

# Contextual control of the retardation of flavour aversion learning by preexposure to the unconditioned stimulus: Acquisition or retrieval deficit?

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## ABSTRACT

Two experiments, using rats as the subjects, and flavour aversion learning with an injection of lithium chloride (LiCl) as the unconditioned stimulus (US), examined the effects of a context shift between phases of the procedure on the retardation of learning produced by preexposure to the US. Experiment 1 showed that the US-preexposure effect (the reduction in the size of the conditioned aversion) was not attenuated when the animals were given both preexposure to the US and the conditioning procedure in a novel context but received the test phase in a different context (the home cages). Experiment 2 showed that, after degrading the injection cues–illness association by interpolating saline injections between LiCl preexposures, the US-preexposure effect was attenuated when there was a context shift between preexposure and conditioning, but that the context shift was without effect when it occurred between conditioning and test. These results are consistent with the proposal that US preexposure obtained in this procedure has its effect by interfering with the formation of the target association; they provide no support for the suggestion that the effect depends on interference at the test stage.

## 1. Introduction

Retarded classical conditioning after prior exposure to the event to be used as the unconditioned stimulus (US) is readily obtained in experiments with rats that use the flavor-aversion procedure (see Riley and Simpson, 2001, for a review). Analysis of the source of this US-preexposure effect (Hall, 2009) has supported an explanation in terms of blocking. Exposure to the event to be used as the US, commonly an injection of a nausea-inducing agent (usually LiCl), means that the state of nausea is preceded by a set of contextual cues. These cues will also be present when the US is presented following the flavor intended as the conditioned stimulus (CS) on a subsequent conditioning trial; they can thus act to block conditioning to that CS. When the procedure is carried out in a fully familiar environment (the rat's home cage) the critical blocking cues have been shown to be those directly associated with the injection procedure (de Brugada et al., 2004). When the procedure is carried out in a separate, distinctive environment, different from the home cage, blocking depends, at least in part, on the contextual cues that constitute this environment. It has been repeatedly demonstrated that the US-preexposure effect can be found when conditioning occurs in the distinctive context used for preexposure, but not when the

rats are returned to the home cage for conditioning and the test (Batson and Best, 1979; Dacanay and Riley, 1982; Domjan and Best, 1980; Willner, 1978). That is, the effect requires the presence of the cues that formed the context of preexposure.

Traditional views of associative learning (e.g., Rescorla and Wagner, 1972) have interpreted this and other instances of blocking as being a consequence of a failure of acquisition by the blocked stimulus. For the US-preexposure procedure, the suggestion is that the acquisition of associative strength by the contextual cues will preclude acquisition by the flavour cue when these occur together on subsequent conditioning trials. An alternative interpretation of blocking, and therefore of the US-preexposure effect, comes from theories that attribute blocking to processes that operate at the time of the test. Perhaps the best developed is Miller's "comparator" theory (e.g., Denniston et al., 2001; Stout and Miller, 2007). This attributes the blocking effect to a failure of retrieval (see, e.g., Balaz et al., 1982). As applied to the US-preexposure effect, the proposal is that the preexposure and conditioning phases of the procedure generate independent memories of the context-US and the CS-US relations. Although the CS-US association will be well formed during conditioning, the memory of the preexposure experience (the context-US association) will interfere with retrieval at the time of

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testing. This hypothesis is not inconsistent with the idea that the source of the US-preexposure effect is the context-US association formed during preexposure; it differs from the more standard blocking account in supposing that this association exerts its effect during test, rather than during acquisition. Thus both interpretations of blocking can accommodate the findings, described previously, showing that a change of context between preexposure and the other phases of the procedure results in an attenuation of the US-preexposure effect. If the preexposure context is not present in the conditioning and test phases, the context-US association cannot interfere with either acquisition or retrieval of a CS-US association.

An obvious strategy for assessing rival accounts of the US-preexposure effect (and one that has been used with success in investigating parallel issues with respect to the effect of CS preexposure; e.g., Aguado et al., 1994; Westbrook et al., 2000) is to manipulate the physical context used in the different phases of the training procedure. Blocking produced by acquisition failure, a failure that occurs during the conditioning phase of the procedure, should still be evident even when the context used for the test is different from that used for preexposure and conditioning. The retrieval failure account, on the other hand, requires the cues present during preexposure and conditioning to be present during the test.

