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Overcoming Avoidance in Anxiety Disorders: The Contributions of Pavlovian and Operant Avoidance Extinction Methods

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Highlights

- Narrative review of extinction of avoidance methods in humans.
- Operant and Pavlovian avoidance extinction has implications for clinical disorders.
- Further research is needed on the validity of avoidance extinction.

Abstract

Avoidance is generally adaptive, yet excessive threat-avoidance may soon become maladaptive and lead to functional impairment and psychopathology. Laboratory-based treatment research has provided important insights about the acquisition, maintenance, and extinction of maladaptive avoidance. Despite this, laboratory research on avoidance learning and extinction in humans is relatively underdeveloped. A better understanding of avoidance extinction methods has implications for basic research with humans and the development of treatment interventions aimed at replacing maladaptive behavior with an adaptive, functional repertoire. The present article reviews, for the first time, the use of the term *extinction* in human research on avoidance, contrasts existing Pavlovian and operant approaches to the extinction of avoidance, considers the validity of approaches to avoidance extinction, and suggests a consistent terminology and research gaps for future translational research on anxiety and related disorders.

Key words: fear; avoidance; extinction; humans; anxiety; threat; Pavlovian; operant.

1. Introduction

Faced with potential threat or danger, avoidance is adaptive. For instance, washing one's hands before eating is a healthy way of reducing the likelihood of infection and preventing illness. However, hand-washing is considered maladaptive when it becomes excessive and disconnected from its motivational function (i.e., to avoid germs) and is a common symptom in clinical disorders such as obsessive-compulsive disorder (OCD). Such maladaptive avoidance can lead to impairment and, ultimately, psychopathology because it prevents disconfirming experiences and insulates the individual from learning about the actual outcomes of one's behavior. As a result, avoidance soon becomes the default way of coping with threat, both real and imagined (Dymond & Roche, 2009; Treanor & Barry, 2017).

Avoidance is a key diagnostic feature of anxiety- and stress-related disorders (American Psychiatric Association, 2014) and treatment of maladaptive avoidance is a central focus of exposure therapy, which is the established form of cognitive-behavioral therapy for anxiety related disorders (Barlow, 2002; Hofmann & Hay, 2018; Scheveneels et al., 2016; Vervliet et al., 2013). Basic and clinical research aimed at improving the effectiveness of exposure therapy and preventing relapse has, however, tended to prioritize other learning mechanisms, such as fear extinction learning (Craske et al., 2018). As a result, comparable research on the learning processes responsible for the acquisition and maintenance of maladaptive avoidance is relatively underdeveloped, despite the central status of avoidance in psychopathology (Cain, 2018; Dymond & Roche, 2009; Hofmann & Hay, 2018; Krypotos et al., 2015; LeDoux et al., 2016; Pittig et al., 2018; Treanor & Barry, 2017). Moreover, research on the treatment or extinction of avoidance and its eventual reduction or replacement is lacking.

In research with humans, Pavlovian fear (threat) conditioning paradigms are combined with operant action-consequence learning to model the learning and unlearning (extinction) of clinically relevant fear and avoidance (LeDoux, 2014; LeDoux et al., 2016). In threat conditioning, a threatening stimulus (conditional stimulus, CS+) is followed by an aversive event, such as electric shock (unconditioned stimulus, US), while another, safe stimulus (CS-) is not. Presentations of CS+, but not CS-, come to elicit conditioned fear responses (CR). Avoidance learning may involve overt responses (e.g., a button pressing; called *active avoidance*) or withholding responses (called *passive avoidance*) with the result that responding or not responding minimizes or prevents contact with the scheduled US[1]. In fear extinction learning, the CS+ is no longer followed by the US, and the CR gradually declines. In commonly employed versions of avoidance extinction procedures, the US is withheld and is hence no longer predicted by the CS+. Given this arrangement, although the option to engage in avoidance is available, it is unnecessary because the aversive event is no longer scheduled, and avoidance should ultimately extinguish (i.e., reduce). Avoidance under these arrangements can appear remarkably resistant to extinction as participants continue to actively engage in (excessive) avoidance responding. Other procedures to extinguish avoidance actively prevent avoidance responses from being made and may or may not withhold the US. Generally, despite variability in how avoidance extinction procedures are implemented, the threat conditioning and avoidance learning paradigm has proven excellent validity as a laboratory-based treatment model for anxiety and related disorders (Arnaudova et al., 2017; Dymond et al., 2018; Krypotos et al., 2018; Scheveneels et al., 2016; Vervliet & Raes, 2013; Zuj & Norrholm, 2019).

Insert Figure 1 About Here

[1] The present article is concerned with avoidance extinction procedures in active avoidance learning only.

Leaving aside research on threat conditioning and extinction learning for now, research on avoidance extinction in humans has increased steadily since the late 1970's (Figure 1). Within this literature, two variant procedures for the extinction of avoidance – withholding the US and either permitting or preventing opportunities to engage in avoidance – are commonplace and have been used somewhat interchangeably. However, avoidance is remarkably persistent in extinction in both humans and nonhumans (e.g., Malloy & Levis, 1988; Rodriguez-Romaguera et al., 2016; Solomon et al., 1953; Williams & Levis, 1991) and may even renew fear when the availability of avoidance returns after successful extinction learning has occurred (van Uijen et al., 2018; Vervliet & Indekeu, 2015). Precise reasons for these adverse side-effects of avoidance renewing fear following extinction learning, and the implications for exposure therapy, remain unclear (Treanor & Barry, 2017).

