentioned impaired contextual processing in patients with schizophrenia (Cohen, Barch, Carter, & Servan-Schreiber, 1999; Reilly et al., 2017), PTSD (Rougemont-Bucking et al., 2011; Sadeh,

Spielberg, & Hayes, 2018), depression (Masuyama, Kaise, Sakano, & Mochizuki, 2018; Msetfi, Murphy, Kornbrot, & Simpson, 2009), addiction (Jones et al., 2013) and anxiety (Kadosh et al., 2015; Richards, Blanchette, & Munjiza, 2007; Wieser & Moscovitch, 2015), which may signal the added challenge in reducing treatment relapse.

Renewal, as a form of relapse or recovery from extinction, signals an emphasis on context as a key determinant. Bouton's (1993) account of renewal helps provide an explanation into the importance of context on signalling retrieval of extinction memories. Although the animal literature regarding renewal is diverse, the clinical translatable processes of renewal in humans with mental health issues require more attention. In addition, the richness of individual's multiple context experiences may post significant struggles for treatment and relapse prevention.

4.2.2 Spontaneous Recovery

The phenomenon of spontaneous recovery was first discovered by Pavlov (1927). Following extinction, a spontaneous recovery of the extinguished response was observed after a simple rest period (see Rescorla, 2004a, for a good review). Like renewal, this effect is highly robust and has since been observed across a wide variety of procedures, such as fear conditioning (i.e., foot-shock) (Quirk, 2002; Revillo, Paglini, & Arias, 2014), appetitive conditioning (Brooks & Bouton, 1993a; Rescorla, 1997), taste aversion (Fujiwara et al., 2012; Mickley et al., 2007), and eyeblink conditioning (Thanellou & Green, 2011). While the aforementioned studies used rats, spontaneous recovery has also been observed in other species such as dogs (Pavlov, 1927) guinea pigs (Wang et al., 2019), pigeons (Rescorla, 2004b; Robbins, 1990), dolphins (Beach III & Pepper, 1972), honeybees (Bitterman, Menzel, Fietz, & Schafer, 1983), rabbits (Baum, 1988) and humans (Bernal-Gamboa, Gámez, & Nieto, 2017a; Lopez-Romero, Garcia-Barraza, & Vila, 2010; Vila & Rosas, 2001).

It seems obvious that one of the primary variables that influences the strength of spontaneous recovery is the length of delay between extinction and test. Spontaneous recovery is usually never complete (e.g., Rescorla, 1997; Rosas & Bouton, 1997), but recovery does seem to follow a pattern of negative acceleration. In other words, as the time between the final extinction session and the test session increases, the recovery becomes greater. This has been demonstrated in a number of studies. Quirk (2002) conducted a parametric study to assess spontaneous recovery after a delay between extinction and test of 0, 1, 2, 4, 6, 10 or 14 days. He found a very clear and gradual increase in conditioned freezing as the number of days increased. By the 10^{th} day, freezing had returned to pre-extinction levels (see also Kim & Richardson, 2009 for a similar result in renewal).

More recently, some studies have focused on the delay between acquisition and extinction. This is the result of a provocative idea that immediate extinction can produce erasure of the fear memory through a mechanism of depotentiation. Myers, Ressler, and Davis (2006) conducted fear conditioning with rats who experienced extinction either immediately (10-60 min after conditioning) or after a delay (24-72 hr after conditioning). Animals were tested for reinstatement (experiment 1), ABA renewal (experiment 2), and spontaneous recovery with a 21-day delay (experiment 3). In all three experiments, the researchers observed less recovery following immediate extinction than delayed extinction. This attenuation of recovery was replicated by several researchers (e.g., Chang & Maren, 2009; MacPherson et al., 2013; Maren & Chang, 2006). However, these studies also demonstrated that while immediate extinction may lead to reduced recovery, it is temporary. Spontaneous recovery is observed after a retention interval is imposed between extinction and testing.

Several studies have contested Meyers et al.'s (2006)'s findings by demonstrating the beneficial effects of delayed extinction over immediate extinction. Rescorla (2004b) showed

that immediate extinction (one day after conditioning) resulted in more spontaneous recovery than delayed extinction (six days after conditioning). Similarly, Woods and Bouton (2008) showed that immediate extinction (10 minutes after conditioning) led to an accelerated decrease in responding compared to delayed extinction (24 hours after conditioning) but ultimately resulted in more spontaneous recovery when tested 24 hours later.

These findings were later observed in fear and appetitive conditioning in rats and pigeons. Several other researchers have since replicated the beneficial effects of delayed extinction in attenuating spontaneous recovery, renewal or reinstatement in both rats and humans (e.g., Alvarez et al., 2007; Golkar & Ohman, 2012; Huff, Hernandez, Blanding, & LaBar, 2009; Schiller et al., 2008).

Johnson, Escobar, and Kimble (2010) investigated the interaction between short and long delays between acquisition and extinction and between extinction and testing. They demonstrated that immediate extinction resulted in less spontaneous recovery compared to delayed extinction; however, this was only true when the delay between extinction and testing was long. Conversely when the delay between extinction and testing was relatively short, more spontaneous recovery was observed. In addition, delayed extinction and increased extinction to testing delay resulted in significantly more spontaneous recovery (i.e., group Extinction-Delayed-Long). To understand the conflicting results in the literature, the authors systematically compared the previous studies on a number of parameters including trial numbers, ITI, and duration between acquisition and extinction and between extinction and testing. They noted that all of the studies which observed more spontaneous recovery after immediate extinction versus delayed (e.g., Rescorla, 2004; Woods & Bouton, 2008) had a delay between extinction and test between 24-48 hours. All of the studies that observed less spontaneous recovery after immediate extinction versus delayed (e.g., Johnson et al., 2010;

Myers et al., 2006) had a delay between extinction and testing that was at least 72 hours or more.

Maren (2014) described two explanations that have been put forward to justify the observed differences in spontaneous recovery following immediate extinction. The first explanation suggests that acquisition and extinction memories interfere with memory retrieval at test. This retrieval interference meant that immediate extinction results in less distinction between acquisition and extinction experiences resulting in increased recovery (Devenport, 1998). The other explanation suggests immediate extinction leads to enhancing the consolidation of fear memory and/or limit the encoding or consolidation of extinction memory (Myers et al., 2006). However, Johnson et al.'s Extinction-Delayed-Long group suggests that failure of extinction memory encoding may not be true. This may suggest that the effect of immediate extinction on spontaneous recovery may be better explained by factors that interfere with memory retrieval at test instead; such as in renewal (Bouton, 1993).

Similar to what has been observed with renewal (e.g., Denniston et al., 2003), spontaneous recovery reduces in magnitude if there were more extinction training. Díaz et al. (2017) conducted a fear conditioning study with human participants. Those given massive extinction (80 non-reinforced trials) reported significantly lower spontaneous recovery compared to those that received only 10 extinction trials. This is consistent with an earlier investigation on the combined effect of massive extinction and extinction over multiple contexts to reduce recovery resulting from a combined context shift and delay (see Laborda & Miller, 2013b). This result is also consistent with early research showing that more inhibitory conditioning leads to stronger conditioned inhibition (e.g., DeVito & Fowler, 1987; Rescorla, 1969). Given that extinction is thought to result in inhibition of responding, as opposed to erasure of the excitatory memory (see Bouton, 2002a) this pattern of responding makes sense.

Bouton (1993) proposed that spontaneous recovery is due to the same mechanism responsible for the renewal effect (but see McConnell & Miller, 2014, for alternative accounts). According to this theory, the context is characterized by the physical features of the setting and *temporal* features. Imposing a long retention interval between extinction and testing results in a new temporal context, which differs from the context of extinction. Thus, according to Bouton, spontaneous recovery is an example of ABC renewal. In support of this idea, research has shown that spontaneous recovery and renewal respond similarly to various manipulations. For example, spaced extinction (temporal context) is shown to alleviate ABA renewal and spontaneous recovery in a fear conditioning paradigm with rats (e.g., Urcelay, Wheeler, & Miller, 2009). Recently, verbal retrieval cues managed to attenuate both AAB renewal and spontaneous recovery (e.g., Alvarado García, Bernal-Gamboa, & Vila Carranza, 2018). A summative effect of renewal and spontaneous recovery were similarly attenuated through massive extinction over multiple contexts (e.g., Laborda & Miller, 2013b). Other evidence in support of a common underlying mechanism comes from research showing summation of spatial and temporal context shifts in producing response recovery (e.g., Rosas & Bouton 1997; 1998). Bouton and García-Gutiérrez (2006) utilized intertrial intervals as a method to investigate if underlying mechanisms of spontaneous recovery and renewal are similar. In their first experiment, rats received extinction trials either in four- or 16-minutes intertrial intervals (ITI). After extinction, a retention interval of 16mins was introduced before testing began. Rats that received 4-minutes ITI produced a significant recovery of conditioned responding, while no recovery was observed for rats that received 16-minutes ITI. Thus, the ITI may be seen as a temporal context, and the group that experienced 4-minutes ITI followed by a 16-minutes retention interval experienced a context shift resulting in renewal.

4.2.3 Reinstatement

Reinstatement refers to the restoration of a previously extinguished response when the organism is exposed to the US again. Reinstatement was first discovered by Rescorla and Heth's (1975) laboratory investigation with rats and has since been documented in many studies. This phenomenon is especially important to researchers interested in clinical relapse of patients with substance abuse histories. Specifically, early studies investigated drug reinstatement in animals following extinction of self-administration of drugs (e.g., heroin, cocaine). These procedures usually begin with animals learning to press a lever to administer drugs directly into their bloodstream via an attached catheter. Once behaviour acquisition has been stabilized, the extinction phase begins. In this phase, the lever pressing does not result in the drug being administered, and gradually behaviour declines. The next phase is the test phase where the drug is administered by the experimenter. Reinstatement is observed when the responding begins to increase (e.g., De Vries et al., 1998; de Wit & Stewart, 1983; Gerber & Stretch, 1975). Since then, recent studies focus on the use of this phenomenon to observe neurobiological operations resulting in reinstatement of drug seeking in humans (for a review, see Bossert, Marchant, Calu, & Shaham, 2013). In the research, there is a focus on reinstatement of drug seeking following experiences of stress (Kosten, Rounsaville, & Kleber, 1986). Studies have demonstrated that the bed nucleus of stria terminalis and the central amygdala play important roles in stress responses. These areas when inhibited or activated modulate the performance of stress-induced reinstatement of drug-seeking (see Mantsch et al., 2016)

Human fear responses have also been found to be capable of being reinstated. In the first demonstration of reinstatement of conditioned fear responses in humans, Hermans et al. (2005b) used a shock procedure on thirty undergraduate students. The participants first learned a CS-US association between a neutral picture to a shock. Following that, extinction

was performed by presenting the neutral picture without the shock. Once extinction has been achieved, the participants were exposed to the US again. Groups that experienced the US during the test phase reported higher fear and US expectancy compared to the control group. Human fear reinstatement has been further demonstrated through other experimental manipulations, such as fear potentiated startle (Norrholm et al., 2006), aversive differential conditioning (Kull et al., 2012), context manipulations (LaBar & Phelps, 2005; Schiller et al., 2010) and multiple context virtual reality (Dunsmoor et al., 2014a).

Similar to renewal and spontaneous recovery, the phenomenon of reinstatement is thought to be contextually modulated. Bouton (1993) explains that extinction is controlled by the context. When the US is presented, the organism fails to retrieve a memory of extinction due to the test context's dissimilarity with the extinction context. As the extinction context is coded as the non-presentation of the US, by presenting the US, a different context is created. LaBar and Phelps (2005) investigated contextual effects of reinstatement in undergraduates. Conditioned fear was achieved through the presentation of a visual CS (blue square) and a loud noise. The participants then underwent extinction trials. Reinstatement was tested by presentation of the loud noise in the same context as previous trainings or in a different novel context. Participants in the context similar to their previous trainings showed greater levels of fear recovery than those in a different context. Thus, the authors concluded that the effect of reinstatement appears to be context specific. The context serves as additional discriminatory information to the stimulus. When the US is presented in a context that is irrelevant, no reinstatement effect is observed. Past studies have also found similar results that US exposures in irrelevant contexts produced little to no reinstatement effect (e.g., Bouton & Bolles, 1979b; Bouton & King, 1983a; Bouton & Peck, 1989). This suggests that exposure to the US alone may not be sufficient to observe reinstatement. Instead, reinstatement is context

specific. Similar to renewal, the context's function is that of an occasion setter providing information to the organism when the CS becomes ambiguous (e.g., Bouton, 1984).

While the reinstatement effect has very clear challenges for patients after treatment for substance abuse, it also has significant impacts on patients with anxiety. For example, a patient having overcome the fear of spiders, reinstatement suggests that an experience of a panic attack, regardless of how it was triggered, may cause a relapse of spider fear.

4.3 Bouton's retrieval model

According to Bouton (1993, 2000) extinction does not erase the excitatory CS-US association. Rather, it creates a new inhibitory CS-noUS association, which competes with the first-learned association for behavioural expression. These conflicting associations create ambiguity in the meaning of the CS, which forces the organism to look to contextual cues to help disambiguate the correct meaning at any given time (e.g., Bouton, 1994; Bouton, 2002a). In other words, the context whereby the ambiguity is experienced (i.e., the extinction context) becomes the occasion setter for the expression of the CS-noUS behaviour (eg., Bouton & Swartzentruber, 1986; Holland, 1992; Swartzentruber, 1995). As it is only when the second-learned association is acquired that ambiguity arises, the context becomes a relevant cue for only the extinction memory, which is why acquisition is less context-dependent (Bouton & Nelson, 1994; Nelson & Bouton, 1997). This is an important point because it is the order in which learning occurs that comes under context control. Nelson (2002) examined the effects of context change on excitatory or inhibitory associations. When inhibition was a first learned association, the second learned excitatory associations were lost with a context switch, while the inhibitory association remained across context. The converse was true for excitatory as first-learned then inhibitory as second learned. Thus, the modulating effect of the context as an occasion setter depends more on second learned associations due to the ambiguity experienced. Likewise, Sissons and Miller (2009) observed

spontaneous recovery of both an excitatory association and inhibitory association, which confirmed Nelson's conclusion that the order in which associations are learned is more important than the associative nature (excitatory or inhibitory) in determining context-specificity of learning. As noted above, these contextual cues can include the physical features of a context, temporal features, internal states, reinforcement histories, and an array of other variables, which can help define a context.

Bouton's (1993) model draws on earlier research on proactive and retroactive interference. Proactive interference refers to the interference of first-learned associations on the retrieval of the memory of second-learned associations. Retroactive interference refers to the interference of the second-learned association on the retrieval of the memory of the first-learned associations (see Bouton & Moody, 2004). In other words, recovery from extinction (i.e., renewal, spontaneous recovery, reinstatement) are all examples of proactive interference, in that the first-learned CS-US association was observed during testing. Bouton's model therefore describes retrieval competition during testing. Miller and Escobar (2002) pointed out that Bouton's model was unable to account for cue competition with the same outcome as each cue should independently retrieve the CS-outcome association without interaction, yet outcome interference has been observed for cues that have been trained apart with the same outcome (e.g., Escobar, Matute, & Miller, 2001; Matute & Pineño, 1998). Miller and Escobar (2002) proposed an extension of Bouton's model to account for such a situation. They explained that the context acts as a priming stimulus that facilitates the cue (i.e., CS) in retrieving associations stored in memory. This would mean that the context activates all other associations that share similar elements with the target association. A target association positively primed by the context would also negatively prime all other associations that may share similar elements (i.e., CS or US) with the target association. The

context's ability to predict interference patterns have been observed in some studies (Amundson & Miller, 2007; Miguez, Laborda, & Miller, 2014a).

In order to mitigate recovery from extinction, methods that facilitate retroactive interference (i.e., extinction memory) should result in less responding at test. For example, there is evidence that more phase one training leads to more proactive interference while more phase two training leads to more retroactive interference (e.g., Delprato, 2005; Isurin & McDonald, 2001; Wichawut & Martin, 1971). Denniston et al. (2003) and Diaz et al. (2017) both showed that increasing the amount of extinction training reduced renewal and spontaneous recovery, respectively. In other words, more phase two training led to more retroactive interference. Likewise, more retroactive interference was observed when the interference training was delayed relative to immediate (Powell, Escobar, & Kimble, 2103). This parallels the observation discussed above that delayed extinction results in less spontaneous recovery than immediate extinction (e.g., Woods & Bouton, 2008).

Bouton's model provides us with an account for explaining recovery from extinction effects observed across multiple phenomenon. Essentially, when learning a second association that interferes with a previously learned association, organisms utilize the context to resolve the ambiguity about the meaning of the CS. Relapse can be thought of as an example of proactive interference due to the failure to retrieve the extinction memory. For example, a patient with spider phobia may have successfully extinguished the fear in therapy. However, seeing a spider in the park triggers a panic attack again. The fear of the spider proactively interferes with retrieval of the extinction memory learned during exposure therapy. Generally, the entire premise of cognitive behavioural therapy predicates on therapists helping patients to gain new associations that will inhibit the retrieval of older memories. In treatment of specific phobias, the success of extinction-based therapy therefore requires successful retroactive interference during memory retrieval. Bouton (2002b) has

suggested that effective therapy may need to be designed in a manner that provides generalization to other contexts (i.e., spatial and temporal), thereby creating a stronger extinction memory compared to acquisition. Evidence for the effectiveness of extinction over multiple spatial contexts (e.g., Krisch, Bandarian-Balooch, & Neumann, 2017; Olatunji et al., 2017a; Shiban et al., 2013b) and temporal contexts (e.g., Rowe & Craske, 1998a; Tsao & Craske, 2000) is encouraging although renewal was attenuated, the original learning is not erased.