## 2. Experiment 1

Studies of the US-preexposure effect in flavor-aversion learning have three phases: initial US exposure, flavor-US conditioning, and testing the aversion to the flavor. Most experiments on the context-blocking effect in this paradigm have used the same (novel) context throughout (call this AAA, with each letter representing one of the three phases) in order to demonstrate the standard effect; and they have demonstrated the role of context by shifting to a different context (i.e., ABB) for the conditioning and test phases. In the studies cited above, context B has been the familiar home cage. The present experiment follows this same scheme except that the subjects experiencing the change of context did so only for the test (i.e., they received AAB). In line with previous work we have used the familiar home cage as the test context for those subjects given a change of context. Of the accounts of the role of contextual factors discussed above, the proposal that US-preexposure blocks the acquisition of strength by the CS predicts that the size of the effect will be unaffected by this context shift; interference at the time of test predicts attenuation of the effect.

The treatment given to the four groups is summarised in the top section of Table 1. All animals received a saccharin solution as CS and LiCl as US. The preexposure groups (AAA-Pre and AAB-Pre) received three LiCl injections during the preexposure stage. The control groups (AAA-Cont and AAB-Cont) received injections of saline in this phase. Groups AAA (Pre and Cont) spent all three phases of training in a novel

**Table 1**  
Experimental Designs.

Groups	Preexposure	Conditioning	Test
<i>Experiment 1</i>			
AAA-Pre	A: LiCl	A: Sac-LiCl	A: Sac
AAA-Cont	A: Sal	A: Sac-LiCl	A: Sac
AAB-Pre	A: LiCl	A: Sac-LiCl	B: Sac
AAB-Cont	A: Sal	A: Sac-LiCl	B: Sac
<i>Experiment 2</i>			
AAB-Pre	A: LiCl, B: Sal	A: Sac-LiCl, B: W	B: Sac
AAB-Cont	A: Sal, B: Sal	A: Sac-LiCl, B: W	B: Sac
ABB-Pre	A: LiCl, B: Sal	B: Sac-LiCl, A: W	B: Sac
ABB-Cont	A: Sal, B: Sal	B: Sac-LiCl, A: W	B: Sac

*Note.* Pre = preexposed; Cont = control; A and B different contexts; LiCl = injection of lithium chloride; Sal = saline injection; W = water; Sac = saccharin. In Experiment 1, context A was novel and context B was the home cage; in Experiment 2 both A and B were novel.

and distinctive context. Groups AAB (Pre and Cont) spent the pre-exposure and the conditioning phases in the novel context and received the test in their home cages. The question of central interest was whether the groups preexposed and conditioned in the novel context and tested in the home cage would show a reduction in the size of the US-preexposure effect.

### 2.1. Method

#### 2.1.1. Subjects and apparatus

The subjects were 32 naive female Wistar rats, with a mean weight of 196 g at the start of the experiment. They were housed in individual home cages (context B) with continuous access to food throughout the experiment and maintained on a water deprivation schedule. The home cages measured 50 cm long x 26 cm wide x 14.5 cm high, and were kept in a large colony room under a 12-h light/12-h dark illumination cycle, with the lights coming on at 8:00 am. All experimental treatments were given during the light period of the illumination cycle. The walls and floors of these cages were made of translucent plastic and the roof of wire mesh; a layer of wood shavings covered the floor. A second set of cages located in a separate small room in the laboratory served as the novel context (context A). The room was dimly illuminated by a 40-W red bulb positioned in a corner close to the cages and contained a speaker supplying a background white noise of 80 dB close to the cages. The walls and floor of these cages were made of opaque grey plastic. The cages were 32 cm long x 22 cm wide x 12 cm high. The floor was covered with commercially obtained cat litter. Fluids were administered at room temperature in a 50-ml plastic centrifuge tube with a rubber stopper fitted with a stainless steel ball-bearing tipped spout. Fluid consumption was measured by weighing the tubes before and after fluid presentation. The unconditioned stimulus was an intraperitoneal injection of 0.15 M LiCl at 20 mL/kg of body weight. Animals from the control groups received saline at 20 mL/kg. The flavor was a solution of 0.1 % sodium saccharin.

