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## **Multiple Cue Extinction Effects on Recovery of Responding in Causal Judgments**

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Many experiments have demonstrated recovery of extinguished responding following a context change and some experiments have shown that extinction in multiple contexts can reduce this response recovery. We report two additional experiments which both showed reduced response recovery following extinction in the presence of multiple partner cues. These experiments also showed reduced response recovery following acquisition in the presence of multiple partner cues. The effect of the multiple extinction treatment was present in tests carried out in presence of the original training cue (ABA design) as well as in the presence of a novel test cue (ABC design), suggesting the effect was mediated by the associative strength of the target cue, rather than by the strength of the partner cue. However, the effect of the multiple acquisition treatment was only present in the ABA design, suggesting this effect was mediated by the associative strength of the partner cues, not by the strength of the target cue.

Pavlovian conditioning is a basic adaptive learning mechanism that is found throughout the animal kingdom. It has been studied intensively with invertebrates (e.g., Kandel & Schwartz, 1982) and vertebrates, including humans (e.g., Hugdahl & Ohman, 1980; Rescorla, 1988). The scope of the analysis to which the basic paradigm has been applied has also been extended from conditioning of simple behavioral responses to the cognitive processes underlying prediction and judgment (e.g., Shanks & Dickinson, 1987). Presumably the ubiquitous nature of this adaptive mechanism stems from the common problem of all organisms, to adjust their behaviors in response to environmental conditions.

However, although Pavlovian conditioning is essential for survival, it has also been implicated in the development and maintenance of a number of important clinical conditions, including phobias and addictions (Wikler, 1948; Wolpe, 1958). In both cases conditioned responses are said to be the basis of characteristic motivational and behavioral changes. For phobias, fear and anxiety responses are elicited by phobic stimuli whereas in addiction, drug-related cues elicit various responses which may be experienced as "craving". Given these similarities it is not surprising that treatments have been developed to extinguish these conditioned responses. Such treatments are commonly known as cue-exposure therapies and usually involve exposure to the target stimulus (e.g., spider or alcoholic drink) so that any reactions eventually decline. However, reviews indicate that there is a contrast in the effectiveness of cue-exposure treatments for phobias and addictions; cue-exposure for phobias is established and effective whereas for addiction evidence is lacking (Chambless & Ollendick, 2001; Conklin & Tiffany, 2002; Foa, Kozak, Tuma, & Maser, 1985). Nevertheless, in both cases, suggestions for improving treatment effectiveness have been geared towards

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reducing recovery of responding to the target when it is encountered once again outside of the extinction context. We briefly review evidence for the importance of response recovery in relapse and evidence for the effectiveness of multiple context extinction techniques to reduce response recovery. We then describe two new studies. There already exist some studies which suggest extinction of target cues in multiple contexts can reduce response recovery. Our new studies demonstrate that extinction in the presence of multiple local cues, rather than global contexts, may also be sufficient to reduce response recovery.

Experimental studies of learning with animals and humans, as well as clinical studies of relapse, suggest that recovery of responding may limit the effectiveness of cue-exposure treatments. For example, using rat subjects, Bouton and King (Experiment 1) paired a tone with electric shock in context A, then extinguished responding to the tone in context B, and finally re-presented the tone in context A. Although extinction appeared successful in context B with a marked reduction in responding over trials, responding recovered on return to A, the original training context (Bouton & King, 1983). The ABA design used by Bouton and King has potentially important implications for cue-exposure therapies owing to the parallels between their procedure and those that might be followed in cue-exposure treatments. For example, in one study of cue-exposure for alcohol dependence, patients were removed from their day-to-day environments (context A), received cue-exposure in a hospital setting (context B), and then returned to context A after treatment had finished (Drummond & Glautier, 1994). Although Drummond and Glautier found some evidence for a better outcome for the cue-exposure treated group over a control group, the effects were not large. Bouton and King's data suggest that responses to drink-related cues might well have been subject to recovery on return to context A and this may have served to undermine the intended therapeutic goals of the cue-exposure treatment.

More direct evidence for response recovery has been obtained in some clinical studies (Collins & Brandon, 2002; Mineka, Mystkowski, Hladek, & Rodriguez, 1999). After cue-exposure based reduction of fear responses to spiders in spider phobics, Mineka et al. found greater recovery of fear responses one week later if responses were tested in a different room to that used for the cue-exposure treatment. Using a much shorter interval (25min) Collins and Brandon (2002) found a similar result with a sample of moderate to heavy social drinkers. They observed greater recovery of salivary and urge responding to an alcoholic drink cue in a test following a period of cue-exposure if the test was carried out in a different room from that in which exposure had been carried out. Although of interest these studies are of limited value because they did not actually condition participants. Therefore we cannot be sure whether we are dealing with context affecting recovery of conditioned responding or some other phenomena (e.g., context switch producing dishabituation).

