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The use of an unpleasant sound as the unconditional stimulus in aversive Pavlovian conditioning experiments that involve children and adolescent participants

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Abstract

Ethical considerations can prohibit the use of traditional unconditional stimuli (USs), such as electric shock or loud tone, when children or adolescents participate in aversive Pavlovian conditioning experiments. The present study evaluated whether an unpleasant sound provides a viable alternative. Fifteen boys and girls aged 13 to 17 years completed a differential Pavlovian conditioning procedure in which a conditional stimulus (CS) was followed by the sound of metal scraping on slate. Acquisition of conditioned responses was found in startle blink magnitude, expectancy judgments of the sound, and skin conductance responses. Extinction of conditioned responses was found in all measures when the CS was no longer followed by the unpleasant sound. Subjective ratings and skin conductance responses indicated that the sound was unpleasant because of its qualitative features, rather than its intensity. The results support the use of an unpleasant sound as a low risk alternative to traditional USs in aversive Pavlovian conditioning experiments with children and adolescents.

Keywords: Pavlovian conditioning; unconditional stimulus; adolescents; children; sounds

Introduction

In aversive Pavlovian conditioning, a neutral conditional stimulus (CS) is paired with an aversive unconditional stimulus (US). In research with healthy adults, researchers have traditionally used a US that is mildly painful or intense, most commonly electric shock and loud tones (see Grillon, 2002; Lissek et al., 2005). However, these stimuli present several ethical limitations when the participants are healthy children and adolescents or are individuals with neurodevelopmental disorders. An electric shock requires the individual to determine an intensity that is "unpleasant, but not painful" during a work up procedure. Children and adolescents may not be sufficiently self-aware to make this judgement. Loud tones (e.g., 100 dB presented for 1 s) may cause pain and discomfort in children and adolescents sensitive to loud stimuli, particularly those with Fragile X syndrome, autistic spectrum disorders, or some anxiety disorders (American Psychiatric Association, 1994). In addition, loud tones may be associated with poor acquisition of conditioned responses (CRs) in experiments with children (e.g., Liberman, Lipp, Spence, & March, 2006). Unpleasant odours (e.g., Flor, Birbaumer, Hermann, Ziegler, & Patrick, 2002) and air puffs (e.g., Suboski, 1967) are alternatives to traditional USs, but require special stimulus delivery systems and obtaining compliance may be difficult in some children (e.g., avoiding movement).

Another stimulus that may function as a viable US in studies with children could be a sound that is unpleasant, not because of its intensity, but because of its inherent characteristics. The psychoacoustic properties of a range of sounds were studied by Halpern, Blake, and Hillenbrand (1986) in a sample of adults. The sounds included a white noise, a blender motor, compressed air sounds, and rubbing two pieces of Styrofoam together, among others. The sound that was rated as most unpleasant was produced by dragging a three-pronged garden tool across slate. Neumann and Waters (2006) made a recording of this type of sound and confirmed its effectiveness when used as a US in a Pavlovian conditioning procedure with adult college students. In addition, the unpleasant sound was rated as more unpleasant than an electric shock and loud tone, although the shock elicited larger skin conductance defence responses than the sound. It was suggested that the sound was effective because of its unpleasant qualitative features rather than its high intensity.

The unpleasant sound may present several advantages in aversive Pavlovian conditioning experiments with children and adolescents. For example, it is presented at only a moderate intensity, does not require subjective calibration via a work up procedure, and uses equipment found in the typical laboratory (computer and headphones/speakers). However, it needs to be empirically demonstrated that children and adolescents will perceive the sound to be unpleasant and that it can serve as a viable US in an aversive Pavlovian conditioning procedure in this age group. For example, it is possible that younger participants may perceive the sound of metal scraping on slate to be less unpleasant than adults because of their shorter learning history and less opportunity for prior exposure.

Evaluation of the unpleasant sound in a Pavlovian conditioning procedure

To evaluate the effectiveness of the unpleasant sound in a Pavlovian conditioning procedure, seven boys and eight girls aged between 13 and 17 years (M = 16.00 years, SD = 1.19) participated in a protocol approved by the Griffith University Human Research Ethics committee. The methods followed those described by Neumann and Waters (2006). A differential conditioning procedure was used (Öhman, Hamm, & Hugdahl, 2000) by pairing one CS (CS+) with the unpleasant sound and presenting another CS (CS-) alone during conditioning. Both were presented alone during a subsequent extinction phase. The CSs were outlines of a diamond and triangle presented for 8 s. The US was a 3 s recording of a three pronged garden fork scraped over slate (see Neumann & Waters, 2006) and did not exceed a peak intensity of 83 dB(A). The resulting sound resembled that of fingernails running down a chalkboard. Pavlovian CRs were indexed by (a) modulation of the startle blink reflex that was elicited by a 50 ms white noise presented at 110 dB(A), (b) self-reported US expectancy, and (c) skin conductance responses (SCRs). These measures were selected because they are among the most commonly employed to measure aversive Pavlovian conditioning in experiments with children, adolescents, and adults (e.g., Lissek et al., 2005) and encompass both signal-based and affective learning measures. The startle blink data from two participants were not used due to non-responsiveness.