#### 2.1.2. Procedure

All the procedures explained here were approved by the Animal Research Ethics Committee (CEEA) from the University of Granada (number 06/06/2019/099). Before the start of training, the animals were subjected for 3 days to a water-deprivation schedule, with access to water, presented in the same tubes as were used later for treatments, being allowed for a period of 30-min. The drinking period began at 11.00 h. In subsequent phases of the experiment, either water or flavoured solutions were presented at that time. Animals also were given an additional 30-min period of access to water at 17.00 h on the conditioning day and on the recovery day that preceded the test.

During the three preexposure days, all subjects were transferred to the novel (A) cages at 11.00 h and were allowed access to water for 30 min. Subjects in the Pre groups were then given an intraperitoneal LiCl injection. They were then returned to the A cages where they remained for a further hour, before being returned to their home cages. Subjects in the Cont groups received the same treatment except that their injection was of isotonic saline. A day of water consumption recovery was given after every preexposure session. In the conditioning phase, all subjects were given access to 12-ml of the saccharin solution in the A context for 30 min, followed immediately by an injection of LiCl. They were returned to context A for one hour before being returned to their home cages. A day of water consumption recovery was given after conditioning day. On the test day, all subjects were given a 30-min presentation of 30 mL of saccharin. Subjects in Groups AAB received the test in their home cages and subjects in Groups AAA in context A.

### 2.2. Results and discussion

No reliable differences were found among the groups in their water consumption on the last day before the preexposure phase. The mean

scores on this session were 12.4 mL for group AAA-Pre, 12.9 mL for group AAA-Cont, 14.2 mL for group AAB-Pre, and 12.5 mL for group AAB-Cont. A factorial ANOVA (analysis of variance), with preexposure (Pre or Cont) and context-group assignment (i.e., A or B for the final test) as the factors showed no reliable effects all  $F_s < 1$ , apart from the interaction,  $F(1, 28) = 1.53$ ,  $\eta_p^2 = .05$ . The rejection level adopted for this and all subsequent analyses was  $p < .05$ . On the conditioning day the scores for saccharin consumption were 10.7 mL for group AAA-Pre, 10.9 mL for group AAA-Cont, 11.0 mL for group AAB-Pre and 11.0 mL for group AAB-Cont. The same factorial ANOVA revealed no differences among these scores, all  $F_s < 1$ .

Although differences in consumption during conditioning were very small we took the precaution (following Willner, 1978) of expressing test scores as a percentage of initial saccharin consumption. These scores are presented in Fig. 1, which also shows (inset) the absolute amounts consumed by the four groups. Overall levels of consumption were higher for subjects tested in the familiar context of the home cage than for those tested in context A. However, the US-preexposure effect was evident both in the AAB condition and in the AAA condition; that is, in both these conditions Cont subjects showed a stronger aversion than those given US preexposure. The size of this effect appears not to be diminished by the contextual change between conditioning and test. These impressions were confirmed by statistical analysis. A factorial ANOVA was performed on the percentage scores summarised in Fig. 1, with preexposure (Pre or Cont) and test context (A or B context) as the factors. This yielded a significant effect of preexposure,  $F(1, 28) = 14.24$ ,  $\eta_p^2 = .34$  and of context  $F(1, 28) = 5.70$ ;  $\eta_p^2 = .17$ . The interaction between the two factors was not significant ( $F < 1$ ). There is thus no indication that the US-preexposure effect was attenuated by the change of context between the conditioning and test phases. This is the result anticipated by the proposal that the effect is a result of an acquisition failure. It gives no support to an interpretation in terms of interference at retrieval.

Before accepting the conclusion that the blocking effect in US preexposure is a consequence of acquisition failure, an alternative interpretation should be considered. The retrieval account expects the US-preexposure effect to occur only when the contextual cues from the training stages are present on the test. And although we have manipulated the cues supplied by the environment (the cages) in which procedures occur, these cues may be less important than those associated with the procedure of administering an intraperitoneal injection. We

have noted that injection-related cues can play a major role in producing blocking effects in US-preexposure studies conducted in a familiar environment (de Brugada et al., 2004d), but there is also some evidence that such cues can be effective even when, as in the present experiment, a novel environmental context is used. De Brugada et al. (2003) reported a study in which a set of saline injections intervened between the US-preexposure phase and the conditioning trial. This resulted in an attenuation of the US-preexposure effect, a result that they attributed to a loss of strength by injection-related cues. This attenuation was found even for rats trained throughout in a distinctive context, different from the home cage.