However, building on numerous studies of response recovery in animals (e.g., Bouton & King, 1983; Grahame, Hallam, Geier, & Miller, 1990; Nelson, 2002) there is now a growing number of carefully controlled experimental studies of response recovery in humans. These demonstrate context dependent recovery of

conditioned responding and provide a basis for detailed study of its mechanisms. A variety of paradigms have been used indicating the generality of the phenomena. Garcia-Gutierrez & Rosas (2003) used causal judgments, Havermans, Keuker, Lataster, & Jansen (2005) used conditioned suppression of an operant response, whereas the studies of Vansteenwegen et al. (2005), and Vervliet, Vansteenwegen, Baeyens, Hermans, and Eelen (2005), both used skin conductance conditioning. The advantage of these experimental studies is the additional control afforded in the learning, extinction, and testing phases. For example, although ABA designs are analogous to what might occur in clinical applications of cue-exposure treatment their interpretation is complicated by the fact that the associative strength of the test context might mediate response recovery (Bouton & King, 1983). Different design possibilities allow tests for this. For example an ABC design in which the final test is carried out in C, an associatively neutral context, can be used. It is noteworthy that Havermans et al. (2005) did not observe recovery effects in an ABC design whereas animal studies have demonstrated recovery effects in ABC designs (e.g., Bouton & Bolles, 1979). Experimental studies can also be used to evaluate suggestions to reduce recovery effects, and thereby improve outcomes after cue-exposure and one such suggestion is to conduct cue-exposure in multiple contexts (Conklin & Tiffany, 2002; Mineka, et al., 1999).

What is the basis for the suggestion to use multiple-context cue-exposure and is there any evidence that this type of procedure might reduce response recovery? The objective of cue-exposure in multiple contexts is to increase generalization of treatment gains beyond that which could be achieved by therapy conducted in a single context. There are several theoretical mechanisms that could operate to produce benefits for exposure in multiple contexts. First, based upon the principle that non-reinforced exposure to a target cue (phobic or drug-related stimulus) creates an ambiguity in the meaning of that cue which is resolved by context (Bouton, 1988, 1993, 1994) exposure therapy in multiple contexts could increase the number of control, or occasion-setting elements (Holland, Commons, Herrnstein, & Wagner, 1983), that gate an inhibitory link between representation of cue and outcome (e.g., sight of cigarette and effects of nicotine). Second, non-reinforced exposure to the target cues should reduce the associative strength of the target cues but according to at least one dominant model of associative learning (Rescorla & Wagner, 1972) should reduce the associative strength of all stimuli that are actually present. Thus, associatively neutral stimuli that are introduced with the therapeutic context could become inhibitory and protect the target stimulus from extinction (Lovibond, Davis, & O'Flaherty, 2000). Each time extinction is conducted in a different context some protective inhibitory stimuli will be absent, removing some protection from extinction, and allowing more complete extinction of the target cues. Finally, and particularly in the case of addiction where drug taking can occur in many different situations (Drummond, Tiffany, Glautier, & Remington, 1995), there may be many different target cues which have acquired associative strength and which should be subject to extinction. Use of multiple extinction settings is one way to maximize sampling of these targets.

Although there are several possible mechanisms by which multiple extinction contexts might produce more robust extinction, there is surprisingly little evidence for this happening. Three studies with rats produced a mixture of evidence. In a flavor aversion study Chelonis et al. found that extinction in three different contexts resulted in more consumption of the illness-paired flavor on a test in the original context (ABA design) than did extinction in a single context (Chelonis, Calton, Hart, & Schachtman, 1999). Using an ABC design, Gunther, Denniston, and Miller (1998) reported less suppression of drinking in thirsty rats after presentation of a shock-paired conditioned stimulus (CS) if that CS had been extinguished in three different contexts than if it had been extinguished in a single context. Running against both of these results, using suppression of food reinforced lever pressing by a shock-paired CS, Bouton et al. found no evidence for reduced recovery following multiple context extinction using both ABA and ABC designs (Bouton, Garcia-Gutierrez, Zilski, & Moody, 2006). In humans, Pineño and Miller studied ABC recovery in a causal learning scenario in which participants had to learn which cues enabled them to rescue refugees in a computer game setting (Pineño & Miller, 2004). Once participants learned which cues signaled their rescue attempts would be successful these cues were extinguished in the original learning context, in a new context, or in three new contexts. In a recovery test, extinction was found to be more robust following the multiple context extinction treatment. However, most recently, Neumann, Lipp, and Cory (2007) did not find any evidence of recovery reduction after multiple context extinction using a shock expectancy conditioning procedure and an ABA design. The data on effects of multiple context extinction on reduction of recovery is also mixed when clinical studies are considered. Two studies with spider phobias have found an advantage of multiple context exposure over single context exposure (Rowe & Craske, 1998; Vansteenwegen, Vervliet, Iberico, Baeyens, Van den Bergh, & Hermans, 2007). In contrast, Lang and Craske (2000), using subjects with fear of heights, did not find any advantage in the multiple context condition.

