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Partial reinforcement of avoidance and resistance to extinction in humans

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A B S T R A C T

In anxiety, maladaptive avoidance behavior provides for near-perfect controllability of potential threat. There has been little laboratory-based treatment research conducted on controllability as a contributing factor in the transition from adaptive to maladaptive avoidance. Here, we investigated for the first time whether partial reinforcement rate, or the reliability of avoidance at controlling or preventing contact with an aversive event, influences subsequent extinction of avoidance in humans. Five groups of participants were exposed to different partial reinforcement rates where avoidance cancelled upcoming shock on 100%, 75%, 50%, 25% or 0% of trials. During extinction, all shocks were withheld. Avoidance behavior, online shock expectancy ratings and skin conductance responses (SCRs) were measured throughout. We found that avoidance was a function of relative controllability: higher reinforcement rate groups engaged in significantly more extinction-resistant avoidance than lower reinforcement groups, and shock expectancy was inversely related with reinforcement rate during avoidance acquisition. Partial reinforcement effects were not evident in SCRs. Overall, the current study highlights the clinical relevance of laboratory-based treatment research on partial reinforcement or controllability effects on extinction of avoidance.

Anxiety disorders are highly prevalent (Kessler, Berglund, Demler, Merikangas & Walters, 2005), with an estimated global lifetime prevalence rate of 7.3% (Baxter, Scott, Vos, & Whiteford, 2013) and annual costs exceeding €74 billion in Europe alone (Gustavvson et al., 2011). Anxiety disorders are characterized by excessive avoidance of real and perceived threat (American Psychiatric Association, 2013). In experimental psychopathology research, the Pavlovian fear/threat conditioning paradigm is widely adopted to study the acquisition and unlearning of avoidance (LeDoux, 2014; Vervliet & Raes, 2013). During fear/threat conditioning, an aversive unconditioned stimulus (US) (e.g., an electric shock) is paired with a neutral conditioned stimulus (CS+), while another stimulus (CS-) is paired with the absence of the US. Presentations of the CS+, but not the CS-, come to induce conditioned fear responses (CRs) akin to clinical anxiety symptoms such as increased physiological arousal. Avoidance learning can then be studied in several ways in the laboratory (LeDoux, Moscarello, Sears, & Campese, 2016). For instance, in signaled active avoidance procedures, a response such as bar pressing, performed in the presence of the CS+ minimizes or prevents contact with the aversive US (Higgins & Morris, 1984; LeDoux et al., 2016; Lovibond, Saunders, Weidemann, & Mitchell, 2008). Once learned, avoidance may be subject to extinction by withholding all US presentations. As avoidance is now unnecessary (since all shock is withheld), responding eventually extinguishes (Baum, 1970; Krypotos, Effting, Kindt, & Beckers, 2015; Lovibond, 2006; Riccio & Silvestri, 1973), although the persistence of avoidance in extinction has been reported (e.g., Malloy & Levis, 1988; Solomon, Kamin, & Wynne, 1953; Williams & Levis, 1991).

The therapeutic implications of experimental psychopathology

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research on avoidance arise when avoidance becomes the excessive and default way of coping with potential threat. Charting this transition from adaptive to maladaptive avoidance, and identifying potential factors which may contribute to the persistence of avoidance, are important issues in laboratory-based treatment research. Indeed, the shift to maladaptive avoidance so often seen in the anxiety disorders means that clients fail to learn that threat cues may not predict impending danger; their avoidance behavior may thus become resistant to extinction (LeDoux et al., 2016; Lovibond, Mitchell, Minard, Brady, & Menzies, 2009; Volders, Meulders, de Peuter, Vervliet, & Vlaeyen, 2012). Extinction of maladaptive avoidance is one of the treatment goals in exposure therapy for anxiety (Barlow, Raffa, & Cohen, 2002, pp. 301–335; Scheveneels, Boddez, Vervliet, & Hermans, 2016; Vervliet, Craske, & Hermans, 2013), yet, to date, there has been minimal research conducted with humans on extinction of avoidance (Dunsmoor, Niv, Daw, & Phelps, 2015; LeDoux et al., 2016; Riccio & Silvestri, 1973). Little is known, then, about factors responsible for the resistance to extinction of maladaptive avoidance.

Here, we investigated extinction of avoidance and the role played by controllability in avoidance (i.e., reinforcement rate) on subsequent resistance to extinction. The study of reinforcement rate or partial reinforcement effects is common across appetitive and non-appetitive learning, yet each domain makes contrasting predictions about the effects on responding during the (unsignaled) shift to extinction. In the domain of appetitive conditioning, a partially reinforced response is known to extinguish less rapidly than a continuously reinforced response when the source of reinforcement is discontinued in extinction (Catania, 2013); an outcome referred to as the partial reinforcement extinction effect (Nevin, 1988). Appetitive approaches to behavior change therefore incorporate partial reinforcement to facilitate subsequent resistance to extinction (e.g., Higbee, Carr, & Patel, 2000; Kazdin & Polster, 1973; Lerman & Iwata, 1996). In non-appetitive domains, such as avoidance learning, partial reinforcement involves manipulating the effectiveness of the operant response at preventing the US (Davenport, Olson, & Olson, 1971). Generally, when avoidance has been partially reinforced, responding during extinction (when shock is withheld) is less resistant to extinction than avoidance acquired under conditions of continuous reinforcement (Galvani, 1971; Olson, Davenport, & Kamichoff, 1971). Thus, contrasting effects of partial reinforcement in extinction are predicted by each domain: in appetitive conditioning, partially reinforced appetitive behavior will be *more* resistant to extinction, while in non-appetitive learning, partially reinforced avoidance behavior will be *less* resistant to extinction than continuously reinforced avoidance behavior.

