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The use of an unpleasant sound as an unconditional stimulus in a human aversive Pavlovian conditioning procedure

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Abstract

Ethical considerations can limit the use of traditional unconditional stimuli (US), such as electric shock and loud tones, when used in a human aversive Pavlovian conditioning procedure. The risk of the US causing pain or excessive anxiety is a particular concern when testing sensitive populations such as children, the elderly, and those with psychological or neurodevelopmental disorders. Two experiments used a differential conditioning procedure to determine whether an unpleasant sound (metal scraping on slate) could support the acquisition and extinction of conditioned responses to the same extent as either electric shock or a 100 dB(A) tone US. Experiment 1 ($N = 48$) demonstrated equivalent or superior conditioning effects for the signal-based learning measures of US expectancy, skin conductance responses, and heart rate. Experiment 2 ($N = 57$) yielded similar outcomes in the affective-based learning measures of startle blink modulation and pleasantness ratings. The results support the use of an unpleasant sound as a US in human Pavlovian conditioning experiments.

Keywords: Pavlovian conditioning; Unconditional stimulus; Sounds

1. Introduction

Aversive conditioning is part of a more general form of associative learning, called Pavlovian conditioning, in which a neutral stimulus known as the conditional stimulus (CS) (e.g. a geometric shape) is paired with an aversive event known as the unconditional stimulus (US) (e.g. an electric shock). The CS initially induces no emotional reaction, but if an association between the CS and US is learnt after repeated pairings, the CS on its own will elicit a conditioned response (CR). The CR can manifest in various ways including physiological changes, changes in affective reactions, and avoidance behaviour (Davey, 1992; Dawson and Schell, 1985; Öhman, 1983; Öhman et al., 2000). Extinction of the CR occurs when the CS signal is no longer paired with the salient US event, but is presented on its own. The CR gradually diminishes over repeated presentations of the CS.

A critical feature of aversive conditioning procedures is that the salient US event must be perceived to be ‘‘unpleasant’’. This is for two reasons. First, the basic definition of aversive conditioning requires that the salient event has biological significance and can elicit a defensive unconditional response (UR), such as avoidance behaviour, regardless of prior learning history. Second, aversive conditioning is one of the most frequently used mechanisms to explain the aetiology of fears and phobias (e.g. Davey, 1992; Rachman, 1977), with a considerable empirical literature demonstrating both significantly faster acquisition of fear learning and more resistance to extinction among anxious individuals relative to non-anxious controls (see Lissek et al., 2005).

In human research, the salient US event that is traditionally used is an electric shock (e.g. Lipp et al., 2001b; Neumann et al., 1997; see reviews by Grillon, 2002 and Lissek et al., 2005). The shock is set at an individual level that the participant describes as ‘‘unpleasant, but not painful’’, with shock voltage varying from 40 to 70 V for most individuals. Although this type of salient US event produces strong learning effects (Lissek et al., 2005), there are a number of limitations to its application. One such limitation is that the electric shock may not be appropriate for use with special populations, such as children (see Grillon et al., 1999; Waters et al., 2005), the elderly, and those with psychological or neurodevelopmental disorders. These populations are less likely to possess the self-

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awareness to determine when a shock is ''unpleasant, but not painful''. Another limitation concerns the cost in that sometimes expensive stimulation hardware is required to ensure that the participant is electrically isolated from the hazardous mains current supply.

Alternative aversive stimuli to electric shock include a loud tone (e.g. Liberman et al., in press), unpleasant odour (e.g. Flor et al., 2002), and air puff (e.g. Suboski, 1967). The most commonly used of these three is the loud tone, typically consisting of a pure frequency played at an intensity of 100–105 dB(A) for 500–1000 ms (e.g. Liberman et al., in press). However, the use of a loud tone also has limitations, particularly with special populations who are extremely sensitive to loud auditory stimuli, such as children with Fragile X syndrome, autistic spectrum disorders, and some anxiety disorders (American Psychiatric Association, 1994). Moreover, loud tones may yield weaker conditioning effects than those observed when an electric shock is used (e.g. Liberman et al., in press).