The current studies set out to continue the exploration of recovery effects in humans, and to further investigate the multiple context extinction effects that have been reported. One novel feature of the experiments that we report is that we explore recovery effects following manipulation of discrete local partner cues whereas previous studies have focused on global contexts (e.g., rooms). A detailed discussion of the local/global cue distinction is beyond the scope of this paper (but see Gallistel, 1990 for an account of global geometric cues) but we note that when contexts have been manipulated in previous studies global cues (e.g., shape of room) have been changed alongside various local features. For example, Gunther et al.'s (1998) contexts differed in overall shape geometry, as well as in terms of more local cues, including the materials used for the flooring and walls. Thus, we consider whether or not recovery effects can be obtained by manipulation of discrete local partner cues, as opposed to global contexts. In addition, we ask whether or not extinction in the presence of multiple partner cues can reduce response recovery. Finally, a particular focus of this investigation was the additional examination of multiple acquisition conditions. As mentioned above,

particularly in the case of addiction, the target behavior is likely to occur in many different contexts and in the presence of many discrete cues (Drummond et al., 1995). Discussion of the potential effects of multiple context extinction is explicitly based upon the idea that learning (extinction) may be more robust and show greater generalization to new settings. However, it seems possible that multiple context acquisition might also be more robust (Chelonis et al., 1999; Schmidt & Bjork, 1992). The immediate implication for the current discussion is whether or not any advantage of multiple cue extinction is present under single as well as multiple acquisitions conditions. In Experiment 1 single and multiple extinction conditions were compared after learning in a single acquisition condition, and the effect of extinction in the presence of a single partner cue was examined after single and multiple acquisition conditions. In Experiment 2 single and multiple acquisition conditions were combined factorially with single and multiple extinction conditions. Experiment 1 used an ABA design whereas Experiment 2 incorporated ABA and ABC designs.

## **Experiment 1**

This experiment and the next examined the effects of exposure to single and multiple partner cues during acquisition and extinction phases of a causal judgment task. Recovery of responding to a target cue as a function of its partner cue treatment was the primary focus. All experiments were approved by the Southampton University School of Psychology Ethics Committee.

## **Method**

### ***Participants***

Twenty-one participants took part after responding to advertisements posted on the University of Southampton campus and word-of-mouth requests. They received course credit on completion. Their average age was 22 years and they included four males.

### ***Apparatus and stimuli***

During the experiment participants operated IBM-compatible PCs with 17 (38.1 cm) inch color monitors running in 800 (width) x 600 (height) pixel resolution. Stimuli serving as cues were 26 images of various cakes and sweets (e.g., candy bar or cream cake) or 26 images of various cheese and mushrooms (e.g., shitake mushroom or cheddar cheese) depicted in 100 x 100 pixel, 8-bit color bitmaps that occupied squares with 3 cm (approximate) sides that were presented in the top half of the screen, centered horizontally. Presentation of each cue was accompanied by a 1s auditory alerting bleep. Outcome information and instructions during the rating phases were presented in the lower part of the screen.

### ***Design, procedure, and analysis***

On arrival participants were given a brief verbal description of the procedure before reading and signing a consent form. Before starting the experiment participants were given a more detailed verbal description of the procedure. This information was presented once again, on-screen, when participants were asked to read the following description before starting:

In this experiment your job is to learn the extent to which each of various foods produce sickness. You play the role of a doctor investigating recent reports of food poisoning. The food poisoning is believed to be linked to cheese and mushrooms [*or cakes and sweets*] purchased at a local market and in order to track the source of the poisoning you have interviewed people who have recently eaten various cheese and mushrooms [*or cakes and sweets*] purchased from the market. You are reviewing the information you have collected on a case by case basis. For each case you have information on which foods were eaten and whether or not the person was well or sick after eating. Your job is to learn the extent to which each of the foods might be a cause of sickness. Note, the sequence of trials is randomly ordered so you can only predict sickness by learning about the food items themselves. At various points you will be asked to indicate what your Judgments are. When you have to make a Judgment this will be signalled on the screen. All you have to do is follow the onscreen instructions and enter a number that reflects your Judgment. Instructions will be given on how to make your rating, please take care to read all of the instructions carefully. Once you have made your judgment press return to carry on. Press a key to continue.