4.4 Techniques used to reduce recovery after extinction

It is clear that extinguished behaviours can recover under various conditions (e.g., after a period of time, a change in context or reexposure to the US). This is evidence that the previous learning continues to exist in the memory of the organism. Thus, extinction is not the loss of the previous association, but a new learning that may be affected by the context in which it was conducted in. Laboratory investigations into the augmentation of the efficacy of extinction procedures have found several methods that appear to be effective in mitigating the production of extinguished behaviours. These procedures serve to increase the robustness of the memory of extinction learning. While there are a significant number of manipulations, as discussed by Laborda, McConnell, and Miller (2011a), the following techniques are chosen for their applicability to a realistic clinical treatment setting.

4.4.1 Massive Extinction (ME)

Massive Extinction (ME) seeks to attenuate recovery through increasing the number of extinction trials during the organism's extinction phase. There are several conflicting results about the efficacy of ME to date. Denniston et al. (2003) conducted a series of experiments in order to investigate the effects of moderate versus ME trials in attenuating renewal. Utilizing a conditioned suppression methodology, fear acquisition through a tone-footshock (i.e., CS-US) was followed by extinction and then tested in either a novel context

(Experiment 1 – ABC renewal) or acquisition context (Experiment 2 – ABA renewal). They found that following ME of 800 trials, a reduction ABC and ABA renewal was observed, this was not similarly found after only 160 trials, in which the authors have defined as a moderate. Interestingly, a study conducted by Tamai and Nakajima (2000) attenuated AAB renewal following 112 trials of fear extinction, while 72 trials yielded no significant results. Also, Tamai and Nakajima were unable to observe an attenuation of ABA renewal using similar methods for massive extinction. Thomas, Vurbic, and Novak (2009) used a conditioned suppression method to investigate extinction over multiple contexts, but in their second experiment they provided 144 vs 36 extinction trials over either one context or three different contexts. The authors found a significant reduction in A(BCD)A (essentially ABA renewal with multiple contexts of extinction) renewal when 144 trials were divided equally between three contexts of extinction but not for the group that experience 144 trials in one context. In another investigation on the effects of ME, Laborda and Miller (2013b) used similar number of trials for moderate versus ME (162 vs 810 trials). Their results were similar to Denniston et al. in that ME attenuated the return of fear more successfully that moderate numbers of trials. In addition, they found additive strength of ME when performed in multiple contexts.

In contrast to these studies, Rauhut et al. (2001) previously found no relative difference between conducting 20 versus 100 extinction trials on ABA renewal. Notably, these numbers are significantly less compared to previous studies and may be the reason for the results observed. Taken together, these studies provide strong evidence for the effectiveness of ME to reduce recovery from extinction.

The mechanisms for the efficacy of ME has not be thoroughly investigated. In terms of its relevance to Bouton's (1993) model, the effectiveness observed with ME provides evidence into a method of strengthening the CS-noUS memory to inhibit the previous CS-US excitatory association. ME thus enhances the memory retrieval required for effective

retroactive interference. While this may therefore contradict the idea that the extinction context is used as an occasion setter, the ME treatment may have reduced the ambiguity of the CS experienced by the organism resulting in less reliance on the extinction context. Although Bouton's theory suggests that increasing trials enhances the value of the extinction context, Denniston et al. (2003) suggested that ME, as a manipulation to enhancing extinction, increases the generalization gradient of the CS – noUS association to contexts that differ from the extinction context.

4.4.2 Retrieval Cues from Extinction

Retrieval cues are stimuli present during the extinction training that, when presented at test, reduce recovery of excitatory responding. Brooks and Bouton (1993b) observed this effect in rats using spontaneous recovery and renewal designs. They suggested that the extinction cue may have retrieved a memory of extinction. The efficacy of extinction cues has been observed in appetitive conditioning experiments (Brooks, 2000; Brooks & Bowker, 2001), reducing the recovery of alcohol tolerance in rats (Brooks, Vaughn, Freeman, & Woods, 2004), reducing alcohol cue reactivity for non-alcoholic drinkers (Collins & Brandon, 2002), reducing return of fear in humans (Dibbets, Havermans, & Arntz, 2008; Vansteenwegen et al., 2006), and reducing public speaking anxiety (Laborda et al., 2016; Shin & Newman, 2017). However, the results are not all uniform, and failures to observe an extinction cue effect have also been reported (e.g., Bustamante, San Martín, Laborda, & Miguez, 2019; Quezada et al., 2018).

Dibbets, Moor, and Voncken (2013) investigated the effect of presenting a cue during exposure training and test to see if this would attenuate renewal for spider fearful individuals. They found a reduction in self-reported spider fear post-extinction. However a switch in context led to an increase in fear reports, suggesting that the extinction retrieval cue did not reduce renewal in the new context. However, there are several methodological issues in the

Dibbets et al. (2013) study, which might have contributed to their null finding. Firstly, the exposure treatment was a massed single session exposure, which may not have been sufficient to eclipse the memory of a strong fear (proactive interference). Moreover, while there has been evidence for one-session phobia treatment (see Davis III, Ollendick, & Öst, 2019; Davis, Ollendick, & Öst, 2012; Zlomke & Davis, 2008), it encompasses more than just behavioural exposure (i.e., psychoeducation, thought confrontation, reinforcement, skills training etc.). In addition, as noted by Dibbets et al. as well, the retrieval cue went largely unnoticed by the participants and was therefore not encoded into the extinction memory. This suggests that the study either failed to actually evaluate the feasibility of retrieval cue during exposure therapy or that retrieval cues may be encoded below awareness in their sub-clinical population. More recent evidence has found retrieval cues that activate multiple senses (e.g., visual, olfactory, auditory and tactile) to be more salient and therefore successful at reducing renewal in people with fear of public speaking (Shin & Newman, 2018). Interestingly however, Shin and Newman also found that 26% of their sample did not remember the cues. Explicit memory of the retrieval cues may not be necessary to attenuate renewal. Although seemingly promising as an augmentation for clinical treatment, Quezada et al. (2018) found that although retrieval cues may be effective at reducing ABC renewal after extinction, this was not maintained over time. When tested 48 hours later, retrieval cues were not able to successfully attenuate renewal, even if they were augmented to be more salient.

Nonetheless, there is enough research to suggest that retrieval cues presented at extinction aids the retrieval of the memory of extinction, thereby attenuating recovery, although this effect might be parameter dependent or subject to other variables not yet understood. The effects of such a manipulation could have significant impact on helping people with other different mental health issues. For example, the use of retrieval cues may help people with substance abuse retrieve memories of abstinence or rehabilitation training

(extinction) (eg., Bouton, 2000; Culver, Stoyanova, & Craske, 2011). Strong attenuation of renewal was observed in a study training alcohol seeking in rats provided with a retrieval cue (Willcocks & McNally, 2014). Interestingly, Willcocks and McNally did not observe an effect of the retrieval cue on reacquisition of the previously extinguished alcohol seeking. In other words, the retrieval of the extinction memory did not affect the reacquisition of the behaviour. Analogously, this would suggest that providing an extinction cue for patients during substance abuse treatment may help attenuate recovery following treatment. However, this cue would have no effect once behavioural relapse occurs and an increase of reacquisition of the substance seeking behaviour. In addition, retrieval cues may lead to encoding a inhibitory value and become a safety signal (Dibbets et al., 2008). Retrieval cues help to retrieve the memory of extinction (i.e., CS – noUS) while safety signals are associated with noUS only (Craske et al., 2014). In a recent study by Nieto, Uengoer, and Bernal-Gamboa (2017), the authors found that recovery was attenuated by the extinction cue, but it did not transfer to the response extinguished without the cue. Translationally, this suggests that while the use of extinction cues may be beneficial for clinical exposure paradigms, they are limited to inhibiting only certain problematic behaviours discussed or confronted during treatment, other problematic behaviours that were not encoded in the extinction memory would not be affected by this enhancement of extinction. Additionally, retrieval cues congruent with original acquisition context may facilitate relapse as well (e.g., Vansteenwegen et al., 2006)

Implications on the future of translating such a method towards clinical use may require cues to be adequately perceived and associated with the extinction treatment. Bouton's (1993) model explained that this effect as providing sufficient reminder of the extinction memory in order for retroactive memory interference (i.e., second-learned association such as extinction) to work against the memory of the first-learned association.

However, the limitations to the attenuation of recovery are that the retrieval cues are also encoded to the specific extinction behaviours only and may not generalize to other problematic behaviours that may lead to behavioural relapse. This may be more thoroughly considered for substance abuse treatment but is also important for anxiety disorders. For substance abuse, substance seeking behaviours may not benefit from the extinction cues unless specifically encoded into exposure training as well. For anxiety disorders, safety behaviours will need to be adequately addressed, inhibited (see Blakey & Abramowitz, 2016) and encoded into part of the extinction behaviours for the retrieval cue of extinction to be effective. It was also suggested that incorporating retrieval cues into multiple context exposure-based therapies may further increase the generalizability of extinction learning to reduce/prevent relapses (de Jong, Lommen, de Jong, & Nauta, 2019).

4.4.3 Spaced Learning

As mentioned in section 4.1.1, manipulating the ITI to be spaced or massed has consequences on the short-term extinction learning and long-term extinction memory. In a series of experiments performed by Urcelay, Wheeler, and Miller (2009b), the authors demonstrated that increasing the intervals between extinction trials, extinction was more persistent compared to massed extinction trials. This manipulation also provided significant attenuation of ABA renewal and spontaneous recovery (experiment 2 and experiment 3). Moreover, Moody, Sunsay, and Bouton (2006a) reported a reduction in reinstatement following spaced extinction, but they failed to observe any effect on spontaneous recovery. These results are consistent with previous evidence regarding the efficacy of spaced acquisition trials over massed acquisition trials (Barela, 1999; Barnet, Grahame, & Miller, 1995).

Similar benefits have been found from studies that explored the effect of spaced extinction *sessions*. Bernal-Gamboa, Gámez, and Nieto (2018) trained rats to perform two

responses. Each response was extinguished in three 30-minutes extinction sessions. For one response, the sessions were separated by a period of 24 hours, and the other was separated by 72 hours. Across a series of experiments, the authors found significantly lower spontaneous recovery, ABA renewal and reinstatement for the response that was extinguished with a 72-hour inter-session interval. As explained by Bouton (1993, 2010) the extinction context helps to set the occasion for the retrieval of extinction memory. A multiple temporal context extinction through spacing extinction sessions may have provided sufficient learning to facilitate the retroactive interference of the extinction memory.

Bjork and Bjork (2006) distinguished between learning and performance. They theorized that immediate or short-term changes in performance do not necessarily reflect learning, which is evidenced as long-term changes in behaviour. This is because the ability to retrieve items in memory is characterized by two functions - storage strength and retrieval strength. In their new theory of disuse, Bjork and Bjork suggested that an expanding retrieval practice, that is, learning that begins with massed ITIs and is gradually spaced out with longer ITIs, is more effective than a uniformly spaced retrieval practice. This is because early massing of trials increases retrieval strength, which would otherwise decay during the ITI, and spaced trials increases storage strength.

Most of the research on the idea of expanding retrieval practice has been conducted in memory research and with educational applications (e.g., Dobson, 2012; Karpicke & Roediger, 2010). In general, this research has found that expanding retrieval practice can lead to improved long-term retention of information compared to uniformly spaced retrieval practice (Landauer & Bjork, 1978), although the results are somewhat mixed. For example, Karpicke and Roediger (2007) found that although expanding retrieval practice resulted in short-term benefits 10 minutes after learning, retention after two days was much better for uniformly spaced retrieval. In their third experiment, they found that delaying the first test

resulted in improved long-term retention regardless of retrieval schedule. However, in another study, Fritz, Morris, Nolan, and Singleton (2007) found that expanding retrieval practice doubled recall in preschool children compared to controls. But they did not have a group with uniform retrieval practice. Their second experiment helped to illuminate some underlying mechanisms of the benefits observed in expanding retrieval practice. The authors compared an expanding retrieval practice group to a re-presentation group (i.e., group that heard the names of the objects for learning again) and found that half of the benefit of expanding retrieval practice came from expanding the schedule of re-presentations and half from the practice of retrieval.

More recent studies continue to report mixed results pertaining to the effectiveness of expanding retrieval practice compared to uniformly spaced retrieval practice (e.g., Dobson, 2013; Gerbier & Koenig, 2012; Kang, Lindsey, Mozer, & Pashler, 2014; Karpicke & Bauernschmidt, 2011). It might be that retrieval practice contributes more to the beneficial effects rather than the schedule of tests (Karpicke & Roediger, 2010). However, if the information is vulnerable to being forgotten (Storm, Bjork, & Storm, 2010), or if testing was immediate (Dobson, 2012; Kanayama & Kasahara, 2016), expanding retrieval practice appears to be superior. One study suggested that expanding retrieval intervals should vary according to skill proficiency for optimum retention (Xiong & Beck, 2014). Orinstein, Urcelay, and Miller (2010) examined expanding retrieval practice in an ABA renewal human extinction learning paradigm. Faster extinction was initially observed for the expanding group, but similar levels of extinction learning was observed overall. The authors observed the same levels of renewal between the two groups, suggesting that the expanding retrieval practice group did not necessarily benefit from better extinction learning compared to the uniform retrieval or control groups. Importantly this data suggests that rapid extinction

observed in clinical settings should only be construed as a performance effect and may not translate to long term extinction learning.

In translational studies utilizing spaced learning on clinical or sub-clinical populations, mixed results were also observed. Rowe and Craske (1998b) found that massed extinction sessions resulted in significantly more short-term loss of spider fear as compared to expanding extinction trials. However, this learning was not maintained when tested one month later or with a novel spider, demonstrating a strong return of fear. Conversely, spaced trials did not exhibit return of fear when tested one month later nor was there appreciable return of fear for the novel spider. The efficacy of spaced extinction trials in the attenuation of recovery after extinction suggests that expanding the method to spacing extinction sessions may result in an overall augmentation to extinction methodology. Indeed, when extinction was carried out as spaced trials or as spaced sessions, both performed better than massed extinction trials at reducing return of public speaking fear at a one month follow-up (Tsao & Craske, 2000). Interestingly, no difference was found between spaced sessions and spaced trials. Conversely, Lang and Craske (2000) was unable to replicate and extend Rowe and Craske's study in their second experiment. Massed trials and spaced trials both reduced fear of heights and no differences were found for return of fear at one-month follow-up.

In most therapeutic settings, exposure therapy would likely be carried out weekly which does coincide with a spaced learning paradigm. This more accurately reflects uniformly spaced learning, which as discussed have demonstrated mixed effectiveness on retention. There is a wealth of evidence for supporting clinical exposure therapies in treating mental health concerns (see Chapter 3). However, it may be helpful to consider some of the research discussed regarding massed sessions, uniformly spaced sessions, expanding retrieval practices. Particularly, these learning schedule paradigms may not need to be mutually exclusive but may be considered on a continuum of treatment. For example, massed sessions

may lead to a faster decrease in fear. This can be followed up by uniformly spaced sessions and then expanding spaced sessions. Understandably, this drastically increases the work of the therapist and the time commitment required for the patient. But if the goal for strong retention of extinction learning, a combination of such effects may be plausible. Alternatively, it is possible for clinicians to shorten the spacing between sessions in order to reflect the trial spacing more similar to Bernal-Gamboa's (2018) study. Additional research designed to be more analogous to clinical treatment settings may provide further insight into this form of enhancement to exposure-based approaches. For example, further increasing the interval from 72 hours, to 168 hours (one week) to ascertain if such an intersession delay may be too long to provide significant recovery reduction. In addition, the interaction of the magnitude of fear and session intervals, on recovery. For example, higher initial fear magnitude may require shorter initial session intervals before increasing the interval time (i.e., massed extinction sessions followed by expanding extinction sessions into uniformly-spaced extinction sessions). This becomes consistent with the suggestion that expanding interval be tailored to the learning abilities of the subject.

4.4.4 Extinction in Multiple Contexts

If renewal is a result of shifting outside of the extinction context, increasing the number of contextual cues associated with extinction could mitigate against renewal. Indeed, this is exactly the suggestion from Bouton (1991) to reduce renewal and other forms of recovery. This idea was first tested by Gunther et al. (1998), who compared the level of ABC renewal after extinction was conducted in one context or three contexts. The researchers found an attenuation of ABC renewal, as evidenced by less conditioned suppression, in the multiple context extinction group compared to single context extinction. These results have since been replicated by many other researchers (e.g., Bernal-Gamboa, Nieto, & Uengoer, 2017b; Krisch, Bandarian-Balooch, & Neumann, 2018; Laborda & Miller, 2013a; Miguez et

al., 2014a; Olatunji et al., 2017a; Shiban et al., 2015a). For example, Chelonis, Calton, Hart, and Schachtman (1999) investigated the effects of extinction in multiple contexts on ABA renewal using a taste aversion learning paradigm. A single pairing of sucrose with lithium chloride was performed in one context, followed by extinction in one or three contexts. A reduction in ABA renewal was observed in rats that experienced extinction in three contexts. Thus, the authors were successful in observing the efficacy of extinction in multiple contexts effect.

The pioneering studies by Gunther et al. (1998) and Chelonis et al. (1999) established the possible effectiveness of attenuating both ABC and ABA renewal by conducting extinction in multiple contexts. These renewal types are most relevant to clinical exposure treatments as therapists only have excess to the extinction context. Often, Context B is a therapists' office and the renewal phenomenon adequately inform us that renewal is almost an inevitable occurrence once the patient leaves the treatment facility. To better understand multiple extinction context's efficacy on humans, Neumann (2006) employed the Martians task, a computerized conditioned suppression preparation experiments for humans. He found that when extinction was conducted across multiple contexts, ABA and ABC renewal were reduced, which agrees with prior studies observing positive effects through this form of extinction enhancement. Similar benefits of this technique in clinical populations have been reported. For example, Vansteenwegen et al. (2007a) investigated extinction in multiple contexts for participants with spider anxiety. They found that compared to participants presented with the spider in one context, those that were presented with videos of spiders in different locations of a house had significantly less return of fear when subsequently tested in a novel context.