It is possible then, that injection-related cues could have played a role even for animals trained in the novel context A of the present experiment. If these injection cues were completely dominant it would be possible to argue that there was, in fact, no effective change of context for any of the subjects. All could then be predicted to show the US-preexposure effect, whether this be a consequence of acquisition or retrieval failure. It may seem unlikely, given the nature of the novel A context used in this experiment, that the rats would quite fail to learn about it. None the less, the design of Experiment 2, include a procedural change intended to diminish any contribution from injection-related cues in a further investigation of the basic effects of interest.

### 3. Experiment 2

In Experiment 1 we followed the procedure, commonly used in previous work on this topic, of conducting the test phase in the home cage for those subjects that experienced a change of context. For the present experiment, we devised a second experimental context, also different from the home cage; these two contexts are referred to as A and B in the experimental design, summarised in Table 1. As the table shows, subjects in the critical experimental conditions were trained with the arrangement AAB. These subjects received preexposure (to the US for group Pre, to saline for group Cont) in context A, conditioning in context A, and the test in context B. As before, the question at issue was whether this change of context would modulate the US-preexposure effect.

In order to reduce the impact of injection-related cues, and thus, potentially, enhance the likelihood that the animals would learn about the cues that constitute the environmental context, we adopted a procedure suggested by a study by Willner (1978, Experiment 2). In this experiment, Willner gave one group of subjects injections of saline intermixed with the LiCl injections of the preexposure phase. This treatment can be expected to degrade the association between injection cues and the effective US. Although Willner found that subsequent conditioning was somewhat retarded (that is, a small US-preexposure effect was still obtained), the effect was much less substantial than that seen in subjects given only the LiCl injections. This result is consistent with the interpretation that the intermixed saline injections had reduced the contribution from injection cues (see also, de Brugada and Aguado, 2000). Accordingly, in our experiment we adopted this same procedure, intermixing saline injections with injections of LiCl during the preexposure phase in order to enhance the likelihood of control by environmental context (cage) cues.

To find a US-preexposure effect in the AAB condition of this experiment would support the acquisition-deficit account. But to strengthen this support it is necessary to demonstrate that our procedure for ensuring control by contextual, rather than injection-related, cues had been successful. To this end we included a second pair of groups (Pre and Cont) that were given a context change after the first stage of training (i.e., the ABB arrangement; see Table 1). This experimental design does not distinguish between the alternative accounts of blocking that have been considered so far – both accounts expect that the US-preexposure effect would be absent in this case. But if the US-preexposure effect is indeed not found after the ABB treatment this would demonstrate that the subjects were sensitive to a change from context A to context B and thus that our attempt to ensure that subjects learned about the environmental

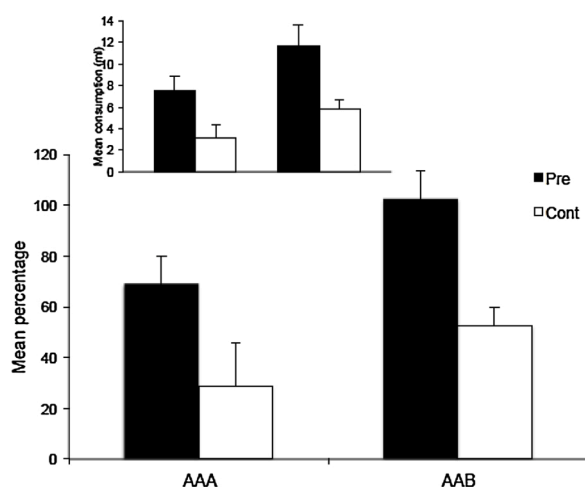


Fig. 1. Average consumption of saccharine on test.

Fig. 1 Experiment 1. Group mean consumption of saccharin on test (as a percentage of consumption on the conditioning trial). Groups labelled Pre had received prior exposure to the US. AAA and AAB refer to preexposure, conditioning, and test contexts (A = context A; B = context B). The inset shows the mean amounts of saccharin consumed on the test. Error bars show the standard error of the mean.

context had been successful.