All participants were then presented with two blocks of 96 trials. Each block was divided into two stages. Stage 1 consisted of 24 acquisition trials plus 24 “filler trials”. The filler trials were included so that there was a mixture of non-reinforced and reinforced trials. Stage 2 consisted of 24 extinction trials and 24 filler trials. Within each stage the order of trials was randomized separately for each participant subject to the constraint that no more than six trials of each type could occur in sequence. Procedurally, each trial started with a 3s presentation of food stimuli. The screen was then cleared and outcome information was shown for 2s. The outcome information consisted of the words “After eating this food the person was:” followed by either “well” or “SICK” according to the design. Reinforced trials were designated “SICK” and non-reinforced trials were designated “well.” The screen was then cleared for a 1s interval before the next trial began.

Participant ratings of the extent to which the various foods caused sickness were obtained during test trials that occurred immediately after Stage 1 and after Stage 2 of each block. On test trials items were presented accompanied by the following instructions:

To what extent do you think this food [*or these foods*] would cause sickness? Use a scale of 0 to 100. 0 means “not a cause.” 100 means “very strong cause.” Use any number 0-100 to make your rating.

The food remained on display until the judgment was made and the next test trial followed after a delay of 1s.

All participants were tested under conditions of (a) single acquisition and single extinction contexts (SASE), (b) single acquisition and multiple extinction contexts (SAME), and (c) multiple acquisition and single extinction contexts (MASE). These treatments are illustrated in Table 1. In Block 1 half of the participants received SASE and SAME trials (columns 2 and 3 of Table 1)

whereas the other half received SASE and MASE trials (columns 4 and 5 of Table 1). Participants presented with SASE and SAME trials in Block 1 received SASE and MASE trials in Block 2. Participants presented with SASE and MASE trials in Block 1 were presented with SASE and SAME in Block 2. All participants were also exposed to two different types of foods; cakes and sweets & cheese and mushrooms. If cakes and sweets were used in Block 1 then cheese and mushrooms were used in Block 2 or vice-versa. The assignment of food type to block was arranged in a counterbalanced fashion across conditions. For each participant the particular images assigned to different cue functions were selected at random from the available pools of 26 items.

Referring to Table 1 to illustrate the SASE and SAME conditions, two target cues (A and B) were reinforced in Stage 1 and non-reinforced in Stage 2. During Stage 1 A always occurred in the presence of another food (E) serving the role of partner cue whereas F served as the partner for B. During Stage 2 A and B were extinguished. Extinction of A took place with a single partner K, whereas extinction of B took place with multiple partners L, M, and N. The filler trials presented during the acquisition and extinction phases of Block 1 and Block 2 consisted of 12 UV-, 6 WX-, and 6 WX+ trials.

Test trials were carried out at the end of Stage 1 and at the end of Stage 2. As with the learning trials, test orders were randomized separately for each participant. At the end of Stage 1 ratings were obtained for compounds AE, BF, CG, and DH and for filler items UV and WX. At the end of Stage 2 A, B, C, and D were again rated with their original training partners (AE, BF, CG, and DH). These tests were for recovery of responding: A, B, C, and D were also rated in their extinction contexts (AK, BL, CO, and DP). Thus, for cues A-D, we have **ABA** designs. In the cases of A, C, and D the extinction phase was carried out with a single partner whereas extinction of B was carried out with three partners. In the cases of A, B, and C acquisition was carried out with a single partner whereas for D, acquisition occurred with three partners.

Data from Test 1 was subject to a preliminary analysis to determine whether or not participants had successfully learned the contingencies that were in force during Stage 1. A 4 (Cue: AE/CG, BF/DH, UV, and WX) x 2 (Condition: single acquisition or single extinction) repeated measures analysis of variance (ANVOA) was computed. The principal analysis was carried out on the data from Test 2. The aim was to assess whether or not there was a recovery effect. This would be revealed in a difference in response to targets A-D presented with different test partners. We also tested whether any recovery effect varied as a function of single and multiple partner exposure and/or as a function of the location of the multiple partner treatment. The data was subject to a 2 (Condition: single acquisition or single extinction) x 2 (Partner: single or multiple) x 2 (Test: extinction or recovery) repeated measures ANOVA. Follow-up t-tests were used where appropriate.

**Table 1**

*Single and multiple partner-cue treatments during the acquisition and extinction phases of Experiment 1. Plus signs indicate reinforced trials, minus signs, non-reinforced. Numbers in parentheses indicate the number of trials of each type.*

	Condition			
	Single acquisition		Single extinction	
	Single extinction	Multiple extinction	Single acquisition	Multiple acquisition
Stage 1	AE+ (12)	BF+ (12)	CG+ (12)	DH+ (4)
Acquisition				DI+ (4)
				DJ+ (4)
Stage 2	AK- (12)	BL- (4)	CO- (12)	DP- (12)
Extinction		BM- (4)		
		BN- (4)		