Despite the effectiveness of multiple context extinction, there are at least two animal (Bouton, García-Gutiérrez, Zilski, & Moody, 2006; Thomas et al., 2009) studies and two

human studies (MacKillop & Lisman, 2008b; Neumann et al., 2007) that have not observed benefits of this form of extinction enhancement. In three experiments using rats, ABA and ABC renewal were tested by Bouton et al. (2006). Following extinction in multiple contexts, no reduction in either renewal effect was observed by the researchers. However, this may be due to insufficient extinction trials (see Thomas et al., 2009).

Using human participants, Neumann et al. (2007) observed an ABA renewal effect in a fear conditioning preparation using shock as an aversive stimulus. In their second experiment, they conducted extinction over multiple contexts using visual and acoustic cues as contextual manipulations (i.e., different contexts had different illumination and sounds). The researchers were unsuccessful in attenuating ABA renewal. The authors attributed this failure to a weak context manipulation. They hypothesised that a larger number of contextual cues may provide the organism with a stronger idea that contexts are different and will result in better extinction learning (Thomas et al., 2003). Nonetheless, Neumann et al.'s (2007) results were also corroborated by a recent study conducted by Bernal-Gamboa, Nieto, and Uengoer (2017c) in which ABC renewal was eliminated when extinction was conducted in multiple contexts but not in ABA renewal for rats. However, when extended extinction training was conducted over multiple contexts, ABA renewal was attenuated. Previous studies have also noticed successful attenuation of ABC renewal only following additional manipulation to the intensity of extinction training. For example, Thomas et al. (2009) was initially unable to detect a reduction in ABC renewal on 36 extinction over multiple context trials however, it was observed when 144 trials were used (Gunther et al. (1998) used 162 extinction trials). The authors noted that insufficient number of trials in each context may be the reason for some studies failing to observe this effect (e.g., Bouton et al., 2006, used 12 trials). This study lends support to an interactive effect between extinction conducted in multiple contexts and the number of extinction trials.

When Laborda and Miller (2013a) investigated the effects of massive extinction and extinction in multiple contexts using rats as subjects in a lick suppression design, they made a distinction between moderate (162 trials) and massive (810 trials) extinction training. The authors followed experimental parameters by Gunther et al. (1998) for extinction in multiple contexts (162 trials) and by Denniston et al. (2003) for massive extinction training. Unlike Thomas et al. (2009), Laborda and Miller's individual manipulations were effective at reducing return of fear. This meant that a summative effective has been found between massive extinction and extinction over multiple contexts. However, in a similar and more recent study, Gonzalez et al. (2016b) did not observe a difference between combining massive extinction and extinction in multiple contexts to either manipulation alone. Either extinction technique appeared to be effective on its own. It is possible that a floor effect was achieved through either manipulation of extinction, and therefore, no observation of additive effects could be found. Nonetheless, this combination of training paradigms was found to be effective with as little as 36 trials evenly spaced over three contexts for human participants in a fear expectancy paradigm (Krisch et al., 2017), suggesting that the summative effect of both manipulations may have potential clinical implication for exposure treatments.

Studies focused on conducting extinction in multiple contexts have exclusively focused on the spatial aspect of contexts (i.e., physical environment). Dunsmoor, Ahs, Zielinski, and LaBar (2014b) investigated the effect of multiple contexts extinction on renewal, reinstatement and spontaneous recovery using a virtual reality paradigm. The authors performed fear conditioning using shocks and separated the participants into three groups: Control, Single context extinction and Multiple contexts extinction. Following extinction, a 24-hour delay was introduced, and spontaneous recovery was tested. The participants all demonstrated increased responding, suggesting that this manipulation may not adequately mitigate spontaneous recovery. However, the renewal and reinstatement test

showed significantly less responding in the multiple contexts group. Of note, the experiment provides evidence for the change in temporal context resulting in renewal (i.e., spontaneous recovery in this study), as suggested by Bouton (1993). It is possible that a multiple-extinction context may require extinction to be conducted across multiple-temporal contexts in addition to physical contexts (Dunsmoor et al.) to effectively attenuate recovery, particularly spontaneous recovery.

The applicability of extinction in multiple contexts on the clinical population have provided some encouraging results. Shiban et al. (2013b) recruited spider-phobic patients fulfilling clinical diagnosis of specific phobia (Animals: Spiders) and provided virtual reality exposure therapy as treatment. Patients experienced exposure to the feared stimulus either in a single context or in multiple contexts. Following that, patients were tested via a behavioural approach test (BAT) using a real spider. Using different lightings across the virtual contexts (e.g., green, blue, pink, yellow), patients were instructed to watch the immobilized virtual spider in the room(s). Fear ratings and BAT scores recorded following the exposure treatment indicated reductions in renewal for the multiple contexts group compared to the single context group. Building on this study, Shiban, Schelhorn, Pauli, and Muhlberger (2015b) compounded multiple contexts with multiple stimuli exposure. The investigators used multiple different coloured virtual spiders and different virtual contexts to conduct exposure treatment on spider-phobic patients. This manipulation of varied CSs found that exposure in multiple contexts only attenuated return of fear if tests were conducted immediately. Follow-up tests revealed multiple stimuli being more efficacious than single stimulus in a single context exposure. The authors explained the lack of evidence for the combination using the expectancy violation theory (see Shiban et al., 2015b, p. 52). If we apply Bouton's (1993) memory interference model, the combination of multiple stimuli and contexts may have inadvertently created multiple extinction memories that never quite reached the subjective

asymptote required for generalization of a retroactive interference memory sufficient to inhibit the first learned fear association. In other words, more trials may have helped Shiban et al.'s study. As this would increase the learning of a varied CS over multiple contexts. Varied CSs have been found to be more effective than static CSs reducing return of fear in one study (e.g., Rowe & Craske, 1998c) although results appear generally mixed (e.g., Goubert, Crombez, & Lysens, 2005; Lang & Craske, 2000).

It is clear that research on extinction in multiple context has much to contribute to current exposure-based approaches. One challenge to translational applications that may need to be addressed is the nature and feasibility of contextual manipulations. Human studies often differ vastly in their context manipulations. For example, some studies have provided auditory and visual cues as context manipulation (e.g., Bandarian-Balooch & Neumann, 2011; Neumann et al., 2007), others have used only pictures and video clips (e.g., Balooch, Neumann, & Boschen, 2012; Krisch et al., 2018; Olatunji, Tomarken, Wentworth, & Fritzsche, 2017b; Pineño & Miller, 2004; Vansteenwegen et al., 2007b) and some have used virtual-reality as an extension of spatial context changes (e.g., Dunsmoor et al., 2014a; Shiban et al., 2013b; Shiban et al., 2015a). At this time there are no guidelines as to how to sufficiently experimentally manipulate a context to be perceived as significantly different from another. The closer researchers can mimic a realistic spatial context change similar to how a patient would experience, the more translatable the findings would be towards clinical treatment. In addition, there is some strong evidence for combining massive extinction with extinction in multiple contexts. Particularly in attenuating ABA and ABC renewal. The clinical analogy of this may be harder to achieve though. Depending on the willingness and severity of the patient, each trial of exposure to a fearful stimulus (e.g., a spider) may require a whole session (approx. 1hour). Thus, while conducting the trial over multiple contexts (e.g.,

park, office, garden, lift etc.) may be feasible, a massive extinction may not be likely without flooding the patient and cause significantly more trauma than healing.

4.5 Summary

Summing up, behavioural extinction has been very well researched over the past few decades since Pavlov's observation. There is a clear consensus that extinction does not equate to erasure of learning or in other words, unlearning. Recovery from extinction phenomena provides sufficient evidence that the memory of the first-learned association persists even following extinction treatment. Renewal is defined by the return of extinguished behaviour following a context change after extinction. Bouton (1993) provides a broad and encompassing explanation of renewal and how other phenomena such as spontaneous recovery and reinstatement may be different versions of renewal. This requires broadening the concept of a context to encompass temporal contexts for spontaneous recovery.

A significant amount of work has been conducted to understand what is learned during extinction and what determines whether extinction learning will be performed at testing as there are many instances in which recovery from extinction have been observed. Therefore, researchers have investigated methods for reducing recovery from extinction, such as increasing extinction trials, providing additional retrieval cues, spacing out the extinction learning, and conducting extinction across multiple contexts. There is a clear goal in all of these studies, which is to provide some form of augmentation that would have translational value towards a clinical population. Clinicians faced with conducting exposure-approaches also accept that relapse is a strong possibility but mitigating the strength of the return would also allow for continued treatment to possibly provide a stronger memory of extinction to interfere with past learned associations.

Consideration for clinical treatment through the use of exposure approaches may find utility is obtaining clearer fear acquisition history prior to treatment as it may influence the

choice of fear reduction enhancements. Garcia (2017) divided phobia subtypes into two distinct types: experiential specific phobias, which arises from a traumatic experience leading to conditioned fear or nonexperiential specific phobia, and genetic factors with no traumatic experiences (innate fears). The authors suggested that the amygdala contributes to nonexperiential phobias because of increased sensitivity and potentiation leading to decreased amygdala habituation, whereas experiential phobias may be due to metaplasticity in the amygdala of certain predisposed individuals. Garcia defined metaplasticity as "a dynamic regulation of synaptic plasticity thresholds in neuronal population". This may account for resistance to extinction or enhanced readiness to be conditioned to fearful stimuli. Both hypothesized fear mechanisms for respective phobia types show promise and warrant additional future research for support. Overall Garcia's hypotheses suggest that if two different neural mechanisms govern different types of phobias (i.e., experiential or nonexperiential), then treatment for specific phobias may also need to be more tailored towards individuals with a different history of fear acquisition. For example, nonexperiential specific phobias or innate fears (e.g., fear of the dark), may require massive extinction procedures (e.g., Denniston et al., 2003) to make up for the decreased amygdala habituation. While experiential specific phobias (e.g., fear of spiders, following spider bite), may require multiple-context extinction learning to decrease renewal of fear (e.g., Bandarian-Balooch, Neumann, & Boschen, 2012).

CHAPTER 5

RESEARCH OVERVIEW

Despite the high efficacy reported for exposure-based approaches for treating phobias (see section 3.2), the high relapse rate of specific phobias suggests that retrieving memories of extinction learning is vulnerable to interference from acquisition. This occurs despite extensive research on methods for making extinction learning (and by extension, exposure therapy), more effective and more enduring (e.g., massive extinction, spaced extinction, extinction in multiple contexts, etc.). It is possible that the reason these methods fail and why relapse continues to be observed is because circumstances present during acquisition influence the subsequent encoding or retrieval of information learned later.

There has been a considerable amount of research on associative learning, the process of extinction and techniques to make extinction learning more robust with the idea that this extends to exposure therapy for anxiety disorders. By comparison, there has been far less research on the conditions of acquisition and how this could affect subsequent treatment. This is troubling because, when we consider the circumstances that lead to the development of specific phobias or other anxiety disorders, there is a strong possibility that fear acquisition involves multiple pathways (as previously discussed in section 2.2), and these different pathways can each be considered different contexts of learning. Gunther et al.'s (1998) second study showed that acquisition over multiple contexts negates the benefit of extinction over multiple contexts. This should be of particular concern as patients with phobias often acquire fear over multiple pathways (Mineka & Zinbarg, 2006) (as previously discussed in section 2.2.3 and 2.2.4). If we consider that each pathway of acquisition may contain different isolated experiences that naturally would have occurred over different contexts, it stands that most phobias would have been acquired over different contexts. Moreover, acquiring fear over multiple contexts could have a significant negative impact on subsequent

extinction learning even if it were augmented to be performed over multiple contexts. From a clinical perspective, this is highly relevant as it has implications on the effectiveness of exposure-based therapies. Treating a patient with spider phobia becomes significantly more challenging if spider fear was acquired over several direct negative experiences (e.g., bitten by a spider, contact with a venomous spider, witnessing others being bitten) and subsequently being told by immediate social groups (e.g., family and friends) to avoid all spiders. The robustness of acquiring such learning over multiple contexts have not been investigated empirically in humans. From a theoretical and research perspective, understanding the variables involved in multiple context learning can help inform our theories about the role of contexts in learning and memory retrieval. More importantly, it can serve to inform clinical practice and current treatment paradigms on reasons behind high rates of relapse, and possible methods to improve the maintenance of treatment gains. Thus, studying the conditions of acquisition is important not just for understanding excitatory learning, per se, but also because the conditions in which an association is learned can have consequences on subsequent learning and behaviour. The present thesis will examine the effect of one condition, which is when an excitatory association is acquired across multiple contexts.

One dominant theme in the research on recovery from extinction is the critical role of the context in determining behaviour. This was discussed in section 4.2 and 4.3. Contexts can act as a predictive signal and a modulator to help an organism disambiguate the meaning of a CS that has been both reinforced and extinguished (Trask et al., 2017; Urcelay & Miller, 2014). Research from occasion setting and modulation have pointed to the important role of the context in controlling behaviour (e.g., Hall & Mondragón, 1998). Palmer and Kristan (2011) wrote an excellent review article that discusses how different types of external and internal contexts influence behaviour, and they highlighted neural mechanisms that are involved in encoding the context. Moreover, several studies have shown that the similarity

between the acquisition and extinction contexts (e.g., Bernal-Gamboa et al., 2012; Laborda et al., 2011b; Thomas et al., 2003) and the similarity between the extinction and test contexts (e.g., Bouton & Bolles, 1979a; Bouton & King, 1983a; Bouton & Peck, 1989) influences the likelihood of recovery from extinction. For example, renewal is observed when the organism is tested in a context outside of the extinction context (i.e., ABA and ABC renewal). Together, this research suggests that the context of retrieval must match or be similar to the context of encoding in order for that behaviour to be exhibited. When the contexts of encoding and retrieval are not the same, then generalisation decrement and interference is observed.

Research on context effects using non-human animals (rats) as subjects have typically manipulated the context by varying the experimental chamber dimensions, presenting different coloured lights, odours, wall patterns, and floor textures. For example, in Chelonis et al.'s (1999) study, the dimensions of the chambers varied by length, breadth and height. Of the four contexts, three had odour cues (e.g., Methyl, Vinegar and Perfume). Lights in the chambers varied by brightness, and sound cues included white noise, tones, clicks and silence. Finally, the material of the experimental chamber was different for each context. Most other non-human animal studies have conducted similar types of manipulations to create different contexts (e.g., Bouton et al., 2006; Chaudhri, Sahuque, & Janak, 2008; Laborda & Miller, 2013b; Miguez et al., 2014a).

Within the human associative learning research, manipulating contexts is more difficult for a number of reasons. One such reason is that our conceptualization of a context is complex and broad. Contexts, as a whole, are comprised of a myriad of different categories as described by Maren et al. (2013). These categories include spatial, temporal, interoceptive cognitive, and social and cultural contexts (see section 4.2.1). Palmer and Kristan (2011) expanded on the spatial and interoceptive contexts to include examples of contextual cues.

For example, external spatial contexts may contain cues such as environmental seasons, presence of mates, food availability and social status. Internal contexts may contain cues such as reproductive state, and various locomotive states.

As previously described by Bouton (1993), contexts can comprise spatial and temporal features. That is, a context can be defined according to the physical items in the immediate surrounding and by the temporal features. Interoceptive contexts are internal states experienced by the organism and can also serve as priming stimuli for associations. For example, mood states are known to create an internal context, which can facilitate retrieval of information that was encoded under the same mood state (e.g., Bouton et al., 1990). Cognitive contexts are thoughts that arise from external or internal experiences that set the context for successful retrieval or encoding of information. For example, explicit information about a CS – US contingency can lead to increased fear reactivity after extinction (Javanbakht et al., 2017). Social and cultural contexts describe life events in relation to one's social environment and larger cultural exposure. For example, being in the company of certain social groups or the individual's identified cultural groups serve as a form of context where information about certain contingencies can be learned, such as attitudes towards recycling and decisions for health care (e.g., Burke, Joseph, Pasick, & Barker, 2009; Derksen & Gartrell, 1993). Manipulation of these contexts for human research can be difficult because some of these contexts overlap and the salience of one context over another will vary greatly between individuals.

This complexity and diversity in the definition of a context is perhaps partially the cause for failures to observe renewal or other context effects in human studies. While certain contexts, such as spatial and temporal contexts, may be readily manipulated, other contexts are intangible and cannot be systematically controlled by the experimenter. However, even within spatial contexts, some human studies have failed to observe renewal. For example,

Stasiewicz, Brandon, and Bradizza (2007) investigated extinction of alcohol cue cravings over multiple contexts. The authors suggested that their null results may be due to participants not sufficiently discriminating between the contexts. Despite using different rooms, the researchers hypothesized that because the rooms were in the same building within the same campus, the building itself became a context of extinction. Similarly, MacKillop and Lisman (2008) failed to observe renewal following cue exposure treatment over multiple contexts for heavy drinkers. The authors used a combination of controlled visual cues (e.g., alcohol use paraphernalia such as images of beer, bottles and bar room table dressings) in a multiple physical room. However, the study used the same imaginal scenarios during exposure to alcohol cues. Thus, despite conducting the experiment in different physical contexts, the actual context of exposure (i.e., imagined scene) may have been the same.

