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Competition between an avoidance response and a safety signal: Evidence for a single learning system

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ABSTRACT

Two experiments examined competition between an instrumental avoidance response and a Pavlovian safety signal for association with omission of electric shock in a human fear conditioning paradigm. Self-reported shock expectancies and skin conductance responses were consistent with blocking of learning of the instrumental contingency by prior training of the Pavlovian contingency, and vice versa. The results support the idea that a common learning mechanism underlies both Pavlovian and instrumental conditioning. The expectancy data suggest that this learning mechanism is cognitive in nature, and that Pavlovian and instrumental learning involve external and internal attributions, respectively. The procedure may thus serve as a laboratory model for attributional processes involved in the acquisition of threat expectancies in anxiety and anxiety disorders.

1. Introduction

Pavlovian and instrumental conditioning are two forms of associative learning that are both considered relevant to anxiety and anxiety disorders. Pavlovian conditioning is one means by which organisms including humans learn predictive or causal associations between initially neutral conditioned stimuli (CSs) and aversive outcomes such as pain or rejection, referred to in the Pavlovian context as unconditioned stimuli (USs). Excitatory CSs signal threat and elicit preparatory responses such as anxiety and arousal. Inhibitory CSs signal safety and allow organisms to focus on other priorities. Instrumental conditioning involves learning associations between voluntary responses and aversive outcomes, typically referred to in the instrumental context as reinforcers. Excitatory associations refer to punishment, and inhibitory relationships refer to escape or avoidance. Although both Pavlovian and instrumental learning are usually adaptive, they can also support maladaptive behaviour, for example when a traumatic event conditions severe anxiety to associated stimuli, or when individuals learn inappropriate or excessive avoidance patterns.

Basic animal research on associative learning has generated successful theoretical models and has led to effective behavioural approaches to the management of anxiety disorders. In particular, exposure and response prevention are widely-used techniques derived from basic research on Pavlovian and instrumental conditioning, respectively (Barlow and Allen, 2004). The study of human learning in the laboratory is a particularly useful model in that it allows phenomena and theories from the animal literature to be tested in human participants. It also allows investigation of the role of cognitive processes such as beliefs and expectancies which are thought to play an important role in anxiety disorders and their treatment (Clark, 1999). For example, the study of protection from extinction in human fear conditioning has provided support for the hypothesis that sources of safety present during exposure therapy interfere with treatment benefits by preventing the disconfirmation of threat beliefs (Lovibond et al., 2000).

However, an important unresolved question in both animal and human associative learning is whether Pavlovian and instrumental associations are learned by the same or different mechanisms. Historically, theorists have been divided on this issue. Skinner (1935) considered the two forms of learning to be quite distinct. Hull (1943) and Spence (1956) attempted to describe both forms of learning in terms of S–R associations, both reinforced by drive reduction. Later researchers have emphasised the separate roles played by instrumental and Pavlovian learning in the same learning situation (e.g., Mowrer, 1960; Rescorla and Solomon, 1967). A recurrent theme is that Pavlovian conditioning is seen as a more

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primitive, automatic form of learning by contrast to the voluntary, decision-making character of instrumental learning (e.g., LeDoux, 1995; MacLean, 1993; Öhman and Wiens, 2003; Seligman and Johnston, 1973).

However, animal research since the 1970s has demonstrated striking parallels between the conditions and mechanisms of Pavlovian and instrumental learning. In particular, both forms of learning appear to require not just contiguity but also a positive contingency between the elements to be associated (Rescorla, 1967). Research on reinforcer/US devaluation has also clarified that the critical association in the case of Pavlovian learning is between the CS and the US (S–S association), whereas in the case of instrumental learning it is between the response and the reinforcer (R–S; e.g., Colwill and Rescorla, 1988). As noted earlier, the US in the Pavlovian case and the reinforcer in the instrumental case are often different terms for the same event (e.g., food or shock), which can be labelled more neutrally as the outcome. Using this labelling, Pavlovian associations are S–O and instrumental associations are R–O. Finally, theorists have placed increasing emphasis on the distinction between learning of associations and performance arising from such learning. Research on the effects of omission and punishment schedules on Pavlovian performance (Coleman and Gormezano, 1979; Williams and Williams, 1969) has demonstrated that Pavlovian conditioned responses (CRs) are involuntary in nature. By contrast, instrumental responses are voluntary. However the possibility remains that the underlying associative mechanism for *learning* Pavlovian S–O associations and instrumental R–O associations is the same.

Exactly this possibility was argued persuasively by Dickinson (1980), who introduced the notation of E1–E2 learning. E1 is the prior (predictive) event and E2 is the subsequent (to-be-predicted) event, usually but not always a biologically significant event such as food or pain. This notation, in which E1 may be a stimulus (Pavlovian) or an action (instrumental), encourages the idea that a single associative mechanism may underlie learning of both types of association. As reviewed by Dickinson, studies on Pavlovian–instrumental transfer support the idea that the two types of learning are related. For example, a Pavlovian signal for shock can facilitate avoidance responding (e.g., Weisman and Litner, 1969). However, a stronger prediction of the single mechanism hypothesis is that stimuli and actions should compete for association with a common E2 or outcome. Research on phenomena such as relative validity (Wagner, 1969) and blocking (Kamin, 1969) has clearly demonstrated competition between CSs for association with a US in Pavlovian conditioning, formalised in the popular Rescorla–Wagner (1972) model. If actions and stimuli can both become associated with a particular outcome, then they should similarly show evidence for competition.