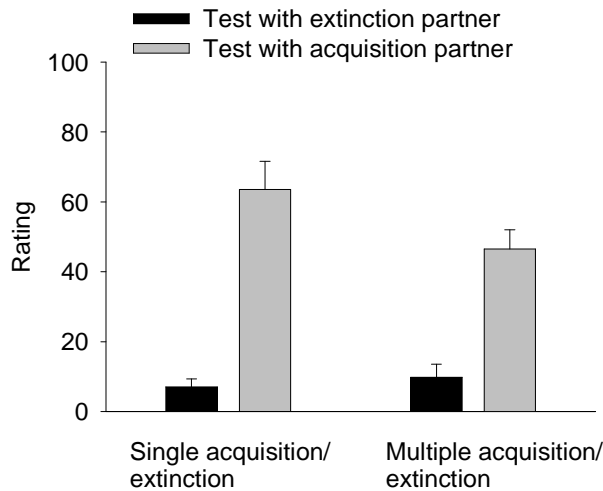


## Results

The preliminary analysis of Test 1 data with a 4 (Cue) x 2 (Condition) repeated measures ANOVA produced a significant effect of cue ( $F(3,60) = 226, p < 0.001$ ), a significant effect of condition ( $F(1,20) = 5.98, p < 0.05$ ), but no significant interaction ( $F(3,6) = 1.57$ ). The effect of cue was produced by differences in ratings for foods associated with different reinforcement contingencies. The average of AE and CG, of BF and DH, and of UV and WX had means of 95.8, 91.9, 50.0, and 6.0 respectively. These ratings showed that participants had learned the contingencies that were in force for the different cues. Follow-up t-tests showed significant differences between all pairs except AE/CG and BF/DH ( $ts(20) > 9.9, ps < 0.001$ ). The effect of condition was caused by higher overall ratings for the cues in the single acquisition condition than in the single extinction condition: The means were 63.3 and 58.7, respectively.

The data from Test 2 was subject to a 2 (Condition) x 2 (Partner) x 2 (Test) repeated measures ANOVA. This produced a significant effect of test ( $F(1,20) = 41.6, p < 0.001$ ) indicating recovery: Ratings for cues with their extinction partners (AK/BL/CO/DP  $M = 8.45$ ) were lower than in with acquisition partners (AE/BF/CG/DH  $M = 55.1$ ). Critically, the analysis also revealed a significant Partner x Test interaction ( $F(1,20)=12.8, p < 0.01$ ) showing that the size of the recovery effect varied as a function of whether or not the cue had been presented with multiple partners. It did not matter whether the multiple partner treatment occurred during acquisition or extinction; no three way Condition x Partner x Test interaction was present ( $F(1,20) < 1.0$ ). No other effects emerged except that there was a marginal effect of partner ( $F(1,20) = 4.08, p = 0.06$ ) that suggests the overall ratings during Test 2 were lower for the compounds containing B and D, which had been exposed to multiple partners either during the acquisition or extinction phase.

Figure 1 illustrates the Partner x Test interaction. Follow-up t-tests showed a significant increases ( $ts(20) > 5.3, ps < 0.001$ ) between extinction and return to original acquisition compounds for the single partner (AK/CO  $<$  AE/CG) and for the multiple partner conditions (BL/DP  $<$  BF/DH). There were no differences at extinction (AK/CO = BL/DP) but there were differences with the original partner (AE/CG  $>$  BF/DH) ( $ts(20) = 1.2$  and  $2.9, ps = 0.26$  and  $< 0.01$ , respectively).



*Figure 1.* Data from Experiment 1 showing that there was a smaller recovery effect when changing between extinction and acquisition if the target cue had been paired with multiple partners than when paired with a single partner, whether or not multiple exposure occurred at acquisition or at extinction.

## Experiment 2

Experiment 1 appeared to show that response recovery was affected when a cue had been experienced with multiple partner stimuli. After extinction, pairing with the original partner produced an increase in responding. This effect was reduced if the target cue had been paired with multiple partners, whether or not this had been during acquisition or during extinction. As indicated in the introduction, there were some grounds for suspecting less recovery following multiple partner extinction. However, although there is limited data on this point, the opposite expectation was in force for the multiple partner acquisition condition but no evidence for this type of interaction was found.

The current experiment was run with the intention of replication and further exploration of the results of Experiment 1. In particular recovery tests were carried out, not only in the original partner cues, but also with novel cues in order to assess the strength of the target cues without the influence of possible differences in strength of the partners inherent in **ABA** designs. Therefore, during Test 2, additional tests were carried out to implement an **ABC** design. In addition, tests of the partner cues were carried out in isolation to independently assess their strength. Finally, the design of Experiment 1 was extended to allow assessment of the effects of multiple partner exposures occurring in both acquisition and extinction phases.

## Method

Differences from Experiment 1 are noted below.

### *Participants*

Twenty participants took part. Their average age was 21 years (range 18-30) and they included three males.