A common difficulty of research in multiple contexts is the limited ability to create meaningful and salient contextual differences. There is no standardised operational definition for manipulating contexts, and thus previous human studies have utilized several methods to create context shifts. Most studies simulate different contexts by simply showing printed names, pictures or videos on a computer screen (e.g., Bustamante, Uengoer, & Lachnit, 2016; Krisch et al., 2018; Olatunji et al., 2017a; Pineno & Miller, 2004; Vansteenwegen et al., 2007a). For example, Pineño and Miller (2004) showed the names of fictious towns paired with a picture on the computer screen to denote different contexts. Similarly, Bustamante et al. (2016) used fictious restaurant names paired with a picture on the computer screen to simulate multiple contexts. Other studies have changed the background screen colour (e.g., Martian task studies; Havermans, Keuker, Lataster, & Jansen, 2005). Similar but slightly improved were studies that used videos of real-life contexts with a target CS (i.e., spiders in a kitchen, or people vomiting) (e.g., Olatunji et al., 2017a; Viar-Paxton & Olatunji, 2012). These manipulations are very artificial in terms of human context perceptions as they only

provide a single dimensional static description of "places" which engage a single sensory perception (i.e., visual) isolated on a computer screen. As these context changes take place only within the space of a computer monitor, such methods lack true immersion of a context. Some studies have used the same physical room but changed the lighting and sound to signal context shifts (e.g., Bandarian-Balooch & Neumann, 2011; Neumann, 2006). While these changes are arguably better at creating contexts by engaging more sensory systems (i.e., visual and auditory), there is a disconnect between the context outside the computer and the task inside the computer. Moreover, these are artificial cues that are not particularly congruent in any daily environments (also see Glautier, Elgueta, & Nelson, 2013a), and participants remain seated the entire time in the same physical room, which limits the distinctiveness between contexts. A few studies have utilized multiple physical rooms in a university building (e.g.,Bandarian-Balooch et al., 2015; MacKillop & Lisman, 2008b), but as noted by Stasiewicz et al. (2007), there is still a tendency for participants to generalise between the rooms because they are located near to each other within the same physical building. Clearly, studying context learning in humans remains challenging. Palmer and Kristan (2011) explained that contexts are perceived through multiple sensory organs and have different neuromodulators (e.g., dopamine, serotonin, octopamine etc.). Thus, a context is a complex stimulus that is arguably impossible to capture within a single static image on the computer screen. Contexts are diffuse environments that organisms move around in and interact with.

Our current technological advances allow us to create virtual environments with high fidelity that mimic physical spaces that people are more likely to encounter in their daily lives. On top of that, these virtual spaces provide high experimental control as specifications can be coded in by software engineers, with specific instructions by the experimenter. The use of VR as a research tool has increased over the last few years. Interest in using VR as a

research or treatment modality spans across multiple domains of psychology. Several studies have established its efficacy in clinical applications for treatment of anxiety disorders such as arachnophobia, acrophobia, social anxiety, post-traumatic stress disorder (PTSD) and panic disorder (for a review, see Carl et al., 2019). For example, Gujjar, Sharma, and Jongh (2017) used VR exposure to a virtual dental treatment procedure for patients with dental phobia. To treat patients with social anxiety disorder, a study used virtual scenarios such as speaking in front of an audience, a job interview or self-introduction as exposure to feared situations (Bouchard et al., 2017). Another study used customized virtual environments to simulate exposure to contexts where military engagements occurred for military veterans with PTSD (Reger et al., 2016). Other areas where VR had been used include paediatric psychology (Parsons et al., 2017), sports psychology (Bird, 2019), and cognitive psychology (Ng, 2017).

In the laboratory, VR has been used in a number of experiments to study multiple extinction context effects (e.g., Dunsmoor et al., 2014a; Shiban et al., 2013a; Shiban et al., 2015b). For example, in Shiban et al. (2013), participants saw a giant virtual spider inside an empty virtual room that could be illuminated in different colours. A later study by the same authors added more texture to the wall of the virtual room, but it was otherwise the same (Shiban et al., 2015). Dunsmoor et al. (2014) created multiple custom virtual environments that varied according to wall and floor textures and the colour of the sky. Participants were automatically moved in a forward direction through these tunnel-like environments. Participants were unable to control the movement themselves. Notably, all of these studies lacked an interactive component, meaning that participants simply watched the virtual environment as if watching a movie, they did not engage with the objects in the environment or have control over their movement within the virtual spaces. Witman and Singer (1998) explained that involvement, or interaction, focuses the attention of the individual resulting in higher reported sense of presence.

Therefore, in order to achieve better immersion and more salient context changes, it is important to make the virtual environments as interactive as possible such that participants can move and interact with the objects in the environment. Using virtual contexts to provide stimulus and context interaction can be achieved through sufficient assets coded into the program. The interactive nature of such a program may provide deeper learning and more powerful context manipulations.

Overall, the goal of this study was to investigate the effect of acquisition and extinction learning in multiple contexts using VR in human participants. This study hopes to replicate the results from Gunther et al.'s (1998) study 2 and expand our understanding on the effects of acquisition over multiple contexts on subsequent extinction learning. The results from this study would inform researchers and clinicians on the reason for high rates of relapses in specific phobia following treatment. Secondary to this implication, this study also hopes to provide a proof of concept that VR may be a suitable medium for future studies into human acquisition learning over multiple contexts.

Thus, this study attempted to study human acquisition and extinction learning over multiple contexts using a high-fidelity custom VR program and a commercially available VR headset. The VR program contained eight distinct virtual environments that allowed full experimental control and elements that encouraged user interaction. Four groups of participants received acquisition in one or three contexts. Orthogonal to this, the groups were extinguished in one or three different contexts. All groups were tested in a novel context. ABC renewal provides a stronger resemblance to real world experiences of clinical patients where the acquisition, extinction, and test likely take place in very different contexts. The hypotheses of this study are as follows:

1. The group trained in one context and extinguished in a different context would have higher expectation of the US when they are tested in a novel context relative to when they are tested in the extinction context. Thus, ABC renewal was predicted.
2. The group that received acquisition in one context and extinction in three contexts will show less renewal relative to the group that received acquisition and extinction in only one context. Thus, we predict that the extinction in multiple context effect will be observed.
3. The group that received acquisition in three contexts and extinction in one context will show more renewal than the group that received acquisition and extinction in one context. Thus, we predict that acquisition in multiple contexts will result in stronger proactive interference.
4. The group that received acquisition in three contexts and extinction three contexts will show more renewal than the group that received acquisition in one context and extinction in three contexts. Thus, we predict that acquisition in multiple contexts will negate the effect of extinction in multiple contexts.

To test hypothesis 2, 3 and 4, planned comparisons were conducted. The study had primary and secondary measures. The primary measure was a conditioned expectation measure, and the secondary measures included a fear of spider questionnaire, anxiety rating, behavioural approach test, heart rate and a reaction to animal test (i.e., discomfort to VR animal). The experiment consisted of five or six phases depending on the randomly allocated group. Details of the methodology will follow in Chapter 6; results are reported in Chapter 7 and a discussion will follow in Chapter 8.

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CHAPTER 6

METHODOLOGY

6.1 Participants

A total of 62 student volunteers were recruited from James Cook University, Singapore (JCUS) campus. The study was advertised in undergraduate psychology classes and utilized the JCUS College of Healthcare Sciences Psychology Research Participant software created by SONA Systems. They were randomly assigned to one of four experimental groups.

The study utilized Virtual Reality (VR) devices. Therefore, exclusion criteria for the study took into account health-related issues that are listed in the Oculus Rift Headset, Health and Safety manual (Appendix A). Participants who were pregnant, have a heart condition or other serious medical conditions were excluded. Furthermore, as the study used a VR headset with a high definition display, participants with pre-existing binocular vision abnormalities were also excluded. Finally, because this study focused on investigating mechanisms related to specific phobias, student who had a DSM-V diagnosis of specific phobias (APA, 2013) were also excluded.

One student was excluded immediately following a panic attack induced by the virtual spider, leaving a total of 61 participants (40 females, 21 males) ranging between 17 and 50 years of age ($M = 22.75$, $SD = 6.37$). All participants had normal or corrected vision. The study was approved by the James Cook University, Australia, Human Research Ethics Committee on 30 August 2016. The project's Ethics Approval identification was H6700.

6.2 Apparatus

Decisions leading to the selection of the computer, the VR headset and the contractor for the custom VR program, were made based on the need for an immersive experience for

participants with ease of operation. Therefore, the study required a computer with optimal specifications to run both the VR program and the VR headset simultaneously without strain.

Laptop Computer

The laptop computer selected was an AFTERSHOCK S15 with the following specifications: Intel Core i7-6700HQ (6^{th} Gen Quad Core processor), 16GB DDR4 2133mhz memory, Nvidia GeForce GTX1070 graphics card, 120GB Samsung EVO 850 M.2 SSD, running Windows 10 Home 64 Bit. Custom specifications were requested for the graphics card and RAM to ensure its capability to run the VR headset.

Virtual Reality Headset

The VR headset was an Oculus Rift consumer version 1, 2016. The headset used a PenTile OLED display of 456 pixels per inch (1080 x 1200 resolution) with a refresh rate of 90Hz. It weighed 471.7 grams. The headset was used along with an XBOX One Wireless Controller, included in the consumer package.

Heart Rate Monitor

The device used to measure heartrate was a Xiaomi Mi Band 3 sports wristband that utilized a photoplethysmography (PPG) optical sensor capable of accurate real-time heart rate measurements.

Stimulus Material – Custom VR Program

A custom-made VR program was developed by Digital Frontier, a creative digital media company, specializing in developing virtual environments for tourism and travel industries.

Eight distinct virtual environments were created that resemble places that people are more likely to frequent daily. These environments contained context appropriate objects (e.g., books and chairs in a library) to improve realism of the environment and encourage immersion. Target objects are placed around the environment for participants to search for

and obtain. The target conditioned stimulus (CS) was a teacup and the unconditioned stimulus (US) was a spider. On trials in which the CS and US are paired together, the spider will crawl out of the cup, and on trials in which the CS and US pairing was being extinguished, the cup would be presented without the spider.

Table 1 displays the types of virtual environments that the participants explored. The Ctx 0, Tutorial Context was an environment all participants first experience. This context served as a space for participants to acclimatize to the VR environment, and to learn the basic mechanics of "obtaining objects". A crosshair was displayed in the centre of the participant's view as a primary focal point on the CS, US and the filler objects. Ctx 1 to Ctx 6 were unique environments that represent places frequently visited in daily life. These environments were counterbalanced as acquisition and extinction contexts. Ctx 7 was always a novel environment experienced by all participants (see Appendix B for examples of VR contexts).

Table 1

Types of Environment that Participants Explored During the Experiment

Context No.	Type of environment rendered
Ctx 0[a]	Tutorial Context
Ctx 1[b]	Living room
Ctx 2	Study Room
Ctx 3	Library
Ctx 4	Café
Ctx 5	Garden
Ctx 6	Office
Ctx 7[c]	Questioning (Test) Room

Note. Eight unique environments were created for the study. All participants experienced these environments.

[a] Ctx 0 used as tutorial space to acclimatize participants to VR.

[b] Ctx 1 to Ctx 6 serve as unique virtual environments that were counterbalanced across all participants as either acquisition contexts or extinction contexts.

[c] Ctx 7 was used as the novel context where all primary and secondary measures were collected. All participants completed the experiment in this room.

6.3 Measures

Measures for the study were collected from all participants in Ctx7, Questioning (Test) Room. Only participants in A1E1 were asked to rate their expectation twice; once in the extinction context and once in the test context.

6.3.1 Primary Measure

1) Conditioned Expectation measure - Participants were asked to verbally rate how much they expect the spider to appear on scale of 0 – 100.

Conditioned expectation is a measurement method used to effectively measure US-expectancy in studies pertaining to human contingency learning (e.g. (Hamm & Weike, 2005). The measure has been used to provide data in human contextual fear conditioning studies (e.g. Vansteenwegen et al., 2008). Boddez et al. (2013) conducted a review of the measure and concluded US-expectancy measure to be a valuable assessment method in research pertaining to fear and anxiety. This study does not seek to condition fear in humans, instead focuses on contingency learning between the CS and US in different contextual spaces.

6.3.2 Secondary Measures

The present experiment is a human contingency learning paradigm. We are primarily interested in conditioned expectation. However, as we are pairing a cup with a virtual spider, we are also interested in whether anxiety is affected by this associative learning. Hence, we included a number of secondary measures.

2) Fear of Spider Questionnaire (FSQ) was administered before the experiment begins. The FSQ is an 18-item self-report questionnaire used to assess spider phobia. It is scored on a 7-point Likert scale and scores range from 18 to 126 (Szymanski & O'Donohue, 1995)

3) Anxiety Rating - Participants were asked to verbally rate their anxiety from 0 (not anxious at all) – 100 (extremely anxious) during the test phase.
4) Behavioural Approach Test (BAT) – The maximum distance that participants were willing to approach the cup was recorded on scale of 0 (not willing to approach) – 100 (as close as possible).
5) Pre-test heart rate measure was collected to establish baseline readings and post-test heart rate measure was collected during the test phase as comparison of physiological arousal. Measured in beats per minute (BPM)
6) Reactions to animal - Participants were asked to verbally rate how uncomfortable the VR spider made them feel on a scale of 0 (not uncomfortable at all) – 100 (extremely uncomfotable).

6.4 Design

The study was a 2 (Acq Ctx: 1 vs. 3) x 2 (Ext Ctx: 1 vs. 3) between-subjects factorial design (Table 3). This resulted in four groups: A1E1, A1E3, A3E1 and A3E3.

1. Group A1E1 received acquisition in one context and extinction in one context.
2. Group A1E3 received acquisition in one context and extinction in three contexts.
3. Group A3E1 received acquisition in three contexts and extinction in one context.
4. Group A3E3 received acquisition in three contexts and extinction in three contexts.

6.4.1 Context Specific Designs

Ctx 0 –Tutorial Context

All participants are loaded into this environment when the experiment begins. This is an open environment with three white floating objects (Cube, Cylinder and Sphere). There are two main goals to achieve in this context. Firstly, Ctx 0 aided participants in acclimatizing to the virtual space. Secondly, Ctx 0 provided a space for a tutorial into the key

mechanism behind obtaining objects throughout the rest of the experiment. Participants are instructed on how to use the crosshair to focus on objects, simultaneously pressing and holding a controller button, to obtain them.

Ctx 1 – Ctx 6 - Acquisition and Extinction Contexts

All participants experience Ctx 1 to Ctx 6 as either acquisition, extinction or novel contexts. Every context had three objects that the participant had to obtain. These objects were either the target association (cup) and/or filler objects. In contexts whereby no target association was required, participants searched for three filler objects. In contexts with a target association, participants looked for the cup and two filler objects. Each acquisition or extinction context provided a target association of either cup and spider (acquisition) or cup and no spider (extinction).

Specific to group A1E1, following extinction in one of these contexts, participants were loaded back into the extinction to report an expectation measure when approaching the cup. This score was used in comparison to the score obtained in Ctx 7 to demonstrate the efficacy of using VR to elicit the renewal effect in humans.

Ctx 7 – Questioning (Test) Room

All participants completed the experiment in this context. This context was always a novel context that had a table and a cup. Primary and secondary measures (except for FSQ) were collected here before completing the experiment.

6.4.2 Target Associations

The target association in the experiment was either a cup and spider association (CS → US pairing) or a cup and no-spider association (CS → No US pairing). To ensure comparable acquisition, all participants were exposed to the cup and spider pairing for 24 seconds. Likewise, exposure to the cup alone was equated across group during extinction.

In the single acquisition context conditions (i.e., Groups A1E1 and A1E3), participants were exposed to one 12-second CS → US pairing in a single context twice (Total exposure time: 24seconds). In the multiple acquisition context conditions (i.e., Groups A3E1 and A3E3), participants were exposed to three 4-second CS → US pairing over three contexts twice as well. Similarly, in the single extinction context condition (i.e., Groups A1E1 and A3E1), participants were exposed to one 12-second CS → No US pairing in a single context twice. In the multiple extinction context conditions (i.e., Groups A1E3 and A3E3), participants were exposed to three 4-second CS → No US pairing over three contexts twice.

The overall context exposure and exposure to the CS and US was therefore equated across groups. All groups received comparable context exposure and extinction trials. They differ only in whether the acquisition and extinction trials occurred all in one context or spread across three contexts.

6.4.3 Filler Objects

Filler objects are context appropriate objects that are most likely found in the contexts, such as food in the café, a bowl in the kitchen, or a book in a study room. All participants were required to find three objects in every environment. They served as a primary motivation for exploration in the environment. Each filler object was unique to the environment and are always located in the same location. Table 2 provides a breakdown of the specific filler items in each context.

Table 2

List of Filler Objects Obtainable in the Environment.

Context No.	Environment	Filler Objects
Ctx 0	Tutorial Context	Sphere, Cylinder and Cube
Ctx 1	Living room	Bowl, Can Drink, Crepe on plate
Ctx 2	Study Room	Pitcher, Textbook, Vase
Ctx 3	Library	Coffee, Book with Bell, Lamp
Ctx 4	Café	Meatballs, Brownie, Sauce Bottle
Ctx 5	Garden	Bench, Plant, Lounge Chair
Ctx 6	Office	Desk lamp, Crystal Globe, Flowers
Ctx 7[a]	Questioning (Test) Room	N/A

Note. [a]There are no filler objects in Ctx 7 because this is the novel test environment where there was a table and the cup (CS) is displayed.

Table 3

Overview of Experiment Phases.