Several animal conditioning studies have directly tested Pavlovian–instrumental competition. Pearce and Hall (1978) carried out 5 experiments in which a 0.5-s stimulus was inserted between a lever-press response and delivery of food reward (correlated condition) or after a lever-press response that was not followed by food (uncorrelated condition). In all experiments, lever pressing was reduced in the correlated condition, a pattern that the authors interpreted in terms of the stimulus being a more valid predictor of the food than the lever-press response. St. Claire-Smith (1979) reported the same pattern using a similar procedure. Garrud et al. (1981) examined the impact of an instrumental response on learning a Pavlovian association. They found in 3 experiments that learning of a clicker–food association was weakened if the food presentations had been contingent on a prior wheel-turn response.

In the aversive domain, Morris (1975) has provided some evidence for a parallel between instrumental avoidance learning and Pavlovian conditioned inhibition. He used a yoking design in animals to show that a stimulus that had the same (negative) relationship to shock as an avoidance response would act as a secondary reinforcer for a new instrumental response. However this study did not directly demonstrate that the yoked stimulus was an inhibitory (safety) cue, nor did it test for competition between instrumental and Pavlovian learning. Furthermore, the studies by Pearce and Hall (1978), Garrud et al. (1981), and Morris (1975) were all conducted with animals. In the present study, we sought to fill this gap by testing for competition between instrumental avoidance learning and Pavlovian inhibitory learning in human participants.

We used a fear conditioning procedure that we have developed to examine avoidance learning in the laboratory (Lovibond et al., 2008). We have already obtained some evidence suggestive of Pavlovian–instrumental competition using this procedure. Lovibond et al. (2009) showed that performance of an avoidance response could act to protect a Pavlovian CS from extinction, using both a physiological measure, skin conductance, and a cognitive measure, shock expectancy. The present research was designed to directly test for competition between an instrumental avoidance response and a Pavlovian safety stimulus for acquisition of an association with a common outcome, the omission of a predicted shock. A demonstration of competition would provide support for the idea that instrumental and Pavlovian learning are mediated by a common mechanism. The first experiment sought to establish a baseline procedure in which an instrumental and a Pavlovian association are trained simultaneously for association with shock omission.

2. Experiment 1

This experiment used a variation of the strategy described by Pearce and Hall (1978) and Garrud et al. (1981). After initial differential Pavlovian conditioning in which one stimulus, A, was paired with shock (+) and another, B, was not (A+/B−), an instrumental avoidance response (button press) was made available during presentations of stimulus A. Pressing the button resulted in cancellation of the shock predicted by stimulus A. Contingent on performance of the avoidance response was a further Pavlovian stimulus, C. In this way, both the avoidance response and the Pavlovian stimulus C were presented in conjunction with omission of the shock that had previously followed stimulus A. In the Test phase we tested separately the ability of the avoidance response and stimulus C to reduce SCL and shock expectancy to stimulus A. If there is competition between the instrumental response and Pavlovian stimulus for association with shock omission (safety), then each of these elements should be less capable of reducing SCL and expectancy to stimulus A by comparison to the training trials in which both elements were present.

In our previous avoidance research (e.g., Lovibond et al., 2008) we had signalled availability of button-press responses by illumination of corresponding lights on the response box. In this experiment, we only made one response button available, and we signalled its availability by an instruction on a computer monitor during the preceding inter-trial interval (ITI). Unlike Garrud et al. (1981) and some human avoidance procedures (e.g., De Houwer et al., 2005), we did not require participants to make the avoidance response. This decision was made because we were concerned that participants may not treat a required response in the same way as a voluntary response. However this procedure heightened a potential problem that already exists in this type of design, namely the possibility that participants will learn a response–stimulus–outcome sequence instead of treating the response and safety stimulus C as independent predictors of the outcome. In such a sequence C would serve merely as a mediator of the causal efficacy of the response, rather than as an independent, competing cause. In order to deal with this problem, we introduced additional BC− trials to try to weaken the response–stimulus C association, and we varied the time interval between the response and stimulus C. We also asked participants to rate the degree of association between the three elements at the end of the experiment.

2.1. Method

2.1.1. Participants

Participants were 53 undergraduate students (20 males and 33 females), who received course credit for participation.

2.1.2. Apparatus

The experiment employed the same apparatus as that described in Lovibond et al. (2008). In brief, participants were tested individually in a dimly lit room with a chair and table. A 38-cm computer monitor on the table was used to display instructions and stimuli. The CSs were a 6-cm blue square and a 6-cm orange square, presented in the centre of the monitor. The US was a 0.5-s electric shock produced by a constant current generator. Skin conductance was measured through electrodes