An alternative to electric shock and loud tones is the use of sounds that are perceived to be unpleasant, not because of the intensity at which they are presented, but because of the inherent characteristics of these sounds. Halpern et al. (1986) examined the psychoacoustic properties of various sounds and found that dragging a three-pronged garden tool across slate or metal, and rubbing two pieces of styrofoam together were rated as more unpleasant than other sounds such as white noise, a blender motor, or compressed air sounds. Moreover, by varying the frequency components of these sounds, Halpern et al. found that removal of the low, but not the high, frequency components lessened the sounds unpleasantness. Hence, low frequency components appear to contribute to the unpleasantness associated with some aversive sounds.

Similarly, Vaschillo et al. (2003a,b) conducted research aimed at defining what features of various sounds make them aversive. They examined sounds sampled from the environment (e.g. crying baby, screaming) and computer-synthesized sounds (e.g. 4000 Hz tone with wide frequency modulation). Importantly, they presented all sounds at an intensity of less than 82 dB(A), which is in the normal range for environmental sounds and is similar to the intensity of sounds used in psychophysiological research with special populations such as children with Fragile X syndrome (e.g. Frankland et al., 2004). Moreover, computer-synthesized sounds were found to be more aversive than environmental sounds, as evidenced by subjective ratings, behavioural avoidance, and greater heart rate acceleration. One of the most unpleasant sounds, as determined by a comparison across all measures, was a combination of a tone and dish breaking with a slow-thin frequency distortion applied. Moreover, the computer-synthesized sounds proved difficult to recognise.

Taken together, the experimental evidence of Halpern et al. (1986) and Vaschillo et al. (2003a,b) shows that certain types of unmodulated environmental sounds, modulated environmental sounds, and artificially synthesized sounds presented at a normal intensity level can be perceived to be unpleasant. Any one of these types of sounds may be a promising alternative to electric shock and loud tones as a salient US event in an aversive conditioning procedure. The low intensity of the sounds, the reduced need for specialized stimulus generation hardware, and the wide range of unpleasant sounds that can be produced may have advantages in future applications of aversive conditioning. We therefore aimed to test whether the sound of metal scraping over slate, a sound similar to fingernails scraping over a chalkboard and the sound found to be most aversive by Halpern et al. (1986), could yield conditioning and extinction effects comparable to electric shocks and loud tones. Moreover, in separate experiments, we considered this question in terms of the two major classes of measures in aversive conditioning research, signal-based (or expectancy) measures and affective-based measures. These two measures are thought to be sensitive to different aspects of Pavlovian conditioning. In particular, evaluative learning, observed as a change in the liking of a stimulus resulting from the pairing of the stimuli with another liked or disliked stimulus, is best indexed by measures of affective change to the CS. In contrast, expectancy learning, which reflects learning of the predictive relationship between CS and US, is best indexed by measures of the signal values of the CS. Although the existence of two distinct learning systems has been debated, (e.g. see De Houwer et al., 2005; Lipp and Purkis, 2005) the distinction between the two classes of learning measures (Öhman et al., 2000; Lipp and Purkis, 2005) provides a useful framework for the present research. Experiment 1 used signal-based measures and Experiment 2 used affective-based measures, to test whether an unpleasant sound US can result in learning effects in both classes of measures.

2. Experiment 1

Experiment 1 was conducted to test whether an unpleasant sound in comparison with electric shocks and loud tones when used as an US could support conditioning in the signal-based measures of skin conductance responses, heart rate, and ratings of US expectancy. Skin conductance responses typically show three phasic components when the CS duration is 8–10 s (Öhman et al., 2000; Prokasy and Kumpfer, 1973). The first interval response (FIR) occurs within the first few seconds of CS onset. It reflects initial orienting to the signal value of the CS and is enhanced during CSs paired with a US (Öhman, 1983). The second interval response (SIR) is statistically independent from the FIR (Öhman, 1972) and reflects the anticipation of the US (Prokasy and Ebel, 1967; Öhman, 1983). The third interval response (TIR) is elicited following CS offset/US onset and permits comparison of the UR across the different USs. Heart rate shows a sequence of deceleration, acceleration, and deceleration during a CS (Öhman et al., 2000). Any of these components may be enhanced following CSs paired with USs. The acceleration component appears to reflect the significance of the CS (Bohlin and Kjellberg, 1979), whereas the second deceleration component reflects the expectancy of the US (Hugdahl, 1995; Öhman et al., 2000). Conscious cognition also appears to play a role in mediating the learning of Pavlovian conditioned associations (Davey, 1992; Dawson and Schell,