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AAB and ABA Renewal as a Function of the Number of Extinction Trials in Conditioned Taste Aversion

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Three experiments explored renewal in conditioned taste aversion after different amounts of extinction. In Experiment 1, three groups of rats received a single conditioning trial where a saccharin solution was paired with LiCl, followed by 3 extinction trials, and a two-trial test. Groups differed in the context where they received each of the phases (AAA, ABA, and AAB). The context change after extinction renewed taste aversion, regardless of whether it involved a return to the conditioning context (ABA), or going to a different context (AAB). In Experiment 2, increasing to 5 the number of extinction trials eliminated renewal in group AAB. Experiment 3 replicated these results within a factorial design. The implications of the differential effect of the amount of extinction on AAB and ABA renewal for a retrieval theory of forgetting are discussed.

When a conditioned stimulus (CS) is presented without the unconditioned stimulus (US) in an extinction procedure, conducting the test in a context different from the context where extinction took place leads to renewal of the conditioned response (CR). Renewal has received a large amount of attention within animal conditioning (for a review see Bouton, 1993). In a typical renewal procedure, conditioning takes place in one context (A), extinction takes place in a different, but equally familiar context (B), and the test is conducted in the conditioning context (ABA renewal, e.g., Rosas & Bouton, 1997). However, renewal has been also found when conditioning and extinction take place in context A, and the test is conducted in context B (AAB renewal, e.g., Bouton & Ricker, 1994), or when acquisition, extinction, and testing are conducted in three different contexts (ABC renewal, e.g., Bouton & Swartzentruber, 1986).

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Renewal adds to other extinction related phenomena, like spontaneous recovery or disinhibition (Pavlov, 1927), showing that extinction does not erase the CS-US association that is assumed to be established during acquisition, as some learning theories predict (e.g., Mackintosh, 1975; McClelland & Rumelhart, 1985; Rescorla & Wagner, 1972; Van Hamme & Wasserman, 1994). Alternatively, extinction seems to lead to the formation of a new association that competes with the expression of the CS-US association established during conditioning (e.g., Bouton, 1993, 1994, 1997; Pearce, 1987; Wagner & Brandon, 1989).

Bouton (1993, 1994, 1997) analysed renewal within a memory framework that has been shown to be able to account for most of the data within this literature. According to this theory, representations of the elements of the real world are stored as nodes or units in memory, including information about the associations (excitatory and inhibitory) established between them. This model assumes that the CS-US pairings that occur during conditioning lead to a representation of an excitatory association between the nodes representing the CS and the US in memory. During extinction, this association is assumed to remain intact, and a new inhibitory association between the CS and the US is assumed to be established. After extinction, the CS is related to both, the presence and the absence of the US; and, according to the model, the CR to the CS would depend on the context where the test takes place. It is assumed that the context is not attended during acquisition, when the meaning of the CS is unambiguous (Bouton, 1997). So, retrieval of the CS-US relationship will not be context specific (e.g., Bouton, 1993). However, when the meaning of the CS becomes ambiguous during extinction, the model assumes that the animal would begin to pay attention to the context, coding the new information as context dependent (Bouton, 1997; Rosas & Callejas-Aguilera, 2007). The model assumes that the context modulates the inhibitory CS-NoUS relationship established during extinction through an intermediate node that works as an AND gate (e.g., see also Estes, 1976; Nelson, 2002). The activation of the intermediate node requires that the cue is presented in the extinction context. Whenever the cue is presented in the extinction context the intermediate node would activate the inhibitory link between the CS and the US, and CR will not appear. However, when such a node is not activated, the inhibitory link will not be activated and renewal will be observed. Note that for this approach the different renewal effects (AAB, ABA, and ABC) would be explained the same way. As the context where acquisition takes place is assumed not to be coded, the three renewal designs would be nominally identical, given that extinction is always conducted in one context and tested in another regardless of the renewal design used.

Subsequently, the three types of renewal design should produce the same amount of renewal.