### *Design and analysis*

After introduction to the experiment all participants were presented with two blocks of 64 trials. The overall number of trials in each block was reduced from the number used in Experiment 1 by only including eight filler trials (4 UV-, 2 WX-, and 2 WX+) in each stage. All participants were tested in a fully within subjects crossing of two factors, single and multiple partner conditions at acquisition and extinction. Table 2 illustrates the design. Columns two and three of Table 2 show the single extinction partner conditions. Both cues A and B were extinguished in Stage 2 with a single partner. Cues A and B differed, however, in their treatment during Stage 1. Stage 1 acquisition for A occurred with a single partner, whereas for B acquisition occurred with three different partners. During Test 2 both cues were tested with their extinction partners (M/N) and with their original partners (E/F) for one test – the **ABA** design. Both cues also had tests carried out with a novel partner (Y) to make the **ABC** design. Columns four and five of Table 2 illustrate the multiple extinction partner conditions. Cues C and D were both extinguished with multiple partners but they differed in their acquisition treatment. Acquisition for C was with a single partner whereas for D multiple acquisition partners were used.

A preliminary 2 (Acquisition: single or multiple) x 2 (Extinction: single or multiple) repeated measures ANOVA was carried out on test items AE, BF, CI, and DJ using Test 1 ratings to examine the equivalence of the conditions after acquisition. This was followed up by two main analyses comprising two 2 (Acquisition: single or multiple) x 2 (Extinction: single or multiple) x 2 (Test: extinction or recovery) repeated measures ANOVA. One of these ANOVAs used the original partner ratings (AE/BF/CI/DJ) for the recovery test (**ABA** design) the other used novel partner ratings (AY/BY/CY/DY) for the recovery test (**ABC** design). Finally a 2 (Acquisition: single or multiple) x 2 (Extinction: single or multiple) repeated measures ANOVA was carried out on the partner cues (E/F/I/J) to determine what role these elements may have had in mediating the results of the ABA design.

**Table 2**

Single and multiple partner-cue treatments during the acquisition and extinction phases of Experiment 2. Plus signs indicate reinforced trials, minus signs, non-reinforced. Numbers in parentheses indicate the number of trials of each type.

	Condition			
	Single extinction		Multiple extinction	
	Single acquisition	Multiple acquisition	Single acquisition	Multiple acquisition
Stage 1	AE+ (12)	BF+ (4)	CI+ (12)	DJ+ (4)
Acquisition		BG+ (4)		DK+ (4)
		BH+ (4)		DL+ (4)
Stage 2	AM- (12)	BN- (12)	CO- (4)	DR- (4)
Extinction			CP- (4)	DS- (4)
			CQ- (4)	DT- (4)

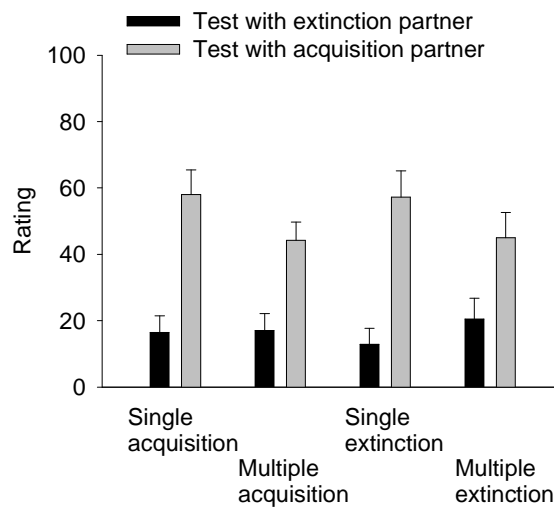
## Results

The 2 (Acquisition) x 2 (Extinction) repeated measures ANOVA confirmed that the ratings of AE, BF, CI, and DJ were equivalent after acquisition. Neither main effect, nor the interaction, was significant ( $F(1,19) < 1.9$ ). For AE, BF, CI, and DJ the means were 93.8, 91.5, 96.0, and 88.0 respectively.

Next the Test 2 data was subject to the two 2 (Acquisition) x 2 (Extinction) x 2 (Test) repeated measures ANOVAs. The first was for the **ABA** design and the second was for the **ABC** design. For the **ABA** design the ANOVA showed significant effects of test and acquisition ( $F(1,19) = 24.6, p < 0.001$  and  $F(1,19) = 5.38, p < 0.05$  respectively). The main effect of test showed that there was a recovery effect; ratings were higher with the original acquisition partners (AE/BF/CI/DJ) than with the extinction partners (AM/BN/CO/DR). The main effect of acquisition showed that there were higher ratings for test compounds AE/AM/CI/CO than BF/BN/DJ/DR, the difference between them being that the latter named had their original acquisition with multiple rather than single partners. Importantly, for the hypotheses under test, the effect of test was subject to an interaction with the acquisition condition ( $F(1,19) = 7.29, p < 0.05$ ) and there was a marginally significant interaction with the extinction condition ( $F(1,19) = 3.94, p = 0.06$ ). These two-way interactions, coupled with the absence of a three-way interaction ( $F(1,19) < 1$ ) replicated the results of Experiment 1. Exposure to multiple partners, either during acquisition or extinction phases, results in greater recovery effects.