In summary, there were four groups of subjects (see bottom section of Table 1). Subjects in the preexposed groups (Pre) were given three LiCl injections in the first phase of training in context A, and the control groups (Cont) received saline injections in A during this phase. All had equivalent exposures to context B and were given a saline injection there. All then received conditioning with saccharin as the CS, in context A for the AAB groups and in context B for the ABB groups. The final test for aversion to saccharin was conducted in context B.

### 3.1. Method

#### 3.1.1. Subjects and apparatus

The subjects were 30 experimentally naive female Wistar rats (7 rats in the pre-exposed groups and 8 in the control groups) with a mean weight of 196 g at the start of the experiment. Conditions of maintenance were identical to those described for Experiment 1.

In addition to the experimental cages described for Experiment 1, a further distinctively different set was available. These were located in another separate small room in the laboratory that was illuminated by two fluorescent overhead lamps positioned above the cages. The cages were 20 cm long x 20 cm wide x 22 cm high. The front wall was made of translucent plastic with a 1.5-cm diameter hole on the centre by which the tubes containing the fluids could be made available. The other three walls were made of white lacquered wood. A 22.5cm x 22.5cm x 6.5 cm tray made of white opaque plastic served as the floor. It was covered with a piece of white paper. The roof consisted of a lid of wire mesh. A cotton filter tip impregnated with a drop of a commercially acquired orange scent was placed in the tray, out of the animal's reach. For half the animals in each experimental group these cages served as the A context, and the smaller, gray plastic cages (described for Experiment 1), served as the B context. For the remaining subjects this arrangement was reversed.

#### 3.1.2. Procedure

During the three preexposure days, subjects in the Pre groups were given an intraperitoneal LiCl injection immediately after spending 30-min, with access to water, in a novel context (context A). They then spent a further hour in that context before being returned to their home cages. For subjects in the Cont groups, the injection was of isotonic saline. One recovery day was given after each preexposure session. On these days the procedure matched that of the conditioning day except that context B was used, and the injection was of saline.

In the conditioning phase that followed, the animals were given a session in the morning with access to 12 mL of a saccharin solution for 30 min, in context A for the AAB groups and in B for the ABB groups. In the afternoon all the animals were given water for 30 min in their home cages. In order to maintain the sequence of context presentations established during the previous phase context B was used on the recovery day for the AAB groups, and context A for the ABB groups. Finally, there were two test sessions, on consecutive days, on each of which the subjects were given access to 30 mL of saccharin in context B for 30 min. Procedural details not specified here were the same as those described for the previous experiment.

### 3.2. Results and discussion

There were no significant differences among the groups in water consumption on the last day before the start of the preexposure phase or in the amount of saccharin consumed on the conditioning day. The mean scores for groups AAB-Pre, AAB-Cont, ABB-Pre, and ABB-Cont were 8.9, 7.0, 9.3, and 9.3 mL for water, and 6.1, 6.4, 6.6, and 7.1 mL for consumption of saccharin. A factorial ANOVA on the water scores with preexposure (Pre or Cont) and conditioning context (A or B) as the variables showed no reliable effects, all  $F_s < 1$ . A similar analysis for consumption on the conditioning day showed no significant effects: for

context  $F(1, 26) = 1.87$ , other  $F_s < 1$ .

As in Experiment 1, we expressed the test scores as a percentage of initial saccharin consumption. The results for the test phase are shown in Fig. 2, which also shows (inset) absolute levels of consumption for the four groups. As the figure shows, for subjects in the ABB condition there was no difference between the Pre and Cont groups (i.e., there was no evidence of a US-preexposure effect). The effect was evident however in the AAB condition, with the Pre group showing greater consumption than the Cont group. This description was confirmed by statistical analysis.

A factorial ANOVA was performed on the data summarized in the main figure for the pooled results over the two tests, with preexposure (Pre or Cont) and context (A or B context) as the variables. This yielded a significant effect of context,  $F(1, 26) = 6.40$ ,  $\eta_p^2 = .20$ , and the interaction between preexposure and context was also significant,  $F(1, 26) = 4.8$ ,  $\eta_p^2 = .16$ . The preexposure factor was not significant  $F(1, 26) = 3.24$ ,  $\eta_p^2 = .11$ . An analysis of simple main effects demonstrated a significant effect of preexposure in the AAB condition,  $F(1, 26) = 7.90$ , but not in the ABB condition ( $F < 1$ ). The same analysis showed a significant effect of context of conditioning in the Pre condition  $F(1, 26) = 10.45$ , but not for the Cont condition ( $F < 1$ ).