However, there are some results in the literature that are in disagreement with this prediction. A number of studies have failed to find AAB renewal in a situation where ABA renewal was found (e.g., Bouton & King, 1983; Goddard, 1999; Nakajima, Tanaka, Urushiara, & Imada, 2000). Tamai & Nakajima (2000) were able to find both, AAB and ABA renewal, but the increase in the number of extinction trials had a deleterious effect upon AAB renewal, while it did not affect ABA renewal. Similary, Thomas, Larsen, & Ayres (2003, Experiment 4) conducted a direct comparison between AAB, ABA, and ABC renewal, finding that the size of AAB renewal was smaller than the size of the other two.

The main goal of the experiments conducted in this study was to conduct a direct comparison between AAB and ABA renewal in conditioned taste aversion by manipulating the number of extinction trials, extending the test of Bouton's (1993) theory to the conditioned taste aversion paradigm. As far as we know, AAB renewal has not been reported in conditioned taste aversion. Thus, our first goal was to test whether AAB renewal could be found using this preparation. Experiment 1 compared AAB and ABA renewal after three extinction trials. The same comparison was conducted after 5 extinction trials in Experiment 2. Finally, Experiment 3 used a factorial design where type of renewal (AAB vs. ABA) and number of extinction trials (3 vs. 5) were manipulated. According to the results reported above, we expected to find that AAB renewal would be more easily disrupted by the increase in the number of extinction trials than ABA renewal.

EXPERIMENT 1

AAB and ABA renewal both seem to be replicable phenomena in animal learning using different learning procedures such as appetitive conditioning (e.g., Bouton & Ricker, 1994; Brooks & Bouton, 1994), or conditioned suppression (e.g., Bouton & Ricker, 1994; Thomas et al., 2003).

The aim of Experiment 1 was to test whether AAB renewal could also be found in conditioned taste aversion, when few extinction trials are used. Rosas and Bouton (1996) took a similar approach on exploring spontaneous recovery from extinction in conditioned taste aversion. They found that spontaneous recovery was consistently found after three extinction trials (Experiments 1, 2, and 3), but it disappeared when the number of extinction trials was increased to 8, even though the length of the retention interval was proportionally increased with respect to the number of extinction trials

(Rosas & Bouton, 1996, Experiment 4). Within retrieval theory of forgetting, spontaneous recovery has been considered a special case of AAB renewal in which the passage of time acts as a context switch. Thus, it seemed reasonable to think that the chances of observing AAB renewal would increase by using the same parameters that Rosas and Bouton (1996) used when reporting spontaneous recovery from extinction in taste aversion learning. Additionally, this experiment was conducted with the aim of comparing AAB and ABA renewal.

Table 1. Experimental designs.

Exp.	Group	Acquisition	Extinction	Test
1	AAA	A: 1S+	A: 3S-	A: 2S-
	AAB	A: 1S+	A: 3S-	B: 2S-
	ABA	A: 1S+	B: 3S-	A: 2S-
2	AAA	A: 1S+	A: 5S-	A: 2S-
	AAB	A: 1S+	A: 5S-	B: 2S-
	ABA	A: 1S+	B: 5S-	A: 2S-
3	AAB5	A: 1S+	A: 5S-	B: 2S-
	ABA5	A: 1S+	B: 5S-	A: 2S-
	AAB3	A: 1S+	A: 3S-	B: 2S-
	ABA3	A: 1S+	B: 3S-	A: 2S-

Note: A & B were two different boxes and times of day, counterbalanced. Context experience was equated. S was 0.05% saccharine solution. "+" was LiCl injection (0.15 molar, 2% body weight). "–" means no injection.

The design of the experiment is presented in Table 1. Three groups of rats received a conditioning trial where saccharin consumption was paired with LiCl in context A. Subsequently, they received three extinction trials with the saccharin. Groups AAA and AAB received extinction in context A, while group ABA received extinction in a different, but equally familiar context (B). Finally, they received two test trials with the saccharin. Groups AAA, and ABA were tested in context A, while group AAB was tested in context B. Thus, the extinction context was changed in both, groups AAB and ABA, with the difference that the change in the context after extinction

in group ABA involved returning to the conditioning context. To ensure equal familiarity with both contexts, rats received two daily sessions of equivalent duration throughout the experiment, one in Context A, and the other one in Context B.

According to the results reported in the literature, we expected the context change to produce renewal of the extinguished taste aversion (e.g., Rosas & Bouton, 1997, 1998). The key questions in this experiment were whether AAB renewal can be found in taste aversion and whether it is weaker than ABA renewal.