Participants were instructed that they would be presented with pictures of geometric shapes and an “unusual sound”. They were asked to try and predict when the sound might occur and to indicate this by using an expectancy dial placed on the table. The expectancy dial could be moved about two extremes of “certain sound will occur” and “certain sound will not occur” and a middle “uncertain” region. During conditioning, there were 8 positive trials followed by the unpleasant sound US, interspersed with 8 negative trials. Intertrial intervals (ITIs) randomly varied between 20, 25, and 30 s. Extinction trials for both trial types followed immediately and were interspersed in a similar manner. Half of the trials (7500 ms following the CS onset) and half of the ITIs contained a blink-eliciting stimulus. Startle blinks were measured as the maximum response occurring 20–200 ms following the onset of the blink-eliciting stimulus. Trials that did not contain a blink-eliciting stimulus were used to measure SCR magnitude as the SCR-CR (latency window of 1-4 s) and SCR-UR (latency window of 9-13 s).

To examine the strength of conditioning, the dependent measures were arranged into two blocks of trials during each of the conditioning and extinction phases and analysed with separate CS x Block ANOVAs. Table 1 shows the relevant statistical effects obtained for each dependent measure. Conditioning of startle blink reflexes and SCR-CRs was confirmed by significantly larger responses during the CS+ than during the CS-. The difference between the CS+ and CS- varied across blocks for expectancy judgments and SCR-URs. The interaction for expectancy reflected that the expectancy of the US increased across blocks for CS+, $t = 4.62$, $p < .01$, whereas it decreased for CS-, $t = 2.99$, $p < .05$. The interaction for SCR-URs reflected that there was a significant decline across blocks for CS+, $t = 10.18$, $p < .01$, but not for CS-, $t = 2.40$, $p > .05$. The extinction of startle blink reflexes, SCR-CRs, and SCR-URs was confirmed by no significant differences between the CS+ and CS-. The extinction of expectancy judgments was reflected in higher expectancy of the US during CS+ than during CS- in Block 1, $t = 9.73$, $p < .01$, but not in Block 2, $t = 2.16$, $p > .05$.

Insert Table 1 about here

The results showed that an unpleasant sound of metal scraping on slate supported the acquisition and extinction of CRs in the entire sample of 13 to 17 year old boys and girls. Conditioned responding was established in measures typically regarded as representative of fear learning (modulation of startle blink), autonomic conditioning (skin conductance responses), and expectancy learning (self-reported ratings). In addition, startle blink potentiation, often described as "fear potentiated startle" (Grillon, 2002), was observed only during the CS paired with the unpleasant sound. The effect sizes (η_p^2) obtained for the difference between the CS+ and CS- during conditioning for the startle blink, expectancy, and skin conductance measures were, respectively, 0.42, 0.95, and 0.39, indicating that the unpleasant sound produced a moderate to large conditioning effect. Moreover, these values are comparable to and even exceed those obtained by Neumann and Waters (2006) in their experiment with adults (0.40, 0.80, and 0.33, respectively). Neumann and Waters (2006) also reported that the effect sizes obtained with an unpleasant sound US were similar to that obtained with electric shock and loud tone USs. Taking the prior results and the present findings together, an unpleasant sound would seem to provide a reliable US for researchers who wish to study aversive Pavlovian conditioning in children and adolescents.

Evaluation of subjective ratings to the unpleasant sound

To examine the subjective properties of the unpleasant sound, we also asked the same sample of participants to provide ratings to the unpleasant sound in comparison to an electric shock, loud tone (100 dBA for 1000 ms), and a blink reflex eliciting stimulus (110 dBA for 50 ms). The 200 ms shock was set individually for each participant to be "unpleasant, but not painful" (final mean level was 5.77 mA, *SD* = 2.07). Participants were presented with each stimulus in random order and after each presentation they were asked to make ratings on 9-point linear scales for pleasantness (0 = very unpleasant, 8 = very pleasant), arousal (0 = very calm, 8 = very arousing), and interest (0 = very boring, 8 = very interesting). The SCRs elicited 1-4 s after each stimulus were also measured.