		Phases			
Groups	**Tutorial**	**Acquisition**	**Extinction**	**Extinction-Renewal Test**	**Test**
A1E1	Ctx0	Ctx1:**12s CS → US** 2 Filler Objects Ctx2: 3 Filler Objects Ctx3: 3 Filler Objects	Ctx4:**12s CS → No US** 2 Filler Objects Ctx5: 3 Filler Objects Ctx6: 3 Filler Objects	Ctx4: CS	Ctx7: CS
A1E3	Ctx0	Ctx1:**12s CS → US** 2 Filler Objects Ctx2: 3 Filler Objects Ctx3: 3 Filler Objects	Ctx4: **4s CS → No US** 2 Filler Objects Ctx5: **4s CS → No US** 2 Filler Objects Ctx6: **4s CS → No US** 2 Filler Objects		Ctx7: CS
A3E1	Ctx0	Ctx1: **4s CS → US** 2 Filler Objects Ctx2: **4s CS → US** 2 Filler Objects Ctx3: **4s CS → US** 2 Filler Objects	Ctx4:**12s CS → No US** 2 Filler Objects Ctx5: 3 Filler Objects Ctx6: 3 Filler Objects		Ctx7: CS
A3E3	Ctx0	Ctx1: **4s CS → US** 2 Filler Objects Ctx2: **4s CS → US** 2 Filler Objects Ctx3: **4s CS → US** 2 Filler Objects	Ctx4: **4s CS → No US** 2 Filler Objects Ctx5: **4s CS → No US** 2 Filler Objects Ctx6: **4s CS → No US** 2 Filler Objects		Ctx7: CS

Note. The acquisition phase and the extinction phase were repeated following the completion of the objective in the last context of that phase. (Boldface to facilitate identification of the target association in that phase).

6.5 Procedures

Procedures for the experiment were broken down into Pre-experiment Phase, Tutorial Phase, Acquisition Phase, Extinction Phase and Test Phase. Specific to group A1E1, an additional phase, Extinction-Renewal Test Phase preceded the CTX7 Test phase. Table 3 provides a detailed overview of the experiment phases.

6.5.1 Pre-experiment Phase

Upon arrival, participants were given an information sheet to read before continuing the experiment. Upon signing of the consent form, participants were asked questions related to the exclusion criteria (e.g., pre-existing health condition and whether they are prone to motion sickness that leads to nausea, headaches and/or vomiting) and asked to fill in the FSQ. The FSQ was immediately scored. Participants who reported high FSQ scores (above 94, 75% of maximum score of 126) were queried about their willingness to continue due to the exposure to a virtual spider. There were no participants that dropped out of the experiment in this phase.

Participants were informed about their right to terminate the experiment at any time and to inform the experimenter immediately should they become unwell. The heart rate monitor was then secured to the participant's left wrist and the pre-test heart rate was measured. Participants were then asked to stand and were assisted in wearing the VR headset. Relevant adjustments were then made to ensure optimal comfort and visual clarity. Participants were informed that they could rest their eyes between phases.

6.5.2 Tutorial Phase

Once the program was executed, the participants are loaded into Ctx0 - Tutorial Space. The XBOX One controller was handed to the participant with a brief instruction on the basic operation. The left thumb stick of the controller controls movement in the three-dimensional (3D) space and the 'A' button was used to obtain the floating objects.

Participants were instructed to freely explore the 3D space and acclimatize to the virtual experience. Specifically, they were encouraged to move their heads to look around the 360° space.

Participants were then instructed to move towards one of the floating objects until they observe the outline of the object glowing, then they were asked to press and hold the 'A' button on the controller until the object disappears or 'obtained'. This served as the main instruction for the basic mechanism that underlies the successful completion of the rest of the experiment. To move on to the next phase, participants had to successfully obtain all of the objects.

Participants were allowed up to ten minutes in this context; however, once they had completed the task, felt well and confident enough to continue, they were allowed to move into the acquisition phase.

6.5.3 Acquisition Phase

The primary objective of this phase was to condition an association between the CS (teacup) and the US (spider). Participants were told that the goal of the game was to find objects in the environments. A picture of the objects was displayed at the top of their heads-up display (HUD). All participants experienced the target association in at least one context.

Participants in the single acquisition context conditions (i.e., Groups A1E1 and A1E3) received one CS → US pairing lasting 12 seconds in one context. Thus, participants observed the teacup for 12 seconds before they are allowed to move on to the next object. During this time, the virtual spider crawled around the teacup. After they obtained the teacup, they were asked to find any additional objects they had not obtained. Once this was completed, participants moved on to the next contexts where they needed to find three filler objects.

Participants in the multiple acquisition contexts conditions (i.e., Groups A3E1 and A3E3) received three CS → US pairings lasting 4 seconds in each of the three contexts.

Similarly, participants were to observe the virtual spider crawling around the cup before moving on to the next objects. Once all three objects were obtained, they were loaded into the next context.

All participants experienced this phase twice. Thus, they each experienced a total exposure of 24 seconds of CS → US association. The three objects in each context could be obtained in any order. Depending on the speed at which individual participants successfully found the objects, this phase lasted between 10 to 20 minutes. Transition to the next phase occurred 1 – 3 minutes after this phase ended.

6.5.4 Extinction Phase

The primary objective of this phase was to extinguish the association between the CS (teacup) and the US (spider). Thus, the virtual spider was not presented to any participants in this phase.

Participants in the single extinction context conditions (i.e., Groups A1E1 and A3E1) received one CS → No US pairing lasting 12 seconds in one context. They observed the teacup until it was obtained. In this phase, the spider did not appear with the teacup. They were allowed to continue their search for other objects after this.

Participants in the multiple extinction context conditions (i.e., A1E3, A3E3) received three CS → No US parings lasting 4 seconds in each of the three contexts. Participants observed the teacup until it was obtained without the presentation of the virtual spider. They were allowed to continue searching for the other filler objects after this.

Similar to the acquisition phase, all participants experienced this phase twice. Thus, they each experienced a total exposure of 24 seconds of CS → No US association. The three objects in each context could be obtained in any order. Depending on the speed at which individual participants successfully found the objects, this phase lasted between 10 to 20 minutes as well. Transition to the next phase occurred 1 – 3 minutes after this phase ended.

6.5.5 Extinction-Renewal Test Phase

This test was specific only to Group A1E1. The program automatically loaded the previous extinction environment following the extinction phase. The participants were instructed to search for the teacup. They were then asked to report aloud their expectation between 0 (Not at all likely) to 100 (Absolutely certain), that a spider will be present in the teacup. The purpose of this was to compare to expectation ratings in the next phase, a novel test context to ascertain that the current manipulation was successful in eliciting basic ABC renewal in humans through the VR experimental paradigm.

6.5.6 CTX7 Test Phase

The primary objective of this phase was to obtain the primary and secondary measures. The context consisted of a single nondescript office table with the teacup on it. All participants were prompted to stand in front of the teacup and focus the crosshair on it. The XBOX One wireless controller was then taken from them. All participants were then asked to provide ratings for their expectation of the spider, anxiety towards the teacup, distance they were willing to approach the teacup, and discomfort towards the VR spider. These scales were all set between 0 to 100. Their physiological arousal, in the form of their heartrate, was also simultaneously recorded.

Once participants completed their self-reports, they were assisted in the removal of the headset and asked how they were feeling. They were allowed to remain in the experiment room to recuperate for as long as they required and should inform the experimenter immediately if they felt unwell. No participants reported lasting negative effects of the VR experience.

CHAPTER 7

RESULTS

Participants were randomly distributed into the four experimental groups: A1E1 (n = 15), A1E3 (n = 16), A3E1 (n = 15), and A3E3 (n = 15). The groups are differentiated by the number of acquisition and extinction contexts (one or three). One-way ANOVA analyses were conducted to investigate differences between the groups on Age (M = 22.75, SD = 6.41), FSQ scores (M = 53.67, SD = 28.96), and baseline heart rate (M = 80.53, SD = 11.89). No significant differences were found for these measures, all scores F<.55, p > .05. Gender also did not appear significantly different between Females (M = 62.56, SD = 21. 56) and Males (M = 52.76, SD = 21.21), F = 2.94, p=.09.

7.1 Measures

The primary dependent variable for the study was a conditioned expectation measure. Secondary measures included Anxiety rating, BAT, post-test heart rate, and reactions to animal. None of the results from the secondary measures were significant (See Table 4), so the results will only focus on the conditioned expectation measure.

7.2 Assumptions Test

Prior to conducting analyses, assumption testing for normality distribution used the Shapiro-Wilk test. Outliers were detected in groups A1E1 and A3E3. Further inspection found that one participant from A1E1 reported expectation scores more than three standard deviations from the group mean, and therefore this case was removed from all further analyses. A3E3 had two participants that reported expectation scores more than one and a half standard deviations from the group mean but less than three standard deviations. Thus, these cases were retained. Homogeneity of variance was assessed using Levene's Test of Equality of Error Variances. The assumption for homogeneity of variance was met $F(3,56)$ = 1.25, p = .30. The data was determined to be suitable for ANOVA analyses.

7.3 ABC Renewal Test

ABC renewal was assessed with a paired-samples *t*-test to compare the expectation scores in Group A1E1 at the end of extinction to the expectation scores in the novel test context. ABC renewal was demonstrated, as shown by higher expectation ratings of a spider when presented with the cup (CS+) in the novel test context (M = 65.36, SD = 10.28) relative to the extinction context (M = 52.14, SD = 9.78), $t(13) = -6.01$, $p < .001$, $d = 1.47$, 95% CI (-17.97, -8.46). Thus, supportive of hypothesis 1. See Figure 1.

7.4 Main Results

A 2 (Acquisition context: 1 vs. 3) x 2 (Extinction context: 1 vs. 3) ANOVA was conducted to assess the effect of multiple acquisition and/or extinction contexts on ABC renewal. This analysis revealed a significant main effect of acquisition contexts, $F(1, 56) = 17.58$, $p < .001$, $\eta_p^2 = .24$. Groups that received acquisition in one context showed less renewal (M = 49.93, SD = 21.27) than group that received acquisition across three contexts (M = 68.33, SD = 17.57). There was also a main effect of extinction contexts, $F(1, 56) = 25.81$, $p < .001$, $\eta_p^2 = .32$. Groups that received extinction in one context showed more renewal (M = 70.34, SD = 13.54) than groups that received extinction across three contexts (M = 48.65, SD = 22.34). There was no significant interaction effect, $F(1, 56) = 3.51$, $p = .07$, $\eta_p^2 = .06$. See Figure 2.

A planned comparison between Group A1E1 and Group A1E3 was conducted to investigate the effect of extinction in multiple contexts. As hypothesized, Group A1E1 showed more renewal (M = 65.36, SD = 10.28) in the novel test context than Group A1E3 (M = 36.43, SD = 19.16), Mean diff = 28.92.56, SE = 5.74, $p < .001$, $d = 1.88$. This result is consistent with previous research showing less recovery after extinction in multiple contexts, and supportive of hypothesis 2.

A second planned comparison between Group A1E1 and Group A3E1 was performed to investigate the effect of acquisition in multiple contexts. Group A3E1 showed stronger renewal (M = 75.00, SD =14.84) relative to Group A1E1 (M = 65.36, SD = 10.28), which is in line with hypothesis 3. This difference just met statistical significance when using a two-tailed test (Mean diff = -9.64, SE = 4.77, p = .05, d = 0.76). It is clearly under the .05 alpha criterion when using a one-tailed test (p = .03). These results suggest that acquisition across multiple context leads to greater recovery from extinction. Thus, supportive of hypothesis 3.

The final planned comparison was performed between group A1E3 and group A3E3 to investigate how acquisition across three contexts affects renewal, even after extinction is conducted in three contexts. As expected, more renewal (i.e., stronger recovery) was observed in Group A3E3 *(M = 61.67, SD = 17.99)* relative to Group A1E3 *(M = 36.43, SD = 19.16),* Mean difference = *- 25.23, SE = 6.33, p* <.001, d = 1.36. This result is consistent with the results reported by Gunther et al. (1998), which is the only other study to show this effect. Thus, supportive of hypothesis 4.

Together, the results confirm that extinction performed across multiple contexts reduces recovery from extinction (in this case ABC renewal) relative to extinction performed in a single context. It also provides evidence that acquisition across multiple contexts increases recovery from extinction relative to acquisition in a single context and that this type of training interferes with subsequent extinction learning, leading to more renewal despite extinction being conducted across multiple contexts.

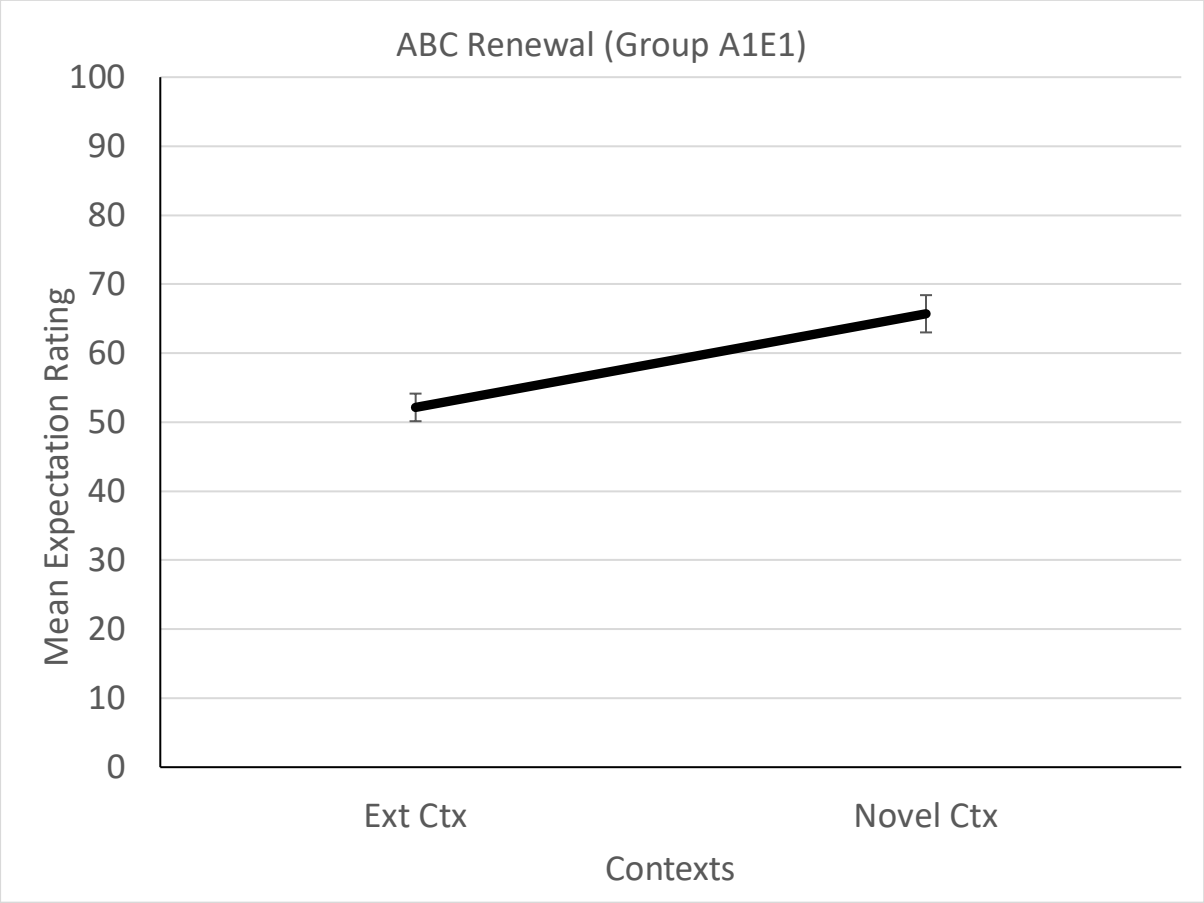

Figure 1. Mean expectation scores between the tests at the extinction context and the novel context for group A1E1 (acquisition in one context, extinction in one context).

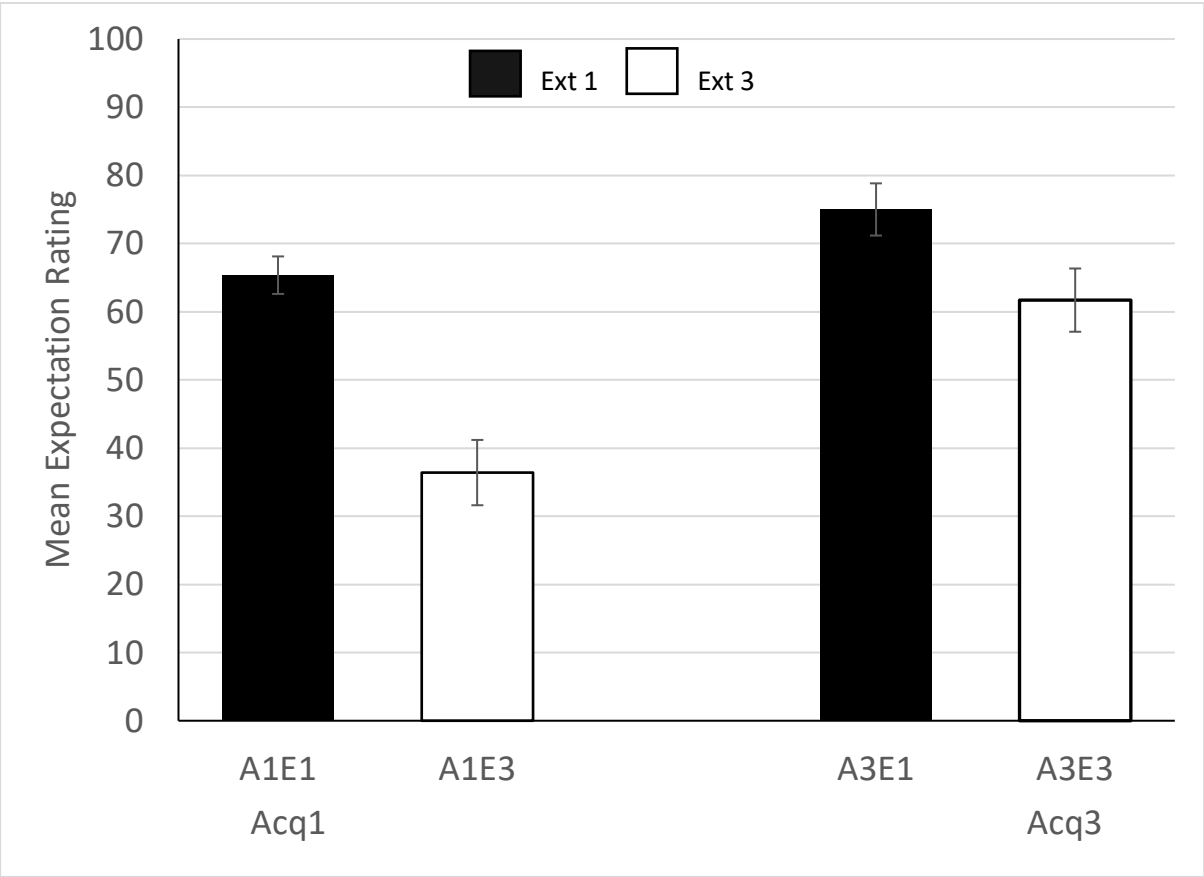

Figure 2. Group mean expectation scores on renewal test for Groups A1E1, A1E3, A3E1 and A3E3 tested in a novel context (i.e. ABC renewal paradigm). Error bars represent the standard error of the mean scores.