METHOD

Animals. Eighteen female Wistar rats with a mean weight of 268.5 grams were used in this experiment. They had received previous training in a T-maze that included two weeks under a food deprivation schedule with food access restricted to 40 min a day. Rats were maintained with ad lib access to food and water for one month before the beginning of the present experiment. They were individually housed in standard Plexiglass cages inside a room maintained on a 12-12 hrs. light-dark cycle with the light part of the cycle beginning at 8 am. Rats were water deprived 24 hr. before the beginning of the experiment. Throughout the experiment rats were maintained on a water-deprivation schedule that included 2 daily 15-min sessions of free access to fluid. The first session took place at 9:00 am, and the second session begun at 7:00 pm.

Apparatus. The test flavor was a solution of 0.05 % saccharine (Sigma Chemical Co.) diluted in distilled water, and illness was induced by a 2% body-weight intraperitoneal injection of 0.15 Molar LiCl. Two different sets of Plexiglass cages (14 x 23 x 23 cm, H x W x D) were used. In one of the sets the walls of the cages were covered with squared pattern paper (red and white squares –7 mm. side). In the other set, the walls were covered with dark green paper, and the floor of the cages was covered by standard two-and-a-half dozen recycled fibre paper egg trays adapted to the floor of the cage. Cages were wiped up, and egg trays were changed after each daily session. For half of the rats, red-square boxes in the morning were context A, and green boxes in the evening were context B, while the opposite was true for the other half. Fluids were administered in 150 ml. bottles with a standard spout.

Procedure. Except where noted, rats received one of the two daily sessions in Context A, and the other in Context B.

Days 1-3. Rats received distilled water in the two daily sessions in the colony room. On day 3, rats were assigned to groups AAA, AAB and ABA matched on water consumption during the three prior days.

Days 4-5. All rats received distilled water in their two daily intakes in the experimental contexts.

Day 6 (Conditioning). Rats in the three groups received free access to the saccharine solution followed by an injection of LiCl in context A. Immediately after the LiCl injection, rats were returned to context A for 15 minutes, before taking them to their home cages. Rats received distilled water in context B during their other session on this day.

Day 7. Rats received distilled water in their home cages.

Days 8-10 (Extinction). All rats received free access to saccharin in one of the two daily sessions while receiving water in the alternate session. Rats in groups AAA and AAB received saccharin in context A, while rats in group ABA received the saccharin in context B for a total of 3 extinction trials.

Days 11-12 (Test). The treatment received by the rats was identical to the extinction treatment, with the exception that rats in group AAB received the saccharin in context B (a context different from the conditioning and extinction context), and rats in group ABA received saccharin in context A, returning to the conditioning context after being extinguished in a different context.

Dependent variable and data analysis. Fluid consumption was recorded throughout the experiment by weighing the bottles before and after the sessions. Consumption was evaluated with an analysis of variance (ANOVA). The rejection criterion was set at $p < .05$.

RESULTS AND DISCUSSION

Mean intake on the two days of water consumption within the experimental contexts (days 4 and 5) was 4.2, 4.5, and 4.0 in context A, and 4.3, 4.8, and 4.2 in context B on day 4, and 4.8, 6.2, and 6.8 in context A, and 5.8, 5.8, and 5.2 in context B on day 5 for groups AAA, AAB, and ABA, respectively. A 3 (group) x 2 (context) x 2 (day) ANOVA found a significant main effect of day, $F(1, 15) = 17.74$ ($MS_e = 2.12$). No other main effect or interaction was significant, largest $F(2, 15) = 1.31$ ($MS_e = 2.05$). Thus, the intake of water increased between days 4 and 5 regardless of the group or context. Most likely, this increase was due to habituation to the new contexts where the animals were placed for the first time on day 4.