Insert Table 2 about here

As shown in Table 2, the stimuli differed significantly in all subjective ratings and in SCRs as assessed by a one-way ANOVA. The sample of boys and girls perceived the unpleasant sound to be in fact unpleasant as shown by a mean pleasantness rating of 2.03 on a scale of 0 (very unpleasant) to 8 (very pleasant). Moreover, the unpleasant sound was rated as more unpleasant than the loud tone and electric shock, both *t*s > 2.50, $p < .05$. On the other hand, the shock was rated as more arousing than the loud tone, $t = 4.39$, $p < .05$, but the unpleasant sound did not differ from any stimuli, all $p > .05$. The unpleasant sound and shock were both rated as more interesting than the loud tone, both *t*s > 4.89, $p < .05$, and the shock was also rated as more interesting than the blink-eliciting stimulus, $t = 4.13$, $p < .05$. Finally, skin conductance defence responses elicited by the shock were larger than those elicited by the unpleasant sound, tone, and blink-eliciting stimulus, all *t*s > 4.19, $p < .01$, which themselves did not differ, all $p > .05$. The magnitude differences seen in the SCRs may reflect the intensity of the stimulus in that the electric shock was set at a level determined by each individual to be "unpleasant, but not painful". This level was set during a shock work-up procedure and is the standard method to set the intensity of this stimulus in Pavlovian conditioning experiments. Because the shock intensity was "unpleasant, but not painful", it may have been perceived to be unpleasant because it is presented at just below the pain threshold. In contrast, the moderate intensity unpleasant sound may have been perceived to be unpleasant due to its qualitative features. Neumann and Waters (2006) observed a similar pattern of results in a sample of adult college students with the subjective ratings to that found in the present research with a mean pleasantness rating of 1.46 on the same rating scale. The similar ratings suggest that the sound is perceived to be unpleasant to a similar degree across a wide age range.

Conclusions

The stimulus of an unpleasant sound of metal on slate was shown to support conditioning. Although it was subjectively rated as unpleasant, it was tolerable and presented fewer ethical concerns than other commonly used aversive stimuli such as electric shock and loud tone. On the basis of the strength of the conditioning effects observed in this study, it would seem likely that the application of the unpleasant sound to examine conditioning in very young children or children and adolescents with neurodevelopmental disorders would be successful.

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Table 1

Mean startle blink magnitude (μV), ratings of unconditional stimulus (US) expectancy (%), skin conductance (√μS) conditioned response (SCR-CR) and unconditional response (SCR-UR) or its omission for the CS+ and CS- in both trial blocks during the conditioning and extinction phases and their associated statistical effects

Measure	CS+				CS-				ANOVA	Effect size
	Block 1		Block 2		Block 1		Block 2			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Conditioning										
Startle Blink	141.2	84.19	103.7	78.16	120.2	92.78	80.98	75.39	CS, F (1, 12) = 8.59, $p < .01$	$\eta_p^2 = .42.$
Expectancy	29.13	28.10	98.37	5.92	-38.93	37.68	-83.73	45.51	CS x Block, F (1, 14) = 29.05, $p < .0005$	$\eta_p^2 = .68$
SCR-CR	1.02	0.56	0.97	0.70	0.70	0.52	0.71	0.57	CS, F (1, 14) = 8.84, $p < .01$	$\eta_p^2 = .39$
SCR-UR	1.92	0.59	0.90	0.63	0.44	0.24	0.17	0.25	CS x Block, F (1, 14) = 31.13, $p < .0005$	$\eta_p^2 = .69$
Extinction										
Startle Blink	100.5	70.09	67.83	62.87	92.31	74.97	65.39	51.80	CS, F (1, 12) = 0.39, $p > .05$	$\eta_p^2 = .03$

Expectancy	34.30	34.37	-65.00	48.17	-55.57	40.34	-85.27	31.25	CS x Block, F (1, 14) = 28.44, $p < .0005$	$\eta_p^2 = .67$
SCR-CR	0.89	0.45	0.72	0.59	0.83	0.50	0.51	0.41	CS, F (1, 14) = 0.43, $p > .05$	$\eta_p^2 = .03$
SCR-UR	0.49	0.59	0.37	0.45	0.30	0.38	0.33	0.37	CS, F (1, 14) = 1.01, $p > .05$	$\eta_p^2 = .09$

Note– Expectancy ratings range on a scale where +100 indicates maximum expectation of the US and –100 indicates maximum expectation of no US. Skin conductance responses (SCRs) for the conditional response (SCR-CR) and unconditional response (SCR-UR) were square root transformed prior to analyses to normalise the distributions

Table 2

Mean subjective ratings for pleasantness, arousal, and interest, and mean skin conductance defence responses (√μS) for the unpleasant sound, shock, loud tone, and blink-eliciting stimulus and their associated statistical effects (standard deviations are in parentheses)

Measure	Stimulus								ANOVA	Effect size
	Sound		Shock		Loud tone		Blink-eliciting stimulus			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Pleasantness rating	2.03	2.11	3.47	1.85	3.73	1.16	3.17	1.94	F (3, 42) = 3.39, p < .039	η_p^2 = .19
Arousal rating	4.20	2.81	5.70	1.44	2.97	2.02	4.50	2.61	F (3, 42) = 6.51, p < .002	η_p^2 = .32
Interest rating	4.73	2.40	6.00	1.60	1.73	1.62	3.47	2.17	F (3, 42) = 17.67, p < .0005	η_p^2 = .56.
Skin conductance response	1.04	0.59	2.09	0.95	0.74	0.81	0.97	0.63	F (3, 42) = 11.63, p < .0005	η_p^2 = .45.

Note– Anchors for the ratings were for Pleasantness: 0 = very unpleasant to 8 = very pleasant; for Arousal: 0 = very calm to 8 = very arousing; and for Interest 0 = very boring to 8 = very interesting.