Table 4

Data from Secondary Measures

Dependent Variable	Mean		SD	
FSQ[a]	53.21		28.94	
Anxiety[b]	34.82		27.17	
BAT[c]	69.21		30.75	
Discomfort to VR spider[d]	34.70		30.79	
Heart Rate[e]	Pre-test 80.40 BPM	Post-test 86.50 BPM	Pre-test 11.9 BPM	Post-test 14.25 BPM

Note.

All results were $p>.05$. Smallest p value was 0.22.

[a]The Fear of Spiders Questionnaire (FSQ) was scored between 18 to 126. A paired samples test shows no relation to the expectation results in the final test context.

[b]Anxiety was self-reported during the test phase and was rated between 0 to 100. ANOVA test shows no effect of number of acquisition or extinction contexts on anxiety.

[c]Behavioural Approach Test (BAT) was the maximum distance that participants were willing to approach the cup scored between 0 – 100. ANOVA test shows no effect of number of acquisition or extinction contexts on BAT.

[d]Discomfort to VR spider was the self-reported between 0 – 100. ANOVA test shows no effect of number of acquisition or extinction contexts on discomfort.

[e]Heart rate (beats per minute, BPM) taken before the experiment and after the experiment were not found to be significantly different within subjects and between subjects.

CHAPTER 8

DISCUSSION OF THE STUDY

The aim of the study was to investigate the effect of acquiring excitatory and inhibitory associations across multiple contexts in a human learning paradigm. The study is the first experiment conducted with humans, and only the second study overall, to show how acquisition in multiple contexts negatively affects subsequent extinction in multiple contexts to reduce ABC renewal. It also successfully replicated the extinction in multiple context effect using virtual reality, and it is the first to do this using a non-Western population.

8.1 Acquisition in multiple contexts

This experiment is one of the only few studies that have investigated excitatory associative learning across multiple contexts. The first study that demonstrated this effect on non-human animals did so with rodents. Gunther et al. (1998) conducted two experiments. In their first experiment, they successfully attenuated ABC renewal following multiple contexts extinction. In their second experiment, they demonstrated that following fear conditioning across multiple contexts and extinction in multiple contexts, recovery of responding (i.e., renewal) was higher than rodents trained in a single context. Similarly, Todd, Winterbauer, and Bouton (2012) found in their fourth experiment that when acquisition occurred over two contexts, ABC renewal was increased. These findings were also replicated by Trask and Bouton (2018) in a similar experimental design. Trask et al. (2017) concluded that the mere shift away from the extinction context allows the CS to control responding, which means that to produce lasting effects of extinction learning, additional manipulations are required. Notably, all of these experiments were conducted with rats. The present experiment is the first to demonstrate this effect in human participants. Group A3E1 reported higher mean expectation of the US in a novel context compared to Group A1E1. Moreover, there was higher expectation in Group A3E3 was compared to Group A1E3, which suggests that

acquisition in multiple contexts negatively impacted the benefit of conducting extinction in multiple contexts. That is, the study demonstrated human learning across multiple contexts strengthened ABC renewal and diminished the effect of extinction across multiple contexts.

Bouton's (1993) memory retrieval model of extinction explains this as proactive interference; the first learned information (phase 1 acquisition) interfered with the retrieval of second learned information (phase 2 extinction). Acquiring an association across multiple contexts may hinder the retrieval of the extinction memory. Miguez et al. (2014b) demonstrated that retroactive interference and proactive cue inference may be determined by the number of contexts the association was learned in. In their study, they found that phase 1 learning across multiple contexts leads to more proactive cue inference, while phase 2 learning across multiple contexts resulted in more retroactive cue interference. In other words, what is observed at test depends on the degree of interference produced in phase one and phase two. Thus, it would seem that acquiring an association across multiple contexts weights retrieval in favour of that association. If two interfering associations are acquired sequentially across multiple contexts (e.g., Gunther et al., 1998), the first-learned association is given preference in terms of memory retrieval. It would be interesting to see if similar preferential treatment for first-learned associations is observed when both the first- and second-learned associations are enhanced in other ways (e.g., massive training of both acquisition and extinction).

According to Bouton's (2004) theory, the first-learned association is predominantly encoded independent of other stimuli, such as the context, while the second-learned association is dependent on the context. Essentially, the first-learned association is treated as a rule for understanding the world (i.e., CS – US); any conflicting information that is learned after is treated as an exception to the rule and thus, conditional to the context of extinction. This is because conflicting second-learned information introduces ambiguity, which requires

the context to resolve (Bouton & Nelson, 1994; Nelson & Bouton, 1997). Thus, in a simple extinction design, the extinction context becomes a negative occasion setter (Holland, 1992). This idea is supported by results from Nelson (2002) and Sissons and Miller (2009), who observed renewal and spontaneous recovery, respectively, of a first-learned inhibitory association.

Challenging this notion, however, some research has reported contextual control of first-learned associations (e.g., Lucke, Lachnit, Koenig, & Uengoer, 2013; Nelson, 2009; Rescorla, 2008; Starosta et al., 2016). Nelson used a three-phase experiment in which a cue received excitatory and inhibitory training, and the final phase was either excitatory (Experiment 1) or inhibitory (Experiment 2). Changing the context for testing reduced responding, regardless of whether the final phase of training matched the first-learned association or second-learned association. They interpreted these results using the suggestion from Rosas, García-Gutiérrez and Callejas-Aguilera (2006), which assumes that once a CS becomes ambiguous, all subsequent learning, even learning that is consistent with the first-learned association, becomes context-specific. Starosta et al. similarly observed context-specificity of first-learned information. They concluded that Pearce's (1994) configural processing model and Rosas et al.'s (2006) extension of Bouton's model can both explain the results. Thus, while it seems clear that all learning can come under contextual control, it remains unclear as to the mechanism by which this occurs.

A comparison of Groups A1E1 and A1E3 in the present study suggests that conducting extinction across multiple contexts reduces the contextual dependency of that learning such that extinction generalises more readily to a novel context. However, conducting acquisition across multiple contexts likewise reduces the contextual dependency of that learning, such that acquisition generalises more readily to a novel context. This was demonstrated in the comparison between Groups A1E1 and A3E1. This explanation assumes

enhanced generalisation is the mechanism by which these effects are observed, and it is in line with Todd et al. (2012), Trask and Bouton (2018), and many others who theorized that learning an association over multiple contexts leads to enhanced generalisation to other contexts. One reason for the increased expectation observed, after acquisition in multiple contexts, might be that training in multiple contexts increased the number of contextual elements or cues that became associated with that learning. Thus, training across multiple contexts resulted in more excitatory contextual elements that were present in the novel test context resulting in higher levels of ABC renewal (Trask & Bouton, 2018) compared to the group that received acquisition in only a single context. A variation of this idea is that training the CS-US association across multiple contexts led to more contextual elements being associated with the target association and capable of priming, or facilitating the retrieval of that association at test, thus leading to more proactive interference (Miller & Escobar, 2002). These two explanations differ in whether they predict the contextual elements themselves acquired excitatory associative properties, which increased expectation of the US at test, or whether they primed the CS-US association, which produced more proactive interference, which was expressed as more responding at test.

Another possibility is that each training trial produced a unique configured cue, which is a single representation that included the CS and all contextual elements present during training (e.g., Pearce, 1987, 1994). According to Pearce's theory, the pattern of stimulation that occurs before a US becomes configured together, and that unified representation becomes associated with the US. Responding generalises to novel stimuli or in novel contexts to the extent that the two representations are similar. In the present experiment, training the CS-US association across multiple contexts may have created multiple configured representations, which generalised more to the test trial than acquisition in only one context, which created only a single configured representation.

Ultimately, whether the acquisition learning generalised more readily due to elemental processing or similarity of configured representations is beyond the scope of the current thesis. Two reasons for why ABC renewal was stronger following acquisition in multiple contexts relative to acquisition in a single context was offered. However, it remains unclear why, when both acquisition and extinction occurred across multiple contexts, thus equating the number of contextual cues that can become associated with each of those associations, proactive interference was observed more than retroactive interference. That is, greater expectation of the US was observed to the target CS in Group A3E3 relative to Group A1E3. Given that all of the acquisition and extinction contexts were counterbalanced, there is no reason for why the test context should share more contextual features or more similarity with the acquisition contexts than the extinction contexts. Thus, neither an elemental nor a configural processing account of generalisation can fully explain the present results. It would appear, however, that when the conflicting associations are learned to an equal degree, Bouton's (2004) assumption that whatever is learned first takes precedence holds true.

While it seems likely that renewal was stronger in Group A3E1 relative to Group A1E1 due to more generalisation (by whatever mechanism) to the test stimulus from acquisition training, there are two other possible mechanisms that can be entertained. Firstly, acquisition training across multiple contexts may have increased the relative strength of the CS – US association or produced less competition from the context for excitatory behavioural control relative to acquisition training in a single context. Data from Polack, Laborda, and Miller (2012) demonstrated that contexts can acquire excitatory and inhibitory associative strength during renewal studies. Therefore, it is possible that in Group A1E1, the acquisition context acquired sufficient excitatory associative strength to compete with the target CS. Conducting acquisition across multiple contexts, however, would have spread the excitatory associative strength out and prevented any one context from becoming a strong competitor

for an association with the US or for behavioural control. This is similar to the explanation suggested by Glautier, Elgueta, and Nelson (2013) for why extinction across multiple contexts results in less responding than extinction in a single context. According to these authors, conducting extinction across multiple contexts resulted in less inhibition being conditioned to the context relative to when extinction was conducted in a single context. Consequently, the extinction context provided less protection from extinction compared to a group that received extinction in only one context. Thus, in the present experiment, conducting acquisition across multiple contexts might result in stronger renewal due to the target CS-US association being stronger (as predicted by a total error correction theory, such as Rescorla-Wagner, 1972) or having stronger behavioural control (as predicted by a response competition theory, such as the extended comparator hypothesis (Denniston, Savastano, & Miller, 2001).

Another possibility is that acquisition across multiple contexts resulted in slower extinction learning relative to acquisition in a single context. Lucke et al. (2013) investigated whether the informational value of the acquisition context affects subsequent extinction learning and ABA renewal. Participants learned an association between a cue and an outcome in a predictive learning task. For some participants, the context was relevant for solving a discrimination between the target cue and the outcome, and for other participants, the context was irrelevant; the cue was reinforced consistently across two contexts. They observed faster extinction in a novel context when the acquisition contexts were relevant to the discrimination compared to when they were irrelevant. The present experiment does not consist of a discrimination task. However, one could argue that pairing the CS with the US consistently across multiple contexts (similar to the Lucke et al. design) made the contexts less relevant to predicting the outcome compared to when the CS was paired with the US in only a single context. This is because the contexts changed but the contingency between the

CS and US remained the same. In Group A1E1, the context was relatively more informative than the contexts in Group A3E1 since the CS was always and only reinforced in that context. Thus, faster extinction should occur in Group A1E1 compared to Group A3E1, which can explain the greater expectation observed at test following acquisition in multiple contexts.

It should be noted that in the latter two proposed mechanisms, increased CS-US strength or increased CS behavioural control and slower extinction following acquisition in irrelevant contexts, are only speculative, and certainly more investigation is needed to ascertain their viability. Further research into any of these proposed mechanisms is required to better understand the effect of acquisition in multiple contexts.

8.2 Extinction in multiple contexts

The results from this study add to a body of research that have investigated extinction in multiple contexts. Using a conditioned expectation task, Group A1E3 reported lower recovery from extinction compared to Group A1E1 at test. These results are consistent with several studies (e.g., Gonzalez et al., 2016b; Krisch et al., 2018; Miguez et al., 2014b; Olatunji et al., 2017b). As research on extinction in multiple contexts was already discussed at length in Chapter 4 of this thesis, these studies will only be reviewed briefly here. There is a considerable amount of research on non-human animal models, particularly rats. Gunther et al. (1998) was the first study to experimentally investigate multiple context extinction in rats. Using a conditioned suppression task, rats acquired a tone-shock association in one context. Subsequently, half of the rats were extinguished in one context, and the other half received comparable extinction in three contexts. They found an attenuation of ABC renewal in the multiple extinction context group when compared to the single extinction context group. This effect was also observed in ABA renewal using a taste aversion paradigm (Chelonis et al., 1999). Rats first experienced a single pairing of sucrose with lithium chloride in one context,

followed by extinction in one or three contexts. A reduction in ABA renewal was observed in rats that experience multiple context extinction compared to single context.

Similar results of attenuation of ABC and ABA renewal have been found in human samples. For example, Neumann (2006) used a gamified conditioned suppression task (i.e., the Martian task) and found attenuation for both ABC and ABA renewal following multiple context extinction in a non-clinical student population. Later studies found similar results for both ABC renewal (e.g., Glautier et al., 2013a; Viar-Paxton & Olatunji, 2012) and ABA renewal (e.g., Bandarian-Balooch & Neumann, 2011; Krisch et al., 2018) in non-clinical samples. These results are generally consistent with animal studies supporting the beneficial manipulation of extinction in multiple contexts. These results motivated researchers to investigate the obvious implications of such an enhancement to extinction on sub-clinical and clinical samples. For example, Vansteenwegen et al. (2007a) presented sub-clinical participants, with spider anxiety, videos of spiders in different locations of a house. Comparing those that were exposed to single video location, those that were exposed to multiple video locations reported lower ABC renewal when tested in a novel context. A more recent study employing similar methodology on sub-clinical snake fearful participants also found similar benefits of extinction in multiple contexts (Olatunji et al., 2017a). In a clinical population, Shiban and colleagues used a multiple virtual reality (VR) context exposure paradigm on patients with spider phobia. Following exposure to virtual contexts, those that experienced multiple contexts reported lower fear ratings and higher behavioural approach scores compared to those that experienced a single context exposure (Shiban et al., 2013b; Shiban et al., 2015a).

The method for manipulating contexts in humans is quite varied. Manipulating contexts for animals generally consists of varying cues such as lights, odours and different dimension of chambers (e.g., Gunther et al., 1998; Laborda & Miller, 2013b; Miguez et al.,

2014a), and the tactile features of the chamber (e.g., walls and floors) (e.g., Bernal-Gamboa et al., 2017b; Bouton et al., 2006; Gonzalez et al., 2016a; Thomas et al., 2009). For humans, context effects have been studied using auditory and visual cues (e.g., Bandarian-Balooch & Neumann, 2011; Neumann et al., 2007), pictures and video clips (e.g., Balooch et al., 2012; Krisch et al., 2018; Olatunji et al., 2017b; Pineño & Miller, 2004; Vansteenwegen et al., 2007b) and virtual-reality (e.g., Dunsmoor et al., 2014a; Shiban et al., 2013b; Shiban et al., 2015a).

Although most of these studies have generally found support for multiple context extinction using the abovementioned contextual manipulations, two studies have notably not observed attenuation of renewal. For example, Neumann et al. (2007) used different coloured lights and acoustic cues (e.g., green light and bass drum, red light and short whistle) to create different contexts within a single room. Since participants were seated reclined within the same physical room at all times, this may not be sufficiently perceived as different contexts by human participants. In another study, MacKillop and Lisman (2008b) used different physical rooms but failed to show a context effect on reactivity to alcohol cues. However, the study used the same imaginal scenarios during exposure to alcohol cues. Thus, despite conducting the experiment in different physical contexts, the actual context of exposure (i.e., imagined scene) may have been the same. Moreover, the rooms were all of the same size and located in the same building. Although they were decorated differently, the contexts remained rather artificial. Although experimental checks for context manipulation were conducted, this may not properly represent the assessment of the imaginal scene, which is largely out of experimental control or how different each context was perceived to be from each other. The difficulties in investigating this effect therefore lie in not only providing sufficient contextual cues to be perceived as different contexts, it must fulfil experimental control for empirical rigor.