A re-examination of the learning processes involved in the extinction of avoidance is therefore required (Beckers & Craske, 2017; Cain, 2018; Dunsmoor et al., 2015; Dymond & Roche, 2009; Krypotos et al., 2015; LeDoux et al., 2016; Pittig et al., 2018; Riccio & Silvestri, 1973; Treanor & Barry, 2017). Given that nowadays it is accepted avoidance involves an instrumental component (Cain, 2018; LeDoux et al., 2016), then understanding the extinction of avoidance requires a consideration of the contributions of operant conditioning research. Moreover, the relative need for further contemporary work on avoidance extinction contrasts with the literature on fear extinction learning (Craske et al., 2018) which "focuses almost exclusively on removing passive fear reactions, with no inclusion of avoidance in the fear conditioning history or during the extinction test phase. Hence, little is known about the effects of fear extinction on avoidance extinction." (Vervliet & Indekeu, 2015, p.2). In basic research with humans, as the above examples illustrate, extinction of avoidance has been defined interchangeably and studied using different procedures. With this in mind, the present article describes criteria that should be met for extinction of avoidance to be inferred from Pavlovian and operant preparations. Indeed, as discussed later in the review, some (operant) methods for the extinction of avoidance may require the repeated delivery of unavoidable USs until attempts to actively avoid the US cease. That is, conditioned fear responses remain, however avoidance responses cease to occur.

Avoidance behavior, as a form of operant negative reinforcement, may be understood "in terms of transitions between situations as well as by postponement or prevention of events within a situation." (Hineline & Rosales-Ruiz, 2013, p. 502). Methodologically, these "transitions between situations" are arranged during extinction of avoidance procedures by removing, rescheduling or preventing a previously effective contingency between the avoidance response and the aversive event. Avoidance extinction procedures resemble a transition state (Sidman, 1960) between the learning history involved in acquiring avoidance and the arrangement of consequences intended to undermine or overcome avoidance. A better understanding of operant and Pavlovian avoidance extinction procedures therefore not only has implications for basic research on the acquisition, maintenance, and reduction of avoidance but may also speak to treatment interventions aimed at replacing non-adaptive behavior with a more adaptive repertoire (Friman & Dymond, 2018).

Recent reviews of avoidance have focused on issues arising from the historical adaptation of threat conditioning paradigms (Beckers & Craske, 2017; Dymond & Roche, 2009; LeDoux et al., 2016), theoretical developments in avoidance learning only with little attention paid to the extinction of avoidance (Corr, 2013; Krypotos et al., 2015; LeDoux & Daw, 2018), the role of associative learning of avoidance in the treatment of anxiety and related disorders (Arnadouva et al., 2017; Pittig et al., 2018; Treanor & Barry, 2017), behavioral and neuroimaging findings from animal-human translational research (Kirlic et al., 2017), the impact of avoidant-like safety behavior in exposure therapy (Meulders et al.,

2016) and coping with pain (Vlaeyen et al., 2016), and on distinct learning mechanisms such as generalization (Dymond et al., 2015, 2018). No existing review has focused exclusively on avoidance extinction procedures.

The aims of the present paper are therefore to:

A. review the use of the term *extinction* in human research on avoidance.
B. contrast existing Pavlovian and operant approaches to the extinction of avoidance.
C. consider the validity of approaches to avoidance extinction.
D. suggest a consistent terminology and research gaps for future translational work to guide empirical understanding and therapeutic interventions for anxiety and related disorders.

In what follows, the present article will briefly describe avoidance learning research, the various types of avoidance extinction procedures from Pavlovian and operant research with humans and give representative examples of research employing the various procedures to illustrate the methodological features involved. Where relevant, overlap with extinction methods employed in other, related domains will be considered and highlight implications for future research on avoidance extinction and anxiety disorders.

2. Theories of avoidance learning

Historically, avoidance has been studied within associative learning and operant conditioning traditions, and often quite separately (Dymond & Roche, 2009; Higgins & Morris, 1984; Krypotos et al., 2015; LeDoux et al., 2016). Classical work on avoidance has tended to be dominated by two-factor theory which maintains that associative and operant processes combine to produce and maintain avoidance responding (Bolles, 1973; Mowrer, 1947). According to two-factor theory, which stems from both the associative and operant traditions, the CS comes to elicit fear responses following its prior associative pairing with the US (when the avoidance response did not occur). During avoidance learning, the fear elicited by the CS is said to mediate operant avoidance responses that occur in its presence, with avoidance being jointly maintained by escape from the CS (as avoidance usually terminates the CS) and by an immediate reduction in its fear eliciting properties. Two-factor theory has several limitations, not least that it “relies on fear to promote avoidance responding and fear reduction to reinforce it’’ (Lovibond, 2006, p. 119). Doing so places unwarranted explanatory emphasis on a subjective state (fear) to explain overt behavior (Dymond & Roche, 2009; LeDoux et al., 2016). Indeed, historically, some of the problems for two-factor theory stemmed from the observation that “every trial is an extinction trial once avoidance is fully acquired. This should extinguish fear elicited by the CS in and of itself, diminishing the motivation to perform the avoidance response. Yet avoidance persists and is quite resistant to extinction.” (LeDoux et al., 2016; p. 3). Two-factor theory also struggles to explain instances of avoidance where CS termination does not occur and when, more broadly, avoidance serves to only reduce or postpone US frequency, like in free-operant discriminated avoidance procedures (Herrnstein, 1969). This notwithstanding, contemporary accounts of avoidance have sought to develop variations of two-factor theory (e.g., Gray, 1975; Lovibond, 2006; Maia, 2010; Seligman & Johnson, 1973). Other approaches have argued it was a misconception to consider avoidance as nothing more than a Pavlovian response and that avoidance may instead be considered part of a defensive mechanism for surviving threats (LeDoux & Daw, 2018). While such an approach does emphasize the instrumental-operant basis of avoidance, it remains silent on the various avoidance extinction procedures which might follow the adoption of a new approach.