Figure 2 shows the Acquisition x Test interaction in the first and second bar pairs. Follow-up t-tests showed significant recovery effects in both the single (AM/CO < AE/CI) and multiple (BN/DR < BF/DJ) acquisition partner conditions ( $t(19) > 3.8, ps < 0.01$ ). The single and multiple partner acquisition conditions

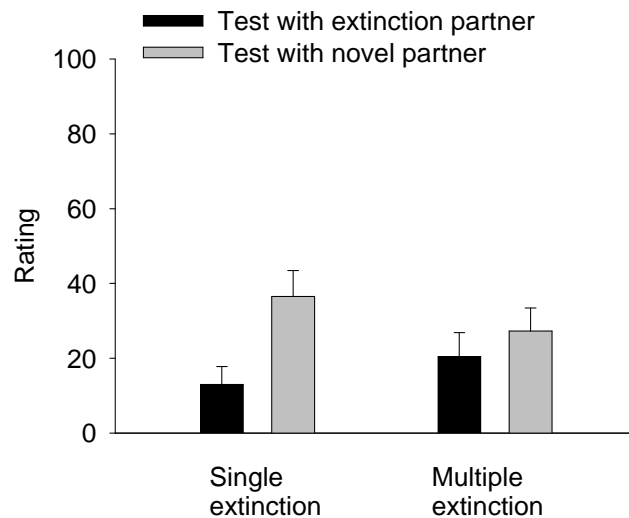
(AM/CO = BN/DR) did not differ at extinction ( $t(19) = 0.31$ ) but there was higher rating on retest with the original partner in the single condition ( $t(19) = 2.61, p < 0.05$ ) indicating more recovery (AE/CI > BF/DJ) in this condition. The third and fourth bar pairs show the Extinction partner x Test interaction. Follow-up t-tests showed significant recovery effects in both the single (AM/BN < AE/BF) and multiple extinction (CO/DR < CI/DJ) conditions ( $ts(19) > 2.76, ps < 0.05$ ). The single and multiple extinction conditions (AM/BN = CO/DR) did not differ at extinction ( $t(19) = 1.46$ ) and their ratings remained equivalent on return to the original partner ( $t(19) = 1.22$ ) indicating equal recovery (AE/BF = CI/DJ) in these conditions.



**Figure 2.** Data from Experiment 2 (ABA design) showing there was a smaller recovery effect between the extinction and acquisition if the target cue had been paired with multiple partners than when paired with single partners. The first and second pairs of bars show this effect in acquisition conditions whereas the third and fourth pairs show the effect in extinction.

For the ABC design the ANOVA produced a significant effect of test ( $F(1,19) = 12.9, p < 0.01$ ) and a Test x Extinction interaction ( $F(1,19) = 5.02, p < 0.05$ ). The effect of test showed a recovery effect and the Test x Extinction interaction indicated less recovery under multiple extinction partner conditions. The three-way interaction was not significant ( $F(1,19) < 1$ ). Figure 3 illustrates the Test x Extinction interaction. The two-way interaction was explored further using t-tests. The recovery effect was significant in the single extinction condition (AM/BN < AY/BY) ( $t(19) = 4.40, p < 0.001$ ) but not in the multiple extinction condition (CO/DR = CY/DY) ( $t(19) = 1.14$ ). Additional comparisons showed that the two extinction conditions were equivalent (AM/BN = CO/DR) and the two recovery tests were equivalent (AY/BY = CY/DY) ( $ts(19) = 1.46$  and  $1.28$ , respectively).

A final 2 (Acquisition) x 2 (Extinction) ANOVA was carried out on the partner cues (E/F/I/J) to determine their role in the pattern of data in the ABA design. There was a main effect of acquisition ( $F(1,19) = 15.4, p < 0.01$ ) but neither the effect of extinction, nor the Acquisition x Extinction interaction reach significance ( $F_s(1,19) < 2.48, p_s > 0.13$ ). The acquisition effect was produced by higher ratings for the single acquisition partner cues (E/I) than for the multiple acquisition partner cues (F/J) with means of 60.4 and 38.1, respectively. Returning to the first two bar pairs in Figure 2, where the ratings with the original partner were higher in the single acquisition condition than in the multiple acquisition condition, this difference may have been due to the difference in the partner rather than target cues. This is supported by the analysis of the ABC design, where the Acquisition x Test interaction was no longer significant, as it had been in the ABA design analysis. In contrast, the Extinction x Test interaction was marginally significant in the ABA analysis and significant in the ABC analysis.