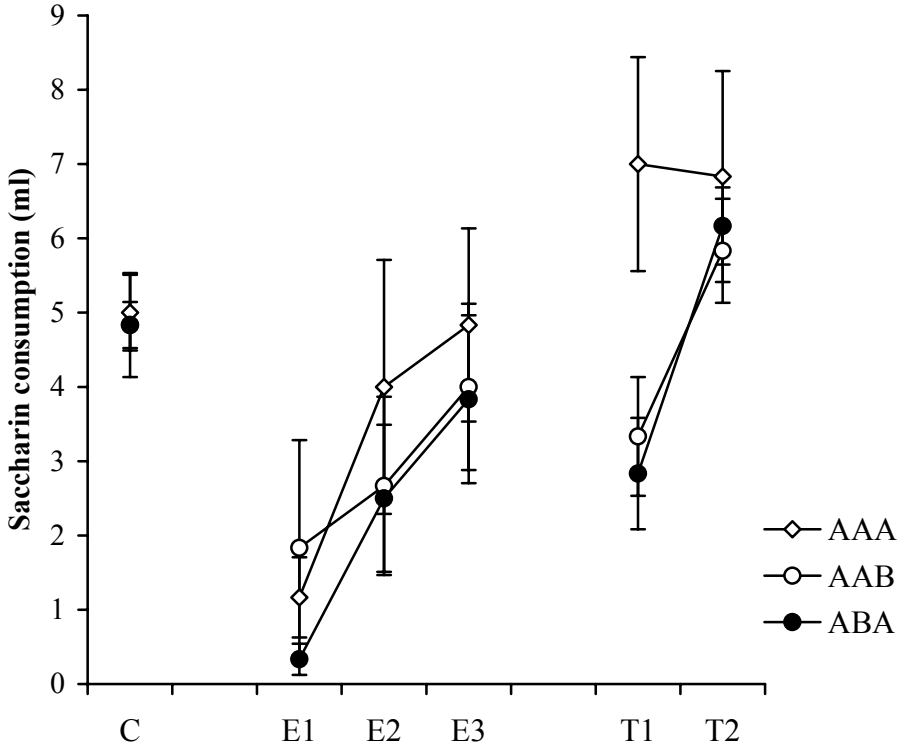

Figure 1. Mean saccharin consumption on the conditioning trial (C), on the 3 days of extinction, and on the 2 test trials in the three groups that participated in the experiment. Group names represent the contexts where conditioning, extinction and test took place. Error bars denote standard errors of the mean.

Figure 1 summarizes the saccharine consumption on the conditioning trial, the three trials of extinction and the two test trials for groups AAA, AAB, and ABA. Conditioning was evaluated by a 3 (group) x 2 (day) ANOVA conducted with the data from the conditioning day and the first extinction day. Only the main effect of day was statistically significant, $F(1, 15) = 51.84$ ($MS_e = 2.48$). Neither the main effect of group, nor the group x day interaction were significant, $Fs < 1$. Thus, conditioning proceeded expectedly, with the three groups showing the same level of taste aversion at the beginning of extinction. Note that the extinction context in group ABA (B) was different from the conditioning context (A). No effect of context change upon acquisition was found.

Extinction was evaluated by a 3 (group) x 3 (day) ANOVA that found a significant main effect of day, $F(2, 30) = 15.77$ ($MS_e = 2.82$). Neither the main effect of group, nor the group x day interaction were significant, $Fs < 1$. Thus, extinction proceeded similarly in the three groups. Note that the context change between conditioning and extinction (group ABA) did not affect the strength of the aversion or the rate of extinction. This is a common result in renewal literature and it suggests that conditioning transfers fairly well across contexts (e. g., Rosas & Bouton, 1997, 1998).

The most interesting results concerned test data. A 3 (group) x 2 (day) ANOVA found a significant main effect of day, $F(1, 15) = 19.40$ ($MS_e = 1.66$). The main effect of group was not significant, $F(2, 15) = 2.15$ ($MS_e = 10.52$). Most important, there was a significant group x day interaction, $F(2, 15) = 6.06$ ($MS_e = 1.66$).

Subsequent analysis conducted to explore the group x day interaction found that the simple effect of group was significant on day 1, $F(2, 15) = 4.75$ ($MS_e = 6.54$), but not on day 2, $F < 1$. Consumption in groups ABA and AAB was lower than in group AAA, $Fs(1, 10) = 6.61$, and 4.96, respectively ($MS_e = 8.13$, and 7.88, respectively). There were no differences in consumption between groups ABA and AAB, $F < 1$.