Since the advent of two-factor theory and its variants, the challenge for operant conditioning remains to explain how the absence of an aversive event can function as a negative reinforcer for avoidance responding (Bolles, 1973). That is, how can the non-occurrence of shock maintain ongoing avoidance behavior, and what are the implications for extinction of avoidance? According to the operant approach, avoidance is an instance of negatively reinforced behavior that serves to prevent or reduce contact with an aversive event (US) and, as a result, avoidance increases in future probability (Hineline & Rosales-Ruiz, 2013). Negative reinforcement is a learning process and a widely accepted empirical fact, and the consequences of avoidance may involve prevention, postponement or reduction in intensity/frequency of occurrence of an event. In this way, operant accounts of avoidance can readily explain the (often delayed) reinforcing absence of an aversive event because they do not require “consequences being contiguous with behavior if they are to reinforce it” (Hineline & Rosales-Ruiz, 2013, p. 494). It is therefore noteworthy that most free-operant research on avoidance has employed postponement procedures (Hineline, 1981) with or without warning signals in which avoidance responses prevent or postpone the scheduled aversive event, but in the absence of continued responding, the aversive event still occurs. The explanatory potential of operant theory was further elaborated by classic research on Sidman avoidance (Sidman, 1953) showing that avoidance in the absence of external warning stimuli is maintained by an overall reduction in US-frequency (Herrnstein & Hineline, 1966), a finding further supported by research with humans (Baer, 1961; Hassoulas et al., 2014; Lejuez et al., 1998). In discriminated free-operant avoidance, responding in the presence of a warning signal delays upcoming shock, but responses during a safety signal (or absence of the warning signal) have no effect (Flores et al., 2018). As a result, responding becomes discriminated, occurring at higher rates under stimulus conditions leading to aversive event frequency reduction (see Schöenfeld (1950) and Dinsmoor (1977) for alternative accounts based on the role of temporal or proprioceptive stimuli in unsignaled avoidance).

3. Varieties of avoidance extinction

The persistence of avoidance in extinction is widely noted (Rodriguez-Romaguera et al., 2016; Solomon et al., 1953). For some, *habitual* avoidance is said to persist during extinction because it has become a form of defensive action or habit, disconnected from the initially reinforcing, goal-oriented consequence of aversive event removal (Gillan et al., 2016; LeDoux et al., 2016). However, it is not the aim of the present review to consider the relative merits of such accounts or the role of fear and avoidance in anxiety disorders per se (for reviews, see Krypotos et al. 2015; LeDoux & Daw, 2018; LeDoux et al. 2016; Pittig et al., 2018). Instead, the aim of the present paper is to review the different procedures used in the extinction of avoidance and to remain agnostic on the conceptual status of the persistence of avoidance behavior in humans.

It is noteworthy that an established body of literature exists on the extinction of positively reinforced behavior (Lerman & Iwata, 1996) and Pavlovian associative extinction (Todd et al., 2014; Rescorla, 2001). The same cannot be said about avoidance extinction in humans. The present paper therefore represents the first such attempt to synthesize these disparate literatures. In what follows, varieties of avoidance extinction procedures will be distinguished by the theoretical approach from which they stem: Pavlovian and operant, respectively (see Figure 2).

Insert Figure 2 About Here

3.1 Pavlovian extinction procedures

3.1.1 Fear extinction. Pavlovian extinction procedures, also referred to as *Pavlovian fear extinction* (Krypotos et al., 2015), involve repeatedly presenting a CS in the absence of the US (e.g., shock; see Figure 2). The contingencies surrounding the avoidance response usually remain unchanged from the preceding threat conditioning phase and transitions between phases tend to be unsignaled. Avoidance is therefore still possible, and although all shock is withheld, responding may be considered unnecessary as the US is withheld (Lovibond et al., 2009; Vervliet et al., 2017); when avoidance continues, it is considered resistant to extinction (Solomon et al., 1953). Fear extinction is widely used in human research on avoidance extinction – in fact, it is probably the most common procedure due largely to the fact that it models exposure treatment (Craske et al., 2018; Vervliet et al., 2013).

Fear extinction produces discriminable effects on avoidance acquired with different reinforcement rates (Xia et al., 2017), with partially reinforced avoidance extinguishing more readily than continuously reinforced avoidance. Interestingly, Xia et al. noted avoidance acquired under conditions that were wholly ineffective at preventing shock, extinguished more rapidly than partially reinforced avoidance when shock was subsequently withheld. Other research with humans has employed fear extinction procedures to investigate low-cost avoidance (Vervliet & Indekeu, 2015; Vervliet et al., 2017; Rattel et al., 2017), avoidance generalization (Boyle et al., 2016; Cameron et al., 2015; van Meurs et al., 2014), the impact of safety signal learning (Sheynin et al., 2014) and the effects of US devaluation (Flores et al., 2018; Gillan et al., 2014).

3.1.2 Response prevention with fear extinction. This procedure involves presenting the relevant CS in the absence of the shock US and simultaneously preventing the avoidance response from occurring (Figure 2). Response prevention procedures, often termed extinction with response prevention (ExtRP), may entail either instructing participants that the avoidance response is no longer available or removing the cue for avoidance availability (Vervliet & Indekeu, 2015). Intended to mimic conditions of exposure therapy, specifically exposure plus response prevention (Rodriguez-Romaguera et al., 2016; van den Hout et al., 2011), the response prevention procedure leads to reliable extinction of avoidance in both humans (Vervliet & Indeku, 2015) and nonhumans (Baum, 1966; Rodriguez-Romaguera et al., 2016) and is the most effective treatment for OCD (Olatunji et al., 2010).