**Figure 3.** Data from Experiment 2 (ABC design) showing there was a smaller recovery effect between the extinction and novel test condition when the target cue had been paired with multiple partners than when paired with a single partner during extinction.

### Discussion

The current report joins the growing body of literature showing recovery effects in humans (e.g., Garcia-Gutierrez & Rosas, 2003; Havermans et al., 2005; Vansteenwegen, et al., 2005; Vervliet, et al., 2005) and adds to those studies which have demonstrated reduced recovery following multiple-context extinction (Chelonis, et al., 1999; Gunther, et al., 1998; Pineño & Miller, 2004). Taken in conjunction with clinical studies (Collins & Brandon, 2002; Mineka et al., 1999; Rowe & Craske, 1998; Vansteenwegen et al., 2007) the emerging picture certainly warrants serious investigation of recovery effects in relapse and of the possible role

for multiple-context cue-exposure treatments. In addition, it seems as though similar effects might be obtained if extinction is carried out in the presence of multiple discrete cues, as well as multiple contexts. It is of interest to establish what factors may be at work when some studies of multiple-context extinction have not shown recovery reduction (Bouton et al., 2006; Lang & Craske, 2000; Neumann et al., 2007).

It was suggested in the introduction that acquisition of conditioned responding with multiple partner cues or contexts could minimize the effectiveness of extinction. However, the current experiments found no support for this. Acquisition of conditioned responding with multiple partner cues was not crucial as far as target cues were concerned. Although Gunther et al. (1998) suggested it may be necessary to maintain a 1:3 ratio of acquisition to extinction contexts for effective recovery reduction this effect was not present in the current studies using partner cues. Clearly, the reasons for the differences between the studies should be explored as discounting the possible effects of multiple acquisition conditions on the basis of one positive and one negative result would be premature. Obvious differences to explore would include the use of more global context-cues versus the partner-cues used in the current studies, and also the use of an electric shock versus a relatively innocuous outcome as an unconditioned stimulus. However, it was found that multiple-acquisition partners did play role when an ABA design was used. Single-acquisition partner cues gained more strength than multiple-acquisition partner cues. The clinical implication is that a target behavior that is tied to very specific cues may be especially vulnerable to relapse if those cues are encountered again so steps to deal with this eventuality should be considered by therapists.

Apart from these practical considerations the theoretical explanations for recovery effects have been the subject of considerable research. Bouton has argued strongly, and provided supporting data, to suggest that context can work to produce recovery effects by gating the inhibitory associations that are produced between the target cue and the outcome during extinction (Bouton, 1993). Whilst this mechanism may operate in typical animal studies where the whole experimental chamber is changed between experimental phases other mechanisms may also operate. As mentioned in the introduction target cues may be protected from extinction by the growth of inhibitory strength of cues present in the extinction phase, and extinction may only involve a subset of relevant targets. Recovery effects produced by the latter two mechanisms would fall within the explanatory reach of standard elemental (Rescorla & Wagner, 1972; Wagner, 2003) and configural (Pearce, 1994) associative theories and would be likely applicable to the types of discrete partner cues employed here. Recovery effects based upon an occasion-setting mechanism would require additional theoretical machinery and may be more likely to involve global context cues than local cues. However, it is also possible that a mixture of associative and occasion setting functions can be acquired by stimuli. Bouton and Nelson (1994) reported experiments with rats in which the feature in a feature negative procedure (T+, LT-) acquired both types of control over responding. They used a global cue

(offset of the houselight in the conditioning chamber) but it seems entirely possible that local cues of the type used in the current studies could also carry more than one function. Nevertheless, the current experiments, although demonstrating recovery effects, do not show which mechanism, associative or modulatory, was involved. Whatever the mechanism these data support the view that recovery effects could be important in relapse and suggest one way to improve cue-exposure treatment outcomes.

Finally, it is worthwhile mentioning the point of departure from the introduction. There it was noted that Pavlovian processes play a role in the development and maintenance of various clinical conditions and this paper has explored how an analysis in these terms can be used to investigate a suggestion for improvements to therapy. We have already briefly discussed some of the theoretical questions of mechanism that remain unanswered but what about the implications for our understanding of the survival value of Pavlovian conditioning? Bouton has proposed that there is an adaptive value in the second-learned meaning of a stimulus being context-dependent, so that the first-learned becomes the context-free “default” (Bouton, 1994, 1997). Of course the first-learned meaning of a stimulus is likely to be the most frequent in the environment so making this the unconditional meaning is efficient but it won’t work in all situations. Sometimes the least frequent meaning might be wrongly set as first-learned default. In that case it makes sense for there to be a mechanism by which a second-learned association can lose its contextual dependency; exposure to that second meaning in multiple contexts is a candidate mechanism for loosening contextual control.

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