Until now, the effects of partial reinforcement on the acquisition and extinction of avoidance has largely been the focus of research with nonhumans (e.g., Davenport et al., 1971; Galvani, 1971, 1973; Marsh & Paulson, 1968; Olson, 1971; Olson et al., 1971; Solomon et al., 1953). Marsh and Paulson (1968), for instance, exposed groups of goldfish to either continuous or partial reinforcement of avoidance before extinction in which shock was omitted on all trials and where CS termination occurred following avoidance. Unpredictably, it was found that partial reinforcement increased resistance to extinction. However, response rates were highest for the continuous reinforcement group throughout the study, suggesting some resistance to extinction in that group, and it is likely that methodological factors such as delayed CS termination and the number of escape responses made in the presence of shock (on non-avoided trials) may have contributed to this outcome. Subsequent nonhuman research on partial reinforcement effects in avoidance sought to develop the “proper procedure” (Davenport et al., 1971, p. 9) for studying extinction of avoidance. Such a procedure should, it was claimed, involve “making a response ineffective in producing the reinforcing consequence that was provided during acquisition” (Olson et al., 1971, p. 12). Davenport et al. (1971) compared groups of rats exposed to partial reinforcement (0%, 25%, 50%, 75%, or 100%) on this revised extinction of avoidance procedure in which responding was no longer effective at preventing shock. Davenport and Olson (1968) found that acquisition of avoidance was a function of reinforcement rate with a lower rate leading to slower acquisition (see also, Galvani, 1971) but found no evidence of a differential effect on avoidance responding in extinction. Finally, Olson et al. (1971) compared groups of rats given 0%, 50% and 100% reinforcement and replicated the finding that responding during acquisition was a direct function of rate of reinforcement but did find that groups differed during extinction, with reduced resistance to extinction in the 100% group as compared to the 50% or 0% groups.

Recently, in an analog study of coping with chronic pain conducted with healthy human participants, Meulders, Franssen, Fonteyne, and Vlaeyen (2016) manipulated the probability of receiving painful electric shock and the effort involved in avoidance of shock. For the experimental group, the fastest and easiest response trajectory (moving a 3 degrees-of-freedom robotic arm) always resulted in shock, while shock could be avoided on 50% or 100% of occasions with either moderate or extreme effort, respectively. Participants in a yoked group received the same reinforcement schedule (shocks) regardless of their behavior. Following acquisition, an extinction test phase was conducted where no shocks were delivered (i.e., CS extinction). The experimental group demonstrated acquisition of avoidance behavior by deviating more from the easiest/quickest response trajectory than the yoked group. Moreover, Meulders et al. found that the experimental group showed resistance to extinction by continuing to avoid more than the yoked group during extinction, despite the response effort involved (see also, Rattel, Miedl, Blechert, & Wilhelm, 2017; van Meurs, Wiggert, Wicker, & Lissek, 2014).

Research on partial reinforcement of avoidance in humans and nonhumans has thus far employed only intensely aversive (e.g., Olson et al., 1971) or painful shocks (Meulders et al., 2016). To date, however, little is known about the role of partial reinforcement on the acquisition and extinction of avoidance in humans, using, by definition, mildly aversive shocks, where only one of the methodological factors described above (i.e., avoidance extinction procedures where the US is withheld) has been examined. Here, we sought to investigate in humans whether partial reinforcement of avoidance influences resistance to extinction.

In clinical settings, one of the goals is to highlight that not every CS+ is followed by a US and that indiscriminate avoidance may be unnecessary. The effects of partial reinforcement of CS-US pairings on conditioned fear and extinction have been well studied (e.g., Allen, Myers, & Servatius, 2014; Grady, Bowen, Hyde, Totsch, & Knight, 2016), but less is known about the effects of partial reinforcement of avoidance in cases where excessive avoidance has become the default way of coping and which may thus be more difficult to treat. Indeed, the clinical relevance of partial reinforcement effects on avoidance extinction centers around the observation that there is never a sense of perfect controllability in clinical anxiety disorders, quite the contrary (Amat et al., 2005; Hartley, Gorun, Reddan, Ramirez, & Phelps, 2014; Maier & Watkins, 1998; de Berker et al., 2016). For instance, in social anxiety disorder, a socially anxious individual will possess various behavioral strategies to avoid threatening events within a social context, yet none will have 100% certainty (e.g., not looking people in the eye does not always avoid being talked to). Similarly, in panic disorder, avoiding supermarkets may decrease the probability of experiencing a panic attack, but the individual may always experience a