Vervliet and Indeku (2015) compared combined response prevention (implemented by either removing the on-screen cue signaling avoidance availability or via instruction), through the removal of an onscreen cue for avoidance availability, and fear extinction with fear extinction only. They found that elevated levels of fear-ratings and avoidance behavior returned when the opportunity to avoid was again available. Overall, it was concluded that “response prevention can renew avoidance behaviors and lead to renewed expectancy of harm” (p.10). Vervliet et al. (2017) employed a similar procedure, referred to as *fear extinction*, but including a response prevention component. They found that avoidance responses readily extinguished in such circumstances and did not recover during delayed extinction recall testing, while SCR, threat expectancy, and relief pleasantness ratings initially increased but decreased during extinction.

In a human fMRI study, Schlund et al. (2015) conducted extinction testing where cues were presented in the absence of the US (point loss) and the opportunity to avoid and found that activity in dorsal anterior cingulate (dACC) and dorsal medial prefrontal cortex (mPFC) mediated avoidance of unavoidable cues. This is particularly noteworthy given that ACC and mPFC may serve opposing functions (Myers & Davis, 2007; Schlund et al., 2016). In Vervliet et al. (2017), under these conditions of response prevention (i.e., removal of the onscreen avoidance cue), the avoidance response could still be made yet was not recorded. In order to track extinction of avoidance and the adoption of clinically relevant patterns of responding, such as a ‘better safe than sorry’ protective mechanism (Lommen et al., 2010), it is advisable to continuously record avoidance behavior during transition.

Roche et al. (2008) found that the symbolic generalization of avoidance extinction was more effective when a generalized cue was extinguished via response prevention (i.e., disabling the operant response key) than when a directly conditioned cue underwent fear extinction (see also, Vervoort et al., 2014). Rattel et al. (2017) employed a variant ExtRP procedure in their study on avoidance costs by withholding shock on trials and preventing one possible avoidance response option involving a short, low-cost option.

3.1.3 Response prevention + US presentation. This procedure involves preventing the occurrence of the avoidance response in the presence of the CS and need not involve withholding the US (see also the sections on operant extinction procedures below). Boeke et al. (2017) recently extended a rodent model of avoidance to the human fMRI environment in which one group of participants (the yoked extinction group) received shock presentations matched to the active avoidance group, but without the opportunity to avoid (i.e., response prevention). This yoked extinction with response prevention procedure lead to enhanced conditioned responding (indexed via skin conductance) to new and existing threats, compared to a procedure where shock was withheld and avoidance possible.

Recently, Krypotos and Engelhard (2018) employed a novelty-based extinction procedure developed by Dunsmoor et al. (2015) and found that it had comparable effects on return of avoidance and explicit fear ratings to standard response prevention and extinction. This approach was centered on the possibly ambiguous role of the CS during ExtRP procedures for avoidance extinction (Bouton, 2002). This account argues that unpaired presentations of the CS establish a new extinction memory (i.e., that the CS is now no longer followed the US) which competes with the initial acquisition memory (i.e., that the CS is followed by the US). The novelty-based extinction procedure involves the CS being followed by a novel, neutral event (e.g., a tone) and is intended to reduce the ambiguity of the CS by the end of the extinction procedure.

3.2 Operant extinction procedures

Three general procedural approaches to the operant extinction of negatively reinforced behavior, like avoidance, may be identified (Lattal et al., 2013).

3.2.1 Removing the aversive event. This operant extinction procedure involves eliminating delivery of the aversive event (e.g., shock) and is usually implemented after training on a free-operant avoidance schedule (Higgins & Morris, 1984). “Shock elimination”

(Lattal et al., 2013, p. 87) procedures like this are, on the one hand, comparable to "continuously delivering all negative-reinforcer-free periods, independent of responding" (p. 87) and, on the other hand, similar to "an abolishing operation in the same way that allowing continuous access to a positive reinforcer abolishes it as a positive reinforcer" (p. 87). In operant research, abolishing operations are a type of motivational operation intended to decrease reinforcer effectiveness (Laraway et al., 2003). Eliminating shock deliveries is thus assumed to undermine the negatively reinforced avoidance response by making it unnecessary.

On the face of it, shock elimination resembles Pavlovian fear extinction procedures described above (Figure 2). The procedure differs however in that it is usually conducted after free-operant avoidance training (signaled or unsignaled) in extensive test sessions where extinction is demonstrated only after continuously-recorded responding decreases to zero or near-zero levels. Generally, findings show that free-operant avoidance responding extinguishes when the negative reinforcer is either temporarily removed or fully eliminated (Ayres et al., 1974).

3.2.2 Making the aversive event noneliminable. This operant extinction method involves eliminating the response-shock removal (cancellation or postponement) contingency (Baum, 1970; Higgins & Morris, 1984); that is, shock occurs regardless of responding (i.e., it is noneliminable; see Figure 2). Operant extinction methods like making the aversive event non-eliminable parallel mechanisms of safety behavior coping where, for instance, a socially anxious individual remains in an aversive social situation and uses avoidance-based safety behaviors to manage their anxiety. In such instances, the feared consequences may still occur (e.g., being spoken to) despite avoidance.

Making shock noneliminable is effective as an extinction procedure because "it engenders maximal change between training and extinction conditions" (Higgins & Morris, 1984, p. 258); responding which previously prevented shock is now followed by shock and should ultimately lead to a reduction in avoidance. Presenting shock at the end of signaled avoidance trials has been shown to extinguish free-operant avoidance responding in rats (Davenport & Olson, 1968; Davenport et al., 1971) and humans (Hefferline et al., 1959; Greene & Sutor, 1971). Baum (1970) recommended behavior therapists consider combining this procedure with response prevention as a “true” way of extinguishing avoidance.