In summary, conditioning and extinction proceeded similarly regardless of the context where extinction took place. More interesting for the goals of the experiment, the context change during the test led to renewal of the extinguished taste aversion, regardless of whether the test took place in a different, but equally familiar context (group AAB), or in the context where conditioning was originally conducted (group ABA).

The lack of context change effects on acquisition in group ABA suggests that associations between the context and the US or the CS are unlikely to play a role in our results, indicating that the recovery of aversion after extinction in this procedure is due to the context change differentially affecting to conditioning and extinction. Most interesting, equivalent results were found when testing was conducted outside the conditioning and extinction context (group AAB). To our knowledge, this is the first report of AAB renewal in conditioned taste aversion.

The fact that no differences were found during the test between AAB and ABA renewal is somewhat surprising. Previous results in the literature with different conditioning procedures suggest that AAB renewal is weaker than ABA renewal (e.g., Thomas et al., 2003). For instance, Tamai and Nakajima (2000) found that AAB renewal was more sensitive to increases in the number of extinction trials than ABA renewal. Experiment 2 was conducted with the aim of exploring this possibility in conditioned taste aversion.

EXPERIMENT 2

Experiment 1 found renewal of a conditioned taste aversion regardless of whether the test was conducted in the conditioning context (ABA) or in a new, but equally familiar context (AAB). This kind of result might be understood as support to Bouton's (1993, 1994) explanation of renewal. According to this author, renewal occurs because the change in the meaning of the CS that is produced by the extinction treatment leads rats to pay attention to the context where extinction takes place, so that extinction becomes context specific (Bouton, 1997). As contexts are not processed until extinction begins, AAB and ABA renewal should be identical, given that in both cases the context is changed after extinction. As such, returning to the conditioning context for the ABA condition should not have a differential effect on retrieval of the information. The results of Experiment 1, with the lack of effects of context change upon conditioning, and the identical effect of context change on test consumption in groups AAB and ABA clearly confirmed the predictions of Bouton's hypothesis (Bouton, 1993, 1994, 1997).

However, there are some results in the literature that suggest that this idea should be qualified. Tamai and Nakajima (2000), using a conditioned-fear preparation, found that AAB and ABA renewal were differentially affected by increasing extinction. AAB renewal is more readily reduced than ABA renewal when the number of extinction trials is increased, suggesting that returning to the conditioning context may play a role in recovery from extinction (see also Bouton & King, 1983; Goddard, 1999; Nakajima et al., 2000; Thomas et al., 2003).

The aim of this experiment was to test AAB and ABA renewal after a larger number of extinction trials. Rosas and Bouton (1998) found ABA renewal after 5 extinction trials in taste aversion. However, an unpublished experiment conducted by these authors failed to find AAB renewal under the same conditions. Given those previous results, the design of Experiment 2 was identical to the design used in Experiment 1, except for the use of 5 extinction trials (see the middle section of Table 1). According to our previous results, we expected to find ABA renewal under these conditions. However, if returning to the conditioning context after being extinguished in a different context plays a role in renewal of the extinguished taste aversion, the increase in the number of extinction trials with respect to Experiment 1 should prompt the differences in renewal of the CR between ABA and AAB groups.

METHOD

Animals and apparatus. Eighteen female Wistar naïve rats with a mean weight of 288.0 grams were used in the experiment. They were kept under the same conditions described in Experiment 1. Apparatus were the same used in Experiment 1.

Procedure. Procedure was identical to the one used in Experiment 1 (see Table 1), except for the use of 5 extinction trials, rather than 3.

RESULTS AND DISCUSSION

Mean water intake within the experimental contexts on the two days prior to the conditioning day was 4.2, 3.3, and 3.8 in context A, and 4.8, 4.5, and 4.7 in context B on day 4, and 4.8, 5.3, and 4.3 in context A, and 5.0, 4.7, and 5.3 in context B on day 5 for groups AAA, AAB, and ABA, respectively. A 3 (group) x 2 (context) x 2 (day) ANOVA found a significant main effect of day, $F(1, 15) = 6.46$ ($MS_e = 1.46$). No other main effect or interaction was significant, Largest $F(1, 15) = 1.85$ ($MS_e = 1.08$). Thus, consumption of water increased between day 4 and day 5 regardless of the group or context. This increase was similar to the increase found in Experiment 1, and it was likely caused by habituation to the contexts between days 4 and 5.