One way to overcome these limitations is to use virtual reality (VR). VR provides a more immersive experience in context exposure as the program may include both high quality audio and visual stimuli. In addition, program specifications may be provided by the experimenter to provide high experimenter control throughout the VR experience. To date, only three other studies have explored the use of VR in multiple context extinction. Dunsmoor et al. (2014b) were one of the first to use VR technology to explore the effects of multiple context extinction renewal. In a human fear conditioning paradigm, the researchers found that the group that experiences multiple virtual context extinction reported attenuated renewal compared to the group that experienced one context. Shiban and colleagues conducted the two studies that found success in enhancement of extinction through multiple virtual contexts on reducing spider fear in a clinical sample (Shiban et al., 2013b; Shiban et al., 2015a). The current study is only the fourth to demonstrate successful attenuation of renewal in humans using VR. Notably, compared to past studies, this study had improved graphical fidelity, a customized interactive VR software, and more unique virtual contexts.

The underlying theoretical mechanism for why extinction in multiple contexts results in less recovery from extinction parallels closely with the discussion above regarding acquisition in multiple contexts. That is, most researchers agree that this treatment increases generalization of that learning to new contexts. According to the perspective, learning across multiple contexts reduces context dependency for retrieval of that information. Put another way, training across multiple contexts increases the number of contextual cues that become associated with the target CS-US association. Thus, extinction in multiple contexts leads to these contextual cues increasing generalization of responding to the novel test context. This leads to an increased likelihood of successfully retrieving the extinction memory allowing for retroactive interference of the first learned association.

8.3 Limitations

Limitations of this study will first be discussed with respect to design variables. Then limitations of using VR in research will be discussed. Most notably, the groups were confounded in terms of the number of trials. Groups that received acquisition in three contexts experienced three 4-second trials, whereas groups that received acquisition in one context experienced a single 12-second trial. The same is true for extinction. Thus, while the overall exposure to the cue and the outcome was equated between groups, as was context exposure and experience in each context, the number of trials was confounded between groups. This was done because in the planning stage, it was decided that asking participants to search for three of the same objects in the same environment might be confusing. Also, it would have either required adding more filler cues to all contexts for all groups in order for the primary acquisition context (Context A) to be associated with both reinforcement and nonreinforcement, which would have substantially increased the experiment duration and complications to programming, or it would mean that Context A is only associated with reinforced trials in Groups A1E1 and A1E3, which was also not ideal. However, not equating trial numbers could have affected the strength of conditioning, based on results from Prenoveau et al. (2013), who observed more extinction after several short trials relative to a group that received comparable extinction but in fewer longer trials. Thus, it is possible that receiving more acquisition trials resulted in better excitatory conditioning and hence more renewal, and more extinction trials resulted in better inhibitory learning and less renewal. This could potentially explain the present results.

Another confound was that the training history was not equated across all of the acquisition contexts. That is, in groups that received acquisition across three contexts (A3E1 and A3E3), each context was associated with reinforcement and non-reinforcement due to the filler cues. However, in groups that received acquisition in only one context (A1E1 and

A1E3), Contexts B and C were only associated with non-reinforcement. This could have affected how the contexts were perceived or to what extent they acquired any associative strength. However, training another cue with the same US in the other contexts might have led to unwanted generalization of learning about the target CS-US association to multiple contexts. Thus, this confound was allowed in order to ensure better distinctiveness between the contexts and context specificity of learning in Groups A1E1 and A1E3.

Another design limitation was the lack of a follow-up test. Thus, this experiment is unable to speak to long-term effects of training across multiple contexts. Of all of the studies that have conducted extinction over multiple contexts, only four human studies have conducted a follow-up test (e.g., Bandarian-Balooch et al., 2015; Dunsmoor et al., 2014b; Shiban et al., 2015a; Viar-Paxton & Olatunji, 2012). Dunsmoor et al. (2014) observed no effect on spontaneous recovery 24 hours post extinction, only mild effects on ABC renewal and a stronger effect on reinstatement. When the delay between test and follow-up was one week, Viar-Paxton and Olatunji (2012) observed a reduction in self-reported disgust-related distress, and this was further reduced at the two-week follow-up. Bandarian-Balooch et al. (2015) studied a clinical population. The benefits of extinction in multiple contexts were maintained one week and one month after the end of extinction. In contrast, Shiban et al. (2015) reported no attenuation of skin conductance responses at a 15-day follow-up test.

Another potential limitation of the study may be the smaller than expected sample size. Past studies in human multiple context extinction, with four groups or less, have had less than sixty participants (e.g., Bandarian-Balooch et al., 2015; Dunsmoor et al., 2014b; Shiban et al., 2015a; Viar-Paxton & Olatunji, 2012). This was the basis for the target of sixty participants for the current study. In addition, as this was a pioneering study in human acquisition over multiple context, it was challenging to determine an adequate sample size. Furthermore, logistical restrictions made recruitment of potential participants exponentially

more difficult. Using G*power to calculate (Faul, Erdfelder, Lang, & Buchner, 2007), the intended sample size using a power of .8, was 120. Data was gathered from 60 participants. Post-hoc power analysis of the study found large main effects for acquisition (*f = 0.53,* power = .99*)*, and extinction (*f* = 0.65, power = >.99), while the interaction effect was found to be medium (*f* = 0.21, power = 0.49). Overall, this suggests that the sample size for the study was acceptable.

One drawback of employing an interactive VR program is potential motion sickness. Specifically, this study required significant movement in the virtual space compared to previous studies. This can result in a stronger experience of sensory conflict resulting in "cybersickness" (i.e., VR motion sickness). Although participants were asked to stand up or sit down depending on their individual experience of nausea or personal comfort and were also given the option to stop the experiment should they feel unwell, some participants required longer breaks between experimental phases due to significant nausea. This also contributed to the consideration towards not controlling for the total amount of time spent in each context. As each participant varied in their ability to find the objects in each context, it was not possible to control for the amount of time spent in each context. Additionally, due to the nature of the virtual contexts some resulted in faster search times compared to others. Accounting for both of these variabilities was not possible for this interactive VR program.

It should be noted that this study utilized a custom VR program created by an external contractor specialized in using VR for creative digital media. As such, the graphical resolution and fidelity of the program surpasses most VR studies in multiple context learning to date. In addition, the VR headset used was a consumer grade headset that has high technological specifications. The combination of high-quality software and hardware provides the user with a better immersive experience. However, this set up may be challenging for other researchers to replicate without sources of funding to obtain the

required high specifications hardware nor access to quality external contractors with similar level of technical expertise in software development.

Finally, while the program was configured to have a significant amount of experimental control, certain difficulties and instabilities occurred during the study. These program bugs were out of the researcher's abilities to troubleshoot and thus, led to some contexts not having an equated training history for acquisition. For example, due to graphical error, the virtual spider's legs were sometimes visible outside of the cup when it was chosen as an acquisition context. Thus, Context 6 was used less as an acquisition context. Another difficulty was unknown errors of the technological hardware, which resulted in the program crashing or stalling. During such instances, the experiment resets which allows certain participants to experience more acquisition and extinction trials than others. Anyone who wishes to pursue this type of research program using VR will likely need an experienced computer technician in-house.

8.4 Future Directions

8.4.1 Mechanisms underlying multiple context learning

Future research should investigate the underlying mechanism of learning across multiple contexts, particularly acquisition across multiple contexts. As mentioned in section 8.1, there are some likely mechanisms that underlie this form of learning. It is possible that learning across multiple contexts reduces context dependency leading to generalization to novel contexts. This idea had been theorized by others previously (Todd et al., 2012; Trask & Bouton, 2018). Increasing the number of contexts allows more contextual elements to become associated with the target association, thus becoming more capable of priming the target association at testing (Miller & Escorbar, 2002). Another possibility is a generalization approach via configured cues (e.g., Pearce, 1987, 1994). Through this mechanism, the CS and contextual elements are configured together into a single representation. Thus, learning

across multiple contexts creates multiple configured representations that generalize to the test context. Research would need to identify which of these mechanisms (elemental or configural) underlie multiple context acquisition and extinction learning.

Research should also consider investigating whether learning across multiple contexts leads to an increase in the relative strength of the target association due to the diffusion of excitatory or inhibitory contextual strength over multiple contexts, resulting in facilitation of the target cue association (i.e., CS – US or CS – noUS) (e.g., Glautier et al., 2013). This in turn affects whether there is less or more protection from extinction or facilitation of acquisition. Another vein of research is the slowing down of extinction learning due to acquiring associations across multiple contexts. As Lucke et al. (2013) demonstrated, the value of learning obtained from the acquisition contexts can impact subsequent extinction learning. Thus, extinction would always need to surpass acquisitional learning values in order to prevent renewal post-extinction (or post-treatment).

Future research may also investigate if other methods for strengthening extinction (e.g., massive extinction or spaced extinction) would be capable of offsetting the robustness of acquisition in multiple contexts. At this time, only Laborda and Miller (2013b) have combined extinction in multiple contexts with massive extinction. Further research may find a combination of treatment that more reliably attenuate renewal following acquisition in multiple contexts.

The underlying mechanisms may benefit from the use of virtual reality (VR) as a medium of investigation. This study demonstrated that multiple contexts associative learning in humans may be successfully manipulated through the use of virtual contexts. The flexibility of VR would allow for testing if context dependency is reduced overall by introducing more novel virtual contexts at testing. Contextual elements are also more easily added in the virtual contexts which could facilitate assessing if these elements are more

readily priming the target association at test. In addition, relative strength may also be assessed at testing by comparing groups that differed on the number of acquisition contexts. Finally, rate of extinction learning may also be investigated by comparing groups that differ in number of acquisition contexts but share similar number of extinction contexts.

8.4.2 Broader definition of contexts

In addition, future research directions for acquisition in multiple contexts may also consider the other forms of contexts where renewal had been observed such as temporal (Brooks & Bouton, 1994; Luck et al., 2018; Urcelay et al., 2009a) and interoceptive (Schepers & Bouton, 2017, 2019). That is, conducting acquisition across multiple temporal or interoceptive contexts. At the point of writing, there have not been any studies that have attempted acquisition learning across multiple mixed contexts (i.e., spatial and temporal). Thus, it is unclear how such a mixed model of acquisition would have on subsequent extinction training. However, based on the current observed research, it is very possible that this would create a significantly more robust first-learned association that potentially creates an enduring memory of the association.

Furthering our understanding of context effects should take into consideration different aspects of contexts, apart from spatial, interoceptive and temporal (i.e., cognitive, social and cultural). While spatial (e.g., Bandarian-Balooch et al., 2015; Gunther et al., 1998; MacKillop & Lisman, 2008b), interoceptive (e.g., Saunders et al., 2014; Schepers & Bouton, 2017; Tsao & Craske, 2000) and temporal (eg., Brooks & Bouton, 1994; Luck et al., 2018; Urcelay et al., 2009a) have been used as context manipulations, there may be interaction between the other contexts that compound learning further in humans. For example, an experience of stress (interoceptive context), triggering a negative thought (cognitive context) in the presence of an extinguished CS within a novel context may result in a renewal of the fear response which leads to a generalization of the fear to the new context. A significant

hurdle would be to successfully induce certain contextual states such as specific thoughts (cognitive) or stress (interoceptive) within certain physical contexts and investigate the interaction of human extinction learning across multiple categories of contexts.

The broader definition of context as suggested here, has also been recently suggested as an important step to account for additional background information about contextual cues that may be guiding behaviour (Javanbakht, 2018). Indeed, Javanbakht has attempted to provide the first encapsulating theory unifying neurobiological mechanisms, with a broad contextual definition (Maren et al., 2013), and mechanisms of psychotherapy. The author suggests that the social context may be seen as the relationship between a patient and the therapist, and connecting to a patient through technology (i.e., telepsychiatry, provision of care through telecommunication technology) in their in vivo context, where feared object may be present, may provide an opportunity for context and cue generalization. This would be conceptually a broad definition of multiple context extinction learning.

8.4.3 Virtual Reality (VR) and Augmented Reality (AR)

A significant concern in future research using VR is the need for better graphics and more detailed experimental control. Unless the program can be fully created by the researcher or through inter-departmental collaborations within the university, hiring external contractors will require significant financial investments. The costs for implementing high fidelity graphical assets as well as experimental control requires significant time and efforts from visual designers and software programmers. However, with the consistent improvements in technology and the increase in demand for such programs, researchers may find contractors with a number of design assets ready to be implemented, reducing financial strain. Researchers should also expect to work in close collaboration with the programmers to ensure that the requirements for experimental control are met. It will be advantageous for

future researchers to obtain some background knowledge in software programming or experience with VR programs.

AR has not been used as a medium for studying multiple contexts learning. AR combines real-world environments with digital overlay viewed from a mobile screen with the use of a camera to facilitate real-time integration. The advantage of AR is the overlay of graphical stimuli over the real-world contexts. This technology may be more helpful in laboratory research using clinical patients as certain specific physical contexts associated with anxiety or phobia may be used in the extinction training. For example, performing the experiment at gardens, parks or streets, captured by a high-resolution camera and displayed through a headset, could be overlaid with a digital spider as a form of AR exposure training across multiple similar contexts. In this fashion, researchers and clinicians may further investigate specific contextual cues that signal to patients with specific phobias that a fearful stimulus may appear. A further augmentation to this may be the incorporation of eye tracking technology within the headset. The blending of the CS-US association in AR will be an unprecedented step into helping researchers better understand human contextual learning.

VR exposure therapy (VRET) has been utilized since the early 2000s. VRET has proved itself to be an effective adjunct to in-vivo exposure, with efficacy found in treating arachnophobia, aviophobia, claustrophobia, and others (see Opris et al., 2012). On the other hand, AR has not been as extensively implemented. AR exposure therapy (ARET) was first used by Botella et al. (2005) to treat cockroach phobia. Follow-up studies utilizing ARET on cockroach phobia also appear to have encouraging results (Botella et al., 2010a; Botella et al., 2011; Wrzesien, Burkhardt, Alcañiz Raya, & Botella, 2011). However, these studies had small sample sizes and lacked control groups.

It may be helpful to see both forms of technology as on a hierarchal spectrum in exposure therapy for treating specific phobias. Most exposure treatment would begin with an

anxiety hierarchy, with the in-vivo exposure being the final step (e.g., touching a spider, or looking down a tall building, or taking the lift). Therapy may begin with imaginal followed by pictures then graduating to VR, eventually moving to AR and finally in-vivo. In addition, during each of these exposure paradigms, the intentional incorporation of exposure over cognitive and interoceptive contexts may further augment the efficacy of exposure therapy across multiple contexts.

8.4.4 Implementation in clinical settings.

Much more research would need to be focused on the clinical population to better determine the practical and clinical aspects of extinction over multiple contexts whether through the use of VR, in-vivo or a combination of both. To date, only about six studies have attempted extinction in multiple contexts with clinical or sub-clinical populations (e.g., Bandarian-Balooch et al., 2015; MacKillop & Lisman, 2008b; Olatunji et al., 2017a; Shiban et al., 2013b; Shiban et al., 2015a; Vansteenwegen et al., 2007a). Future studies may need to consider the practical aspects of such a protocol in clinical settings where most therapy actually takes place. Treatment should also be carried out by qualified practitioners as this would inform researchers on the feasibility and logistical challenges that may present themselves in such settings. Overall, the main goal is to discover strategies in which this form of exposure manipulation may ultimately provide better treatment maintenance for patients.

8.5 Clinical implications of current study

8.5.1 Aetiology of Specific Phobias and other disorders

The results of the current study help to provide some explanation of the aetiology of some specific phobias and other anxiety disorders. It also provides some insight into why some individuals relapse after treatment whereas others do not. If the fear association is acquired across multiple contexts (which can include temporal or interoceptive contexts) (Bouton, Mineka, & Barlow, 2001a), this would create a very strong and dynamic associative

history between the CS and US. The encoded association may include the physical spatial context in addition to temporal contexts, interoceptive contexts, cognitive contexts, and social/cultural contexts (Maren, Phan, & Liberzon, 2013a). It is possible that specific phobias and other anxiety disorders may always be acquired over multiple contexts.

There is difficulty in identifying which contexts may have contributed to the acquisition of a phobia. A direct conditioning account (e.g., CS – US) may not always be recalled (Davey, 1991; Menzies & Clarke, 1993b). Yet, some have recalled multiple conditioning pathways (i.e., direct experience, vicarious, informational) (Kheriaty, Kleinknecht, & Hyman Jr, 1999). Researchers often do not collect data on the context information; however, it may be assumed that each learning pathway is a context of learning. As discussed earlier, broadening the definition of contexts, as specified by Maren et al. (2013a), helps researchers better understand aversive fearful experiences. Each experience would have occurred in a spatial, temporal and interoceptive context, while negative informational pathways would involve both the social and cognitive contexts in learning about the fearful stimuli.

Multiple negative experiences over multiple broad contexts can contribute to the development of a phobia. A case study of a patient with choking phobia, described by Scemes, Wielenska, Savoia, and Bernik (2009), found multiple instances of aversive experiences leading up to the development of the phobia-related dysfunction. The patient first experienced a choking episode which led to food avoidance. This was further aggravated by another choking episode later on. Five years later, her family and friends shared several frightening stories of choking, which lead to a dramatic increase in food avoidance. Over time, her body weight decreased rapidly, and she eventually developed agoraphobic symptoms. In this case study, multiple pathways of fear acquisition occurring over a mixture of direct conditioning experiences and negative informational transfer are observed. Each

direct conditioning experience contains a spatial, temporal and interoceptive context. The association of food and choking also becomes part of a cognitive context that is an expectation of choking when eating. Additionally, her friends and family sharing negative information becomes associated with a social context. All of which reinforces a conditioned aversion to food because of a fear of choking.