In applied behavior analysis, an extinction method based on continuing to present the negative reinforcer, called escape extinction, is effective at reducing problem behavior such as food refusal (Iwata, 1987; LaRue et al., 2011; Piazza et al., 2003). The negative reinforcer in this case is the removal of food which is the consequence of attempts to refuse or escape from food presentations; decades of applied research shows that if food is continuously presented, and escape prevented, that it leads to sustained reductions in food refusal. To date, however, no studies have employed this procedure in research on avoidance extinction with humans.

Eliminating the response-shock removal contingency and, in effect, replacing it with a response-shock contingency, on the face of it, resembles a punishment procedure but the learning principles involved are quite distinct (Baron, 1991; Dinsmoor, 1977; Estes, 1969; Hineline & Rosales-Ruiz, 2013; Jean-Richard-Dit-Bressel et al., 2018). Punishment occurs when “some specified behavior produces a consequence, resulting in a subsequent decrease in the occurrence of that behavior” (Hineline & Rosales-Ruiz, 2013, p. 483). In punishment, the consequence can take one of two forms: “the presentation of a stimulus or situation (positive punishment) or (b) the removal of a stimulus or situation (negative punishment)” (Hineline & Rosales-Ruiz, 2013, p. 485). Avoidance and punishment appear similar, but they are in fact functionally distinct; the former leads to an increase in the frequency of behavior, while the latter decreases behavior. One coherent means of classifying these seemingly divergent events is by function; that is, what are the functional consequences of behavior that produces or causes an aversive event like shock to occur? Defined in functional terms, a procedure may only be deemed to be an instance of punishment if it results in the suppression of behavior.

This notwithstanding, as an extinction procedure, making shock non-eliminable approximates a form of positive punishment. However, it is in fact contraindicated to superimpose a punishment contingency on a learned, negatively-reinforced behavior like avoidance (Lerman & Vorndran, 2002). Positive punishment is effective at reducing positively reinforced behavior and often occurs in contexts where the reinforcers (e.g., food) and putative punishers (e.g., shock) differ. Presenting response-contingent shock (i.e., implementing a positive punishment procedure) following a period of avoidance learning does involve manipulations of the same aversive consequence (shock), but with ostensibly different functional effects. On the one hand, the absence of shock is negatively reinforcing (and serves to maintain ongoing avoidance), while on the other, the contingent presentation of shock is generally behavior-reductive (punishing) for multiple responses and classes of behavior, not just avoidance. In research on punishment, there is, however, no requirement that the punisher be either formally or functionally related to the reinforcer used in the acquisition of the behavior. In such cases, and for present purposes, superimposing punisher deliveries on previously learned avoidance responses is assumed to have a general reductive effect on the suppression of behavior (cf. Solomon et al., 1953). Such an arrangement is more likely to be used when the functional reinforcers that maintain the behavior are difficult or impossible to identify (Azrin & Holz, 1966; Dinsmoor, 1998).

3.2.3 Response-independent termination of the aversive event. This operant extinction procedure involves arranging shock-free periods independent of responding (Figure 2). Providing response-independent deliveries of the negative reinforcer (i.e., shock-free periods) has been shown to reduce negatively-reinforced responding in pigeons (Hutton & Lewis, 1979) and rats (Coulson et al., 1970) to near-zero levels. Hutton and Lewis (1979) first arranged brief, fixed deliveries of shock and reinforced pigeons' (escape) responding with longer, shock-free periods. Additional shock-free periods were also available independently of responding and it was found that escape responding decreased as response-independent presentations of the negative reinforcer increased. By ensuring responding had no effect on shock delivery, Coulson et al. (1970) observed that free-operant (Sidman) avoidance response rates in rats were less resistant to extinction than under conditions when shock was withheld. That is, response rates were higher during noncontingent shock conditions (referred to as “shock-extinction”), than under no-shock extinction conditions. Presenting noncontingent shock to extinguish avoidance behavior provides “more similarity to the avoidance procedure than extinction by removing the shock completely” (Coulson et al., 1970, p.310) because “shocks … tell the animal that it is in an avoidance situation” (Sidman, 1966, p.485).

The response-independent presentation of the negative reinforcer resembles procedures used in applied behavior analysis with time-based schedules of positively-reinforced behavior to reduce problem behavior (Geiger et al., 2010; Poling & Normand, 1999) and have long histories in operant and Pavlovian conditioning (Skinner, 1938; Rescorla & Skucy, 1969). Noncontingent escape procedures allow periods of escape, usually from instructional demands, by disrupting the response-escape contingency (Vollmer et al., 1995). That is, response-independent (time-based) delivery of escape from aversive tasks undermines the relation between problem behavior and escape from task demands. Making the reinforcer (i.e., breaks from demands) freely available means that the deprivational or motivational states responsible for establishing the effectiveness of the reinforcer in the first place are weakened, and thus reducing the likelihood of the problem behavior from continuing to occur. When that reinforcer is the absence of shock, the motivation for engaging in escape or avoidance is undermined. Viewed as transition states, contingencies like these provide multiple opportunities to establish alternative means of obtaining reinforcement and have implications for therapy by providing other ways of achieving relief and safety (Vervliet et al., 2017).