Previous work has shown that the effects of US preexposure can sometimes survive (although they may be attenuated; see, e.g., Willner, 1978) a change of context following preexposure (i.e., in the ABB condition of our experiment). Such a result is not necessarily of theoretical significance as it might arise simply because the contextual features that were changed were not salient enough to control the animal's behavior. In the present experiment we took steps to avoid this problem by using two distinctive and novel contexts, both different from the home cage, and by devaluing cues associated with the injection procedure by interspersing injections of saline with those of LiCl. The results for the ABB groups, which showed a complete abolition of the US-preexposure effect when the context was changed for the conditioning and test phases, demonstrates the effectiveness of these procedural changes in establishing contextual control.

In spite of the fact that our procedures for establishing contextual control were fully effective, there was no sign of an effect of change of context in the AAB groups. The absence of a US-preexposure effect in the ABB condition is anticipated by both the acquisition-failure and retrieval-failure accounts of blocking. They differ, however, in their predictions for the AAB condition, and here we find, in accord with the acquisition-failure account, that a change to a different context for just the test phase does not abolish the effect.

## 4. General discussion

These experiments confirm that preexposure to the US generated by an injection of LiCl results in a reduced aversion to a flavor CS after CS-US pairing. This result has been interpreted as an instance of blocking, consequent on the formation of an association between the context of training and the US during the preexposure phase. At issue is whether the context exerts this effect during the conditioning phase or in the test phase, when the aversion controlled by the CS is assessed. Our experiments show that this US-preexposure effect is abolished when the context is changed between the preexposure and the conditioning and test phases of the procedure (Experiment 2). It is not, however, influenced by a context change between conditioning and the test (Experiments 1 and 2). This pattern of results is expected by the proposal that

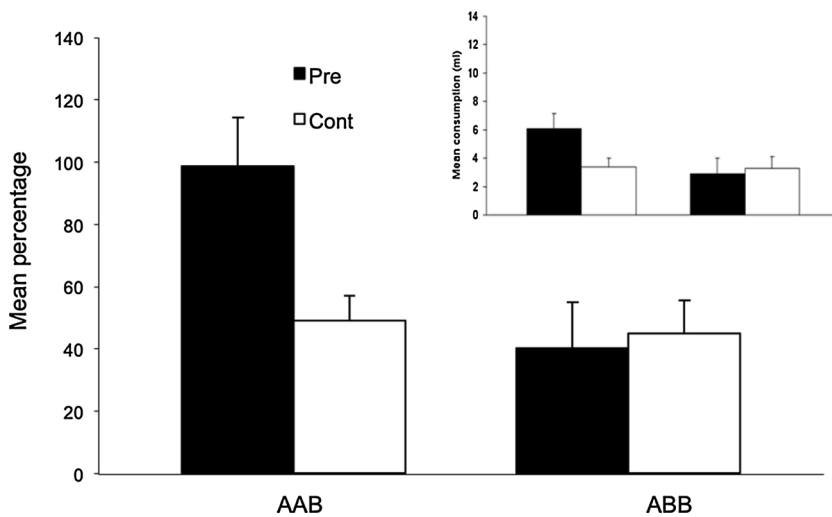


Fig. 2. Average consumption of saccharine on test.

Fig. 2 Experiment 2. Group mean consumption of saccharin on test (as a percentage of consumption on the conditioning trial). Groups labelled Pre had received prior exposure to the US. AAB and ABB refer to the preexposure, conditioning, and test contexts (A = context A; B = context B). The inset shows the mean amounts of saccharin consumed on the test. Error bars show the standard error of the mean.

US preexposure has its effect at acquisition rather than at retrieval; according to this analysis, a change of context following acquisition would be without effect whereas a change of context between preexposure and conditioning would be expected to reduce the size of the effect.