In another example, Wald (2004) interviewed five patients on their history of fear of driving. Four patients reported a history of traumatic experiences which included multiple vehicle accidents or close calls. Additionally, other experiences of fear were acquired vicariously, being criticized while driving, and through negative information by friends and family. The patients reported an increase in driving avoidance and phobic responses only after multiple negative experiences rather than after a single traumatic experience. In these cases, the traumatic experiences occupy both spatial and temporal contexts. The car provides an immediate spatial context, while the place the patient was driving provides an additional secondary spatial context. The temporal context may be the time of day and traffic flow as well (e.g., morning traffic being busier and contributed to a traumatic experience). Each event contributes to the cognitive context (Maren et al., 2013a) in that every time they consider driving, it triggers an expectation of an aversive outcome (e.g., I am driving in the morning, I will likely get into an accident). Following an accident, the stress and anxiety of driving becomes an interoceptive context for fear activation as well. Therefore, there is a cascade of contextual activations prior to negative information transfer from the social context.

Acquisition of experiences across multiple contexts can also have an impact on other aspects of psychopathology. Mrug, Loosier, and Windle (2008) found in a sample of 601 adolescents, those who were exposed to violence across three spatial contexts of home, school and community were more likely to experience anxiety, depression and aggression. While the study did not find an effect for multiple contexts, the cumulative experience across

multiple contexts was strongly predictive of maladjustment. Similar to experiences of trauma, victims who have experienced multiple traumas also present with more symptoms than single trauma victims (Green et al., 2000). Such traumatic experiences have also been found to increase posttraumatic stress disorder symptomology and depression in adolescents (Suliman et al., 2009). Particularly concerning, Heffner, Blom, and Anthenelli (2011) found a relationship between each traumatic event that evoked fear, helplessness or horror to an increased risk of relapse to drug and alcohol dependence by 46% in women.

From these studies, there is clear evidence for phobias to be acquired across multiple contexts. The current study has demonstrated that acquisition across multiple contexts can have significant negative influences on extinction learning, even if extinction is performed over multiple contexts. That is not to say that conducting extinction across multiple contexts does nothing. There is a clear benefit of this treatment, and even in the current study, this was exemplified by lower conditioned expectation of the US in Group A3E3 relative to Group A3E1. However, the fact that Group A3E3 had stronger renewal compared to Group A1E3 shows that acquisition across multiple contexts largely negated the effect of extinction across multiple contexts. As suggested above, an additional augmentation to this treatment could be to perform it in combination with massive extinction (Laborda & Miller, 2013a), which managed to eliminate renewal completely.

8.5.2 Current treatment

The current study highlights the importance of standard clinical practice to obtain a detailed patient history. The associative learning history of a patient with specific phobia or other forms of anxiety disorders may have important implications on their subsequent response to treatment with exposure-based approaches. Firstly, it may inform the clinician of potential spatial contexts in which previous incidences occurred and other contexts that the fear might have generalized towards. Secondly, a broader history into similar presentations of

fear without the stimulus may reveal the other categories of contexts the patient associated the stimulus with (e.g. cognitive, interoceptive, social/cultural). This broader understanding and more intentional investigation into patient context learning history will inform subsequent treatment. Overall though, more robust treatment effectiveness may be achieved if exposure is conducted across multiple contexts (Craske et al., 2008).

The addition of multiple contexts into current treatment methods for specific phobias may not require substantially more training or equipment. Rather, an understanding of the importance of contexts and an intentional application to provide the experience over multiple contexts. The easiest low-cost implementation would be through imaginal exposure followed by in-vivo. The conscious implementation of such a manipulation may serve to further reduce chances of relapse or renewal.

8.6 Conclusion

The study focused on the investigation of acquisition and extinction learning in humans over multiple contexts. The results demonstrate that the history of learning, specifically those acquired over multiple contexts, lead to a certain robustness that negates extinction learning even if carried out across multiple contexts. It is unclear what mechanism underlies this phenomenon at this time. It is likely that multiple context learning reduces the reliability of the context in the target association. Training in multiple contexts might be increasing the total number of contextual cues associated or it might have created multiple configured cue representation. More research will need to be carried out to determine the mechanisms.

Results from this study also helps provide some explanation for the robustness of specific phobias and other anxiety towards the poor maintenance of treatment gains. Acquiring fear across multiple categories of contexts impacts the subsequent exposure treatment paradigms. More importantly, this study further highlights the importance of

obtaining detailed clinical history from the patient. Obtaining key information about contexts of acquisition helps clinicians to formulate treatment plans that are more targeted and more effective at fear reduction.

Finally, this study has provided some evidence towards the use of VR technology in researching human acquisition learning across multiple contexts. Manipulation of contexts for humans can be challenging and unreliable as humans have a significantly more complex understanding of contexts (i.e., different category of contexts beyond spatial). Current technological advances could provide researchers with more experimental control while maintaining immersiveness and reliability in their studies.

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Health and Safety

* These health & safety warnings are periodically updated for accuracy and completeness. Check *www.oculus.com/warnings* for the latest version.

⚠ WARNING **HEALTH & SAFETY WARNINGS: TO REDUCE THE RISK OF PERSONAL INJURY, DISCOMFORT OR PROPERTY DAMAGE, PLEASE ENSURE THAT ALL USERS OF THE HEADSET READ THE WARNINGS BELOW CAREFULLY BEFORE USING THE HEADSET.**

⚠ WARNING Before Using the Headset:

- Read and follow all setup and operating instructions provided with the headset.
- Review the hardware and software recommendations for use of the headset. Risk of discomfort may increase if recommended hardware and software are not used.
- Your headset and software are not designed for use with any unauthorized device, accessory and/or software. Use of an unauthorized device, accessory and/or software may result in injury to you or others, may cause performance issues or damage to your system and related services.
- To reduce the risk of discomfort, adjust the inter-pupillary distance (IPD) for each user before use of the headset.
- A comfortable virtual reality experience requires an unimpaired sense of motion and balance. Do not use the headset when you are: Tired; need sleep; under the influence of alcohol or drugs; hung-over; have digestive problems; under emotional stress or anxiety; or when suffering from cold, flu, headaches, migraines, or earaches, as this can increase your susceptibility to adverse symptoms.
- We recommend seeing a doctor before using the headset if you are pregnant, elderly, have pre-existing binocular vision abnormalities or psychiatric disorders, or suffer from a heart condition or other serious medical condition.

⚠ WARNING Seizures:

Some people (about 1 in 4000) may have severe dizziness, seizures, eye or muscle twitching or blackouts triggered by light flashes or patterns, and this may occur while they are watching TV, playing video games or experiencing virtual reality, even if they have never had a seizure or blackout before or have no history of seizures or epilepsy. Such seizures are more common in children and young people under the age of 20. Anyone who experiences any of these symptoms should discontinue use of the headset and see a doctor. Anyone who previously has had a seizure, loss of awareness, or other symptom linked to an epileptic condition should see a doctor before using the headset.

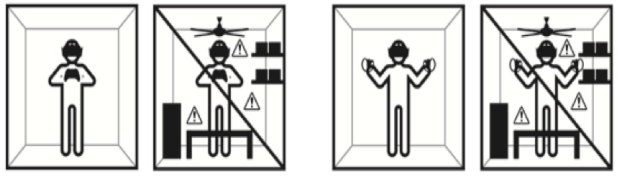
⚠ WARNING Children:

This product should not be used by children under the age of 13, as the headset is not sized for children and improper sizing can lead to discomfort or health effects, and younger children are in a critical period in visual development. Adults should make sure children (age 13 and older) use the headset in accordance with these health and safety warnings including making sure the headset is used as described in the Before Using the Headset section and the Safe Environment section. Adults should monitor children (age 13 and older) who are using or have used the headset for any of the symptoms described in these health and safety warnings (including those described under the Discomfort and Repetitive Stress Injury sections), and should limit the time children spend using the headset and ensure they take breaks during use. Prolonged use should be avoided, as this could negatively impact hand-eye coordination, balance, and multi-tasking ability. Adults should monitor children closely during and after use of the headset for any decrease in these abilities.

⚠ WARNING General Precautions:

To reduce the risk of injury or discomfort you should always follow these instructions and observe these precautions while using the headset:

- **Use Only In A Safe Environment:** The headset produces an immersive virtual reality experience that distracts you from and completely blocks your view of your actual surroundings.
  - **Always be aware of your surroundings before beginning use and while using the headset. Use caution to avoid injury.**
  - Use of the headset may cause loss of balance.
    - Remember that the objects you see in the virtual environment do not exist in the real environment, so don't sit or stand on them or use them for support.
    - **Remain seated unless your game or content experience requires standing.**



- Serious injuries can occur from tripping, running into or striking walls, furniture or other objects, so clear an area for safe use before using the headset.
- Take special care to ensure that you are not near other people, objects, stairs, balconies, open doorways, windows, furniture, open flames, ceiling fans or light fixtures or other items that you can bump into or knock down when using—or immediately after using—the headset.
- Remove any tripping hazards from the area before using the headset.
- Remember that while using the headset you may be unaware that people and pets may enter your immediate area.
- Do not handle sharp or otherwise dangerous objects while using the headset.
- Never wear the headset in situations that require attention, such as walking, bicycling, or driving.

- Make sure the headset is level and secured comfortably on your head, and that you see a single, clear image.
- Make sure the headset and sensor cables are not choking or tripping hazards.
- Ease into the use of the headset to allow your body to adjust; use for only a few minutes at a time at first, and only increase the amount of time using the headset gradually as you grow accustomed to virtual reality. Looking around and using the input device when first entering virtual reality can help you adjust to any small differences between your real-world movements and the resulting virtual reality experience.
- Do not use the headset while in a moving vehicle such as a car, bus, or train, as this can increase your susceptibility to adverse symptoms.
- Take at least a 10 to 15 minute break every 30 minutes, even if you don't think you need it. Each person is different, so take more frequent and longer breaks if you feel discomfort. You should decide what works best for you.
- Listening to sound at high volumes can cause irreparable damage to your hearing. Background noise, as well as continued exposure to high volume levels, can make sounds seem quieter than they actually are. Due to the immersive nature of the virtual reality experience, do not use the headset with the sound at a high volume so that you can maintain awareness of your surroundings and reduce the risk of hearing damage.

⚠ WARNING Discomfort

- **Immediately discontinue using the headset if any of the following symptoms are experienced: seizures; loss of awareness; eye strain; eye or muscle twitching; involuntary movements; altered, blurred, or double vision or other visual abnormalities; dizziness; disorientation; impaired balance; impaired hand-eye coordination; excessive sweating; increased salivation; nausea; lightheadedness; discomfort or pain in the head or eyes; drowsiness; fatigue; or any symptoms similar to motion sickness.**
- **Just as with the symptoms people can experience after they disembark a cruise ship, symptoms of virtual reality exposure can persist and become more apparent hours after use. These post-use symptoms can include the symptoms above, as well as excessive drowsiness and decreased ability to multi-task. These symptoms may put you at an increased risk of injury when engaging in normal activities in the real world.**
- Do not drive, operate machinery, or engage in other visually or physically demanding activities that have potentially serious consequences (i.e., activities in which experiencing any symptoms could lead to death, personal injury, or damage to property), or other activities that require unimpaired balance and hand-eye coordination (such as playing sports or riding a bicycle, etc.) until you have fully recovered from any symptoms.

- Do not use the headset until all symptoms have completely subsided for several hours. Make sure you have properly configured the headset before resuming use.
- Be mindful of the type of content that you were using prior to the onset of any symptoms because you may be more prone to symptoms based upon the content being used.
- See a doctor if you have serious and/or persistent symptoms.

⚠ WARNING Repetitive Stress Injury:

Using the device can make your muscles, joints or skin hurt. If any part of your body becomes tired or sore while using the headset or its components, or if you feel symptoms such as tingling, numbness, burning or stiffness, stop and rest for several hours before using it again. If you continue to have any of the above symptoms or other discomfort during or after use, stop use and see a doctor.

⚠ WARNING Interference with Medical Devices

The Headset, Sensor, and Remote contain magnets or components that emit radio waves, which could affect the operation of nearby electronics, including cardiac pacemakers, hearing aids and defibrillators. If you have a pacemaker or other implanted medical device, do not use the headset without first consulting your doctor or the manufacturer of your medical device. Maintain a safe distance between the headset and your medical devices, and stop using the headset if you observe a persistent interference with your medical device.

⚠ WARNING Remote

The remote supplied with your headset contains a coin/button cell battery.

- CHOKING HAZARD. The simple input device is not a toy. It contains a battery, which is a small part. Keep away from children under 3.
- DO NOT INGEST BATTERY. CHEMICAL BURN HAZARD
- If the coin/button cell battery is swallowed, it can cause severe internal burns and potential perforation of esophagus in just 2 hours and can lead to death.
- If you think batteries might have been swallowed or placed inside any part of the body, seek medical attention, and have your doctor call the battery ingestion hotline at (202)625-3333.
- Keep new and used batteries away from children. If the battery compartment does not close securely, stop using the product and keep it away from children.
- Keep in original package until ready to use. Dispose of used batteries promptly.
- Risk of fire. Batteries can explode or leak if installed backwards, disassembled, charged, crushed, missed with used or other battery types, or exposed to fire or high temperature.
- Warning required by the State of California: Perchlorate Material - special handling may apply, see *www.dtsc.ca.gov/hazardouswaste/perchlorate*.
- Refer to *www.oculus.com/support* for proper maintenance, replacement, and disposal of batteries.

⚠ WARNING Controller

- Your headset may have come with a third-party controller, consult the manufacturer for health and safety warnings for the controller.
- If available, use wrist straps with controllers to secure the controller to your wrist when in use.
- Do not install batteries backwards, charge, put in fire or mix with used or other battery types as this may result in battery damage or leak causing injuries. Replace all batteries at the same time.
- Reference Microsoft Xbox controller User Manual for proper maintenance and handling.

⚠ WARNING Electrical Shock

To reduce risk of electric shock:

- Do not modify or open any of the components provided.
- Do not use the product if any cable is damaged or any wires are exposed.

⚠ WARNING CA Prop 65

This product contains a chemical known to the State of California to cause cancer and birth defects or other reproductive harm.

⚠ CAUTION Damaged or Broken Device

- Do not use your device if any part is broken or damaged.
- Do not attempt to repair any part of your device yourself. Repairs should only be made by an authorized servicer.

⚠ CAUTION Contagious Conditions

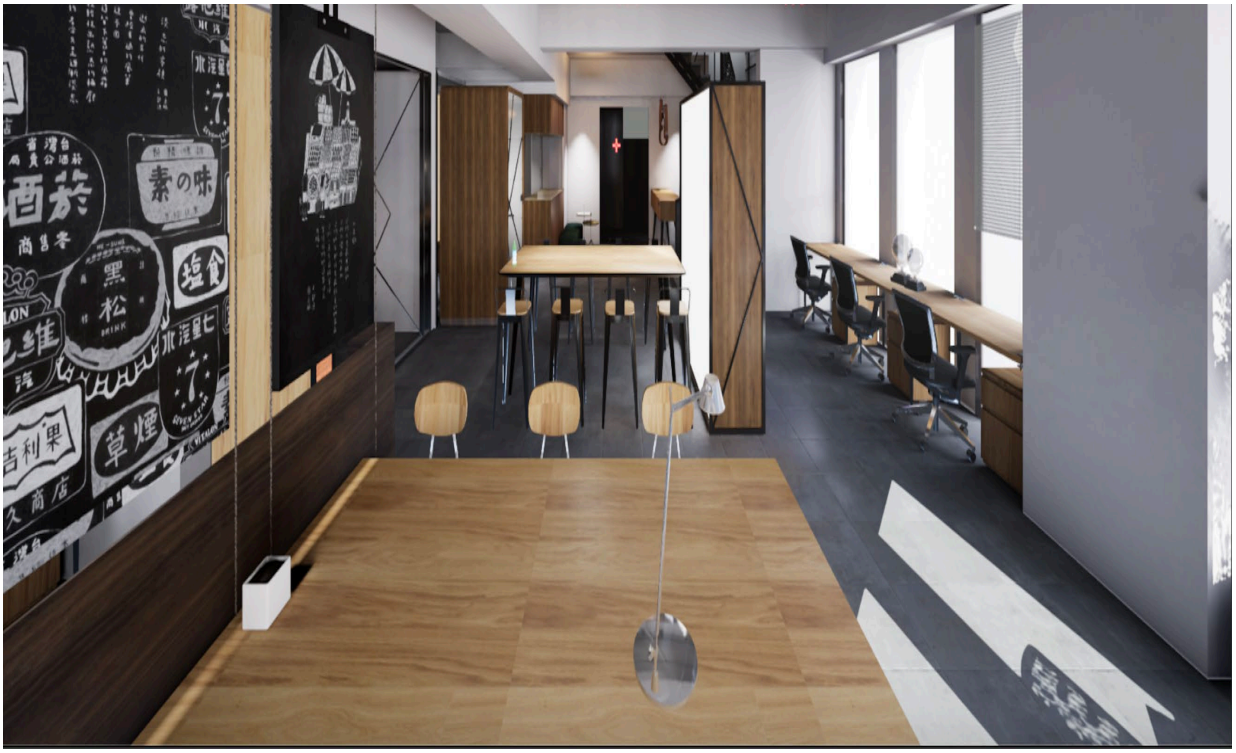
To avoid transferring contagious conditions (like pink eye), do not share the headset with persons with contagious conditions, infections or diseases, particularly of the eyes, skin or scalp. The headset should be cleaned between each use with skin-friendly non-alcoholic antibacterial wipes and with a dry microfiber cloth for the lenses.

⚠ CAUTION Skin Irritation

The headset is worn next to your skin and scalp. Stop using the headset if you notice swelling, itchiness, skin irritation or other skin reactions. If symptoms persist, contact a doctor.

APPENDIX B

Examples of VR contexts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