Research with humans employing response-independent shock presentations is limited. Angelakis and Austin (2018) found that non-contingent presentation of safety signals (cues previously indicating that avoidance was successful) eliminated avoidance behavior in participants scoring high in obsessive compulsive disorder (OCD) traits. Related findings from research on fear extinction has shown that unpaired shocks during extinction strengthened extinction learning compared to normal extinction treatment (Culver et al., 2018; Vervliet et al., 2010). Relatedly, superior fear reduction effects are found with a US habituation procedure compared to traditional extinction (Haesens & Vervliet, 2015). In an ABA renewal paradigm (where the traditional extinction group received trials of the danger cue in context B, whereas the US-habituation group received shock-only trials in context B), it was observed that after US habituation, participants showed ‘renewal' of US-expectancy during danger cue tests in context A, but that skin conductance measures were eliminated across contexts. The relevance of US habituation remains to be seen in the context of research on avoidance extinction with humans.

3.3 Comparison of operant extinction of avoidance procedures

Both eliminating the negative reinforcer and response-independent presentation of the negative reinforcer procedures lead to immediate reductions in responding but also reduced exposure to the negative reinforcer (i.e., periods without shock). This is not necessarily a limitation in the domain of aversive control and translational research aimed at augmenting exposure therapy for anxiety disorders, but it may be a sufficient drawback when the negative reinforcers include typically appetitive (i.e., approach) domains such as food and social attention. Operant extinction by making the negative reinforcer non-eliminable does, by definition, increase exposure to the negative reinforcer and can support the development of adaptive coping responses to deal with the aversive event, although emotional side-effects are also likely (Lattal et al., 2013).

4. The validity of avoidance extinction

Evidence from a range of sources supports the external validity of laboratory-based fear and avoidance learning research models (Pittig et al., 2018; Vervliet & Raes, 2013). Despite this, the validity of experimental research on avoidance extinction, as a determinant of future evidence-based efforts aimed at understanding and treating anxiety disorders, has somewhat lagged behind that of avoidance learning research (Dymond et al., 2018; Pittig et al., 2018). Applying the different, but not necessarily independent, tests of validity (face validity, diagnostic validity, predictive validity, and construct validity) to avoidance extinction procedures may be helpful in identifying gaps in research and highlighting future research directions (Krypotos et al., 2018; Scheveneels et al., 2017).

Face validity is “the degree of phenomenological similarity between the behavior in the model and the symptoms of the disorder” (Vervliet & Raes, 2013, p. 2241; Scheveneels et al., 2017), and avoidance extinction procedures have excellent validity in this regard. *Fear extinction* procedures clearly mimic real-world conditions where threat is absent, yet excessive avoidance persists, while *response prevention* closely resembles therapeutic interventions aimed at overcoming maladaptive avoidance. Furthermore, *response-independent presentations of the aversive event* procedures are akin to situations where the aversive outcome is still experienced despite efforts aimed at ameliorating or preventing contact with the feared event, while *making the aversive event non-eliminable* is also common in coping with anxiety-related disorders (e.g., in panic disorder, panic attacks may still occur despite avoidance; Salkovskis et al., 1991). In terms of diagnostic validity, findings obtained with clinical or subclinical populations should indicate that "the behaviors differ from healthy individuals (in intensity or frequency)" and support the model as a potential diagnostic marker (Vervliet & Raes, 2013, p. 2242). The evidence for the potential diagnostic validity of the model of avoidance extinction is sparse, perhaps due to the fact that there are many disparate approaches to the study of extinction. As a result, little research has been aimed at directly comparing whether or not clinical or sub-clinical groups differ from healthy participants on the acquisition and extinction of avoidance. However, research using a specific procedure (US devaluation) has shown the persistence of well-established, habitual avoidance following devaluation of the aversive event in patients with OCD (Gillan et al., 2014; but see, de Wit et al., 2018) and individuals with high intolerance of uncertainty (Flores et al., 2018).

The application of predictive validity tests means that "performance in the model predicts performance in the disorder" (Vervliet & Raes, 2013, p. 2241). In general, research on avoidance extinction is supportive of the role played by Pavlovian and operant processes in successful exposure therapy for anxiety disorders, however little work has directly tested how such these assumptions apply to the characteristics of anxiety and related disorders. Finally, construct validity refers to "the disease relevance of the methods by which the model is constructed, with a focus on recreating the etiological process in the model" (Vervliet & Raes, 2013, p. 2242). While evidence is supportive of the underlying learning mechanisms involved in fear learning (Pittig et al., 2018), research on the clinical application of avoidance learning and extinction is somewhat limited.

Clearly, much remains to be done in the empirical analysis and clinical application of research on avoidance extinction. The external validity of laboratory-based procedures, such as *fear extinction* and *response prevention* are relatively well-established, although their impact with clinical populations remains under-investigated. The potential of operant methods such as *response-independent presentations of the aversive event* and *making the aversive event non-eliminable* should also be a key focus of future basic and applied research on avoidance extinction, and the potential overlap with Pavlovian methods such as occasional presentations of the aversive event during extinction (Culver et al., 2018) should be fully investigated.

4. Gaps and directions for research on avoidance extinction

Historically disparate, although not incompatible, theoretical approaches to the study of avoidance extinction has led to variability in the terms used to describe various procedures. Consistency in terminology is needed, not only between associative and operant learning domains but also between clinicians and researchers. With that in mind, future research may benefit from the following classifications of avoidance extinction procedures. The proposed terminology draws on the nomenclature developed by Pavlovian and operant approaches and has the advantage of making the procedures employed readily accessible to researchers from different domains involved in translational investigations of avoidance extinction. The use of a consistent terminology in avoidance extinction research may also help to bridge the gaps and foster a closer synthesis between the operant and Pavlovian domains. Indeed, there is a growing awareness of the need to look beyond fear or threat related responses and to understand how behavioral engagement opportunities (approach or avoidance) may be maximized (LeDoux et al., 2016; Pare & Quirk, 2017).