Evidence relevant to, our present results, comes from experiments investigating the effect of varying the interval (the retention interval) between phases of training.<sup>1</sup> It is open to both of the accounts under consideration to suppose that the strength of associations formed during preexposure and conditioning will decline with the passage of time, and thus both can accommodate any decline in the size of the response controlled by the CS on test when a retention interval is inserted at some point prior to the test. But the alternative theories make different predictions about the consequences for the US-preexposure effect when the retention interval is inserted between the conditioning and test phases of the procedure. According to the retrieval account, weakening of the context-US association during this interval will reduce the ability of this association to interfere with the effects of conditioning, and the US-preexposure effect should therefore be attenuated. The acquisition failure account, however, predicts no such attenuation in this case – the context-US association will have done its job (in restricting acquisition by the flavor CS) at the time of conditioning, and the US-preexposure effect should occur whatever the delay before the final test. Experiments using this design have given mixed results. Neither Cole et al. (1993) nor Aguado et al. (1997) found any diminution of the US-preexposure effect when a retention interval (of 11 and 15 days respectively) was interposed between conditioning and testing. These findings are thus in accord with those of the new experiments reported here. Batsell (1997), however, (using a 14-day retention interval) found there to be an attenuation of the effect under certain conditions (specifically the attenuation depended on the amount of conditioning and the degree to which the context was familiar). This matter remains unresolved for the time being.

Finally, the results obtained here form an interesting contrast with those produced by the effects of preexposure to the CS (the latent inhibition effect). It is well established that the latent inhibition effect is attenuated when (in a version of the ABB design) preexposure occurs in one context, and conditioning and the test in another (e.g., Channell and Hall, 1983). This result could reflect retarded acquisition of the CS-US

association by a CS that is already predicted by another cue (the context) (the interpretation offered by Wagner, 1979); but experiments manipulating contextual cues show that this cannot be the complete explanation. For example, Bouton and Swartzentruber (1989) have demonstrated that the effect of changing the context for the conditioning phase in the latent inhibition procedure can be attenuated when the test is carried out back in the preexposure context (i.e., the ABA design). And we have already noted that the latent inhibition effect is attenuated by the insertion of a retention interval between conditioning and the test (Aguado et al., 1994; Westbrook et al., 2000), a procedure that may be equated with the AAB design when the physical context is changed.

The demonstration of these effects for CS preexposure has led to the conclusion that the latent inhibition effect is (at least in part; Hall, 1991) a product of interference at the test stage between information acquired in the previous stages of training (see Escobar and Miller, 2010). In particular, it accords with the notion that exposure to a stimulus later to be used as a CS establishes an association between the CS and the absence of a consequence akin to that produced by extinction (Hall and Rodríguez, 2019; Westbrook and Bouton, 2020) and that appropriate contextual cues on test will aid retrieval of this interfering association. The case will be different, however, for US preexposure. It may be that the subject will learn (as in latent inhibition) that no consequence follows the preexposed stimulus, but that will not be relevant for a test procedure that assesses learning in which the preexposed stimulus is used as a consequence (i.e., as a US) in the conditioning procedure. In this case blocking by contextual cues is to be expected.

In conclusion, the results reported here support the view that the US-preexposure effect in flavour-aversion learning, with LiCl as the US, is a consequence of the formation of a context-US association during preexposure, which then blocks the formation rather than the retrieval of the CS-US association. A clear demonstration of this effect requires awareness of the fact that in this procedure contextual cues associated with the US will include not only those that characterise a particular place but also those associated the process of administering an intraperitoneal injection. Our Experiment 2 shows how the role of the latter can be eliminated by devaluing the relation between injections and subsequent illness. It remains to determine whether equivalent effects can be obtained with USs other than LiCl. Finally, the results for the effects of context change on US preexposure in this paradigm are shown to be different from those found in the case of CS preexposure, suggesting that competition between rival associations on test plays a role in the latter but not in the former.

<sup>1</sup> The distinction between the context change procedure and that of varying a retention interval is not clearcut. One account of the effects of a retention interval (when they are found) is that the passage of time itself will produce a gradual change in context, in which case the forgetting that occurs over such an interval is taken to be an instance of retrieval failure produced by a change from the context of training (e.g., Bouton, 1993).

## Author statement

**Isabel de Brugada:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding acquisition. **Felisa González:** Methodology, Investigation. **Antonio Cándido:** Methodology, Investigation. **Geoffrey Hall:** Conceptualization, Writing - Original Draft, Writing - Review & Editing, Supervision.

## Declaration of Competing Interest

The authors report no conflict of interest.

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