It is proposed that when *response prevention* is included in a procedure, it should be accurately labelled as such. The terms, *US extinction*, should be reserved for procedures where the US is withheld but avoidance may still occur; *US extinction + response prevention* is recommended when the US is withheld and avoidance is actively prevented (and response rates under such conditions should be continuously measured); the terms, *unavoidable* *aversive event* are suggested for instances where the aversive event is non-eliminable and the avoidance response remains available, and the terms, *unavoidable aversive event + response prevention* may be used where the aversive event is non-eliminable and the avoidance response is not available.

The continuous measurement of avoidance behavior is essential for informing the findings of laboratory-based treatment studies of avoidance extinction. Reducing avoidance behavior to zero or near-zero levels requires that all phases be continuously measured in order to determine robust treatment effects. It is therefore noteworthy that some studies of avoidance extinction in humans employing response prevention procedures have not recorded behavior during the crucial extinction test phase (Vervliet et al., 2017), making it impossible to determine whether or not avoidance had, in fact, extinguished. Much of the research reviewed here used a flooding procedure (Baum, 1970; ExtRP) and tested avoidance extinction when the response was available again, finding that persistent avoidance occurs with mere US extinction, but that gradual extinction occurs under ExtRP. Clearly, the assumption that removal of the opportunity to avoid, by for instance removing an on-screen cue, is sufficient for avoidance to decrease and extinguish (usually within a fixed number of trials) should be carefully evaluated. Avoidance is, of course, still measured during subsequent testing when the avoidance option is available again but determining the effectiveness of response prevention necessitates demonstrating that responding was in fact prevented and eliminated. Doing so may also have implications for the identification of subtle avoidance behaviors used by clients in therapy and which may go unnoticed, and hence untreated, by therapists. Therefore, continuously recording avoidance responding during *all* extinction sessions is essential for informing the clinical utility of the procedures. The complete extinction of avoidance may not however be a clinical target, and it is therefore important that future research states what level is practical and or clinically significant to achieve before avoidance can be said to have extinguished.

This notwithstanding, future research should adopt predetermined acquisition and mastery criteria to ensure stability of trained avoidance prior to any manipulations of avoidance extinction. Stable avoidance criteria should include discriminated responding (i.e., high rates of avoidance in the presence of the CS+ and low or zero rates of avoidance in the presence of the CS-), and participants excluded if criteria are not met but data held for subsequent subgroup analyses. Adopting acquisition and mastery criteria will likely impact on the accuracy of a priori sample size estimates, but the advantages of ensuring that all analyzed data meets predetermined criteria should outweigh any practical challenges in data collection. Relatedly, future research aimed at the empirical understanding of avoidance extinction should carefully justify criteria used to infer extinction of avoidance by, for example, determining thresholds within which avoidance may be said to have extinguished. When so doing, it is good practice to measure performance across multiple blocks of trials and/or sessions.

Research on avoidance extinction should develop and evaluate novel experimental paradigms that model ongoing, excessive avoidance in complex situations (Krypotos et al., 2018; Pittig et al. 2018). There is a need to look beyond discrete stimulus presentations and simple, overt avoidance responses to more creative ways of modelling ecologically-valid avoidance and its extinction. Advances in technology such as virtual reality (VR) should be fully investigated by, for example, embedding avoidance acquisition and extinction trials within the context of an ongoing (appetitive) VR task, allowing for continuous measurement across time and contexts (Carl et al., 2018; Dunsmoor et al., 2014; Shiban et al., 2015).

Further work that makes use of research designs such as yoked control designs (Boeke et al., 2017), triadic designs (Hartley et al., 2014), and small-*N* designs (Smith & Little, 2018), may prove helpful in understanding the underlying learning mechanisms and boundary conditions of avoidance extinction, often without the need to recruit large samples of participants. The interplay between avoidance extinction processes and other fear learning and renewal processes, such as reinstatement (van Uijen et al., 2018) and resurgence (e.g., Alessandri et al., 2015) is warranted. It is notable, for instance, that little work has been conducted on reinstatement of avoidance (but see, Cameron et al., 2015) compared to the literature that exists on fear reinstatement (Haaker et al., 2014). A better understanding of the role of reinstatement in maintaining maladaptive avoidance and its subsequent extinction has obvious clinical relevance (Vervliet et al., 2013). Moreover, further translational work is needed to investigate the role of the availability of alternative reinforcement on resurgence and renewal of negatively reinforced escape and avoidance behavior (Alessandri et al., 2015). Research on methodological factors, including the relative utility of different avoidance paradigms such as passive vs. active and signaled vs. unsignaled for informing the acquisition and extinction of clinically relevant avoidance in humans, is also required. Similarly, factors such as the co-occurrence of CS termination with avoidance responses and the availability of US escape responses, particularly when scheduled in conjunction with operant extinction procedures, as well as the impact of US devaluation procedures, should all be subject to robust scrutiny with validated procedures.

Future research studies should investigate the role of individual differences and clinically relevant trait variables in avoidance extinction (Krypotos et al., 2018). The extant data indicate roles for neuroticism, intolerance of uncertainty, behavioral flexibility, experiential avoidance and distress tolerance, among other traits, in the acquisition (e.g., Hassoulas et al., 2014; Morriss et al., 2018), extinction (e.g., Flores et al., 2018; Vervliet & Indekeu, 2015; Vervliet et al., 2017) and generalization of avoidance (e.g., Arnaudova et al., 2016; Hunt et al., 2017; Lommen et al., 2010). Further analyses with large samples are therefore needed to make clear the validity of avoidance acquisition, generalization and extinction paradigms for informing clinical treatment of anxiety-related disorders. Moreover, it is recommended that future studies present frequency distributions (e.g., Morriss et al., 2018) or apply statistical methods such as latent growth curve modelling (Krypotos, Moscarello, et al., 2018) to identify heterogenous subgroups of participants who do or do not acquire (extinguish) avoidance and explore any predictive relationships with relevant trait factors. Finally, work is needed on the neural substrates of persistent avoidance in different groups of patients and healthy controls (Boeke et al., 2017; Schlund et al., 2010).

Developments in these areas could impact on translational neuroscience research which typically adopts behaviorally validated paradigms. Indeed, it is possible that the relative dearth of research on avoidance extinction compared to that on fear extinction may in part be due to the lack of novel experimental paradigms and the predominant, one-system view that avoidance is a product of fear and fear circuits (e.g., Fanselow & Pennington, 2018; Perusini & Fanselow, 2015). If, instead, neuroscience research viewed fear and avoidance as dissociable (LeDoux, 2014; LeDoux & Pine, 2016), then there is scope and potential for neuroscience to develop mechanistic theories of avoidance extinction with immediate treatment implications for domains such as anxiety disorders (e.g., social anxiety: Rudaz et al., 2017), addiction (Sheynin et al., 2016), and pain (Meulders et al., 2016; van Vliet et al., 2018). However, without validated behavioral approaches and a shift away from fear-based views of avoidance, neuroscience-based approaches will remain disconnected from contemporary clinical research and treatment of avoidance. Decades of operant work on avoidance extinction offer tremendous promise in this regard.

5. Conclusion

The translational relevance of experimental psychopathology, associative learning, and operant conditioning approaches, separate and combined, in understanding the acquisition, maintenance, generalization, and extinction of fear and avoidance is widely accepted. Research drawn from these approaches continues to inform therapeutic interventions for anxiety and related disorders, and the validity of laboratory-based treatment studies is well established. Despite these advances, research on fear has predominated that on avoidance, most likely due to the theoretical disputes surrounding the status of avoidance itself (Dymond & Roche, 2009; LeDoux et al., 2016). Given that, it is perhaps not surprising that avoidance extinction in humans has been studied using different procedures drawn from disparate domains.

Opportunities exist for research on avoidance extinction to view the arrangement of extinction procedures as facilitating a behavioral transition state (Sidman, 1960). Overcoming pathological avoidance is central to effective behavioral treatment for anxiety related disorders and arranging contingencies for avoidance extinction thereby also fosters conditions necessary for changing behavior. Approached in this way, avoidance extinction represents a type of transition state between a maladaptive, learned behavioral repertoire and an adaptive, replacement set of skills. Much of the research on avoidance extinction reviewed here has tended to focus on the former aspect at the expense of the latter. Potentially neglected transition states that arise during avoidance extinction may include operant-based approach-avoidance training (Van Dessel et al., 2018) and reflective versus reactive learning situations (Pittig et al., 2018), amongst others. Similarly, a detailed analysis of the role of prior learning history, in particular stressor controllability (Hartley et al., 2014) and reinforcement rate (Xia et al., 2017) on the subsequent effectiveness of extinction, is needed. Moreover, counterconditioning (Gambril, 1967; Kang et al., 2018) or differentially reinforcing replacement behaviors that compete with the protective mechanisms of avoidance are worthy, yet under-examined issues of enormous clinical relevance (Bennett et al., 2018). Investigating these issues with complex/ambiguous settings and naturalistic avoidance tasks

(Pare & Quirk, 2017) to further understand the interaction with basic fear learning and generalization mechanisms (Pittig et al., 2018), and monitoring the long-term effectiveness of avoidance extinction procedures with clinical and healthy populations also warrants further empirical attention.

Consistency in terminology is essential if research on avoidance extinction is to continue to grow and yield insights into the reduction and generation of behavior. Accurately classifying procedures in terms of their underlying associative or operant principles will greatly aid dissemination of findings and the widespread adoption of avoidance paradigms. For too long, associative and operant paradigms have approached the study of avoidance and its extinction separately, with little interaction between the domains, and with each employing its own empirical and theoretical nomenclature; the present article suggests they may each have more in common with one another than at first suspected. Synthesizing these disparate literatures involves considerable response effort, yet there is much to be gained from this and future attempts to bridge theoretical and empirical divides to the study of avoidance extinction and other learning processes. Closer attention to the potential for collaborative exchange between the different research approaches to avoidance extinction will help facilitate the empirical and clinical resurrection of avoidance for understanding the acquisition, maintenance, spread, and extinction of adaptive and maladaptive avoidance behavior.

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Figure Captions

Figure 1: Number of publications indexed in *Web of Science* with the search terms 'avoidance', 'extinction' and 'human', 1978-2018 (as of March 27th 2018).

Figure 2: Varieties of Pavlovian and operant avoidance extinction procedures. Arrows indicate left-right temporal sequence. **(a)** During threat conditioning, a previously neutral, on-screen cue (in this case, a triangle) is followed by electric shock (CS+); another cue (not shown) is followed by the absence of shock (CS-). **(b)** In avoidance learning, a simple, overt action or response (e.g., button-pressing) made in the presence of CS+ cancels the upcoming shock delivery. **(c)** Three main types of Pavlovian avoidance extinction procedures. In fear extinction, shock is withheld, and avoidance is still available. In fear extinction with response prevention, shock is withheld, and avoidance is prevented. In response prevention + US, shock is not withheld, and avoidance is prevented. **(d)** Three main types of operant avoidance extinction procedures. In shock extinction, shock is withheld, and avoidance is still possible. In making shock non-eliminable (i.e., unavoidable shock), shock is not withheld, and avoidance is still available. In response-independent shock-free periods, shock is withheld non-contingently, regardless of behavior, and cycles between periods of shock presentation and avoidance availability. See text for details.