Figure 2 presents the saccharine consumption on the conditioning trial, the five extinction trials, and the two test trials for groups AAA, AAB, and ABA. Conditioning was evaluated by a 3 (group) x 2 (day) ANOVA conducted with the data from the conditioning and first extinction days. Only the main effect of day was statistically significant, $F(1, 15) = 83.36$ ($MS_e = 2.94$). Neither the main effect of group, nor the group x day interaction were significant, $Fs < 1$. Replicating the results obtained in Experiment 1, groups did not differ in the level of conditioning on the first day of extinction, regardless of whether that extinction took place in the conditioning context (groups AAA, and AAB), or in a different, but equally familiar context (group ABA).

Saccharine intake during extinction was evaluated by a 3 (group) x 5 (day) ANOVA that found a significant main effect of day, $F(4, 60) = 76.83$ ($MS_e = 1.88$). Neither the main effect of group, nor the group x day interaction were significant, $Fs < 1$. Thus extinction proceeded similarly in the three groups.

The most relevant results concerned test data. A 3 (group) x 2 (day) ANOVA found that the main effect of day fell short of statistical significance, $F(1, 15) = 4.12$ ($MS_e = 1.14$), $p = .06$. The main effect of group

was not significant, $F(2, 15) = 1.68$ ($MS_e = 4.34$). The group x day interaction was not significant either, $F(2, 15) = 2.51$ ($MS_e = 1.14$).

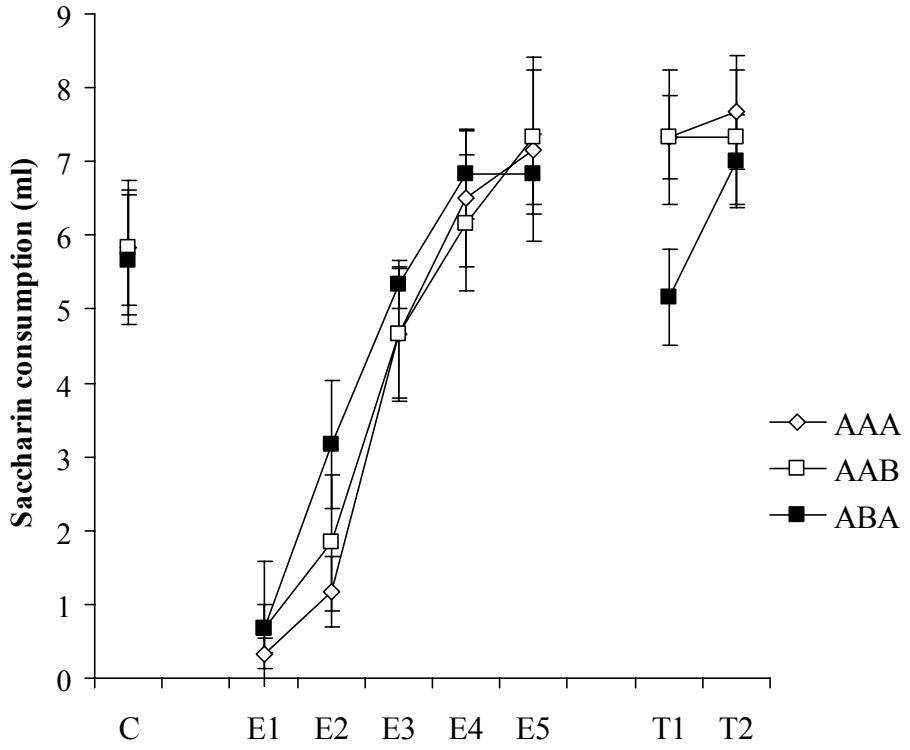

Figure 2. Mean saccharin consumption on the conditioning trial (C), on the 5 days of extinction, and on the 2 test trials in the three groups that participated in the experiment. Group names represent the contexts where conditioning, extinction and test took place. Error bars denote standard errors of the mean.

Though no significant group x day interaction was found, planned contrasts were conducted to evaluate groups' intake in the first and second test trials (T1 and T2). Groups differ on their intake in T1, $F(2, 15) = 3.78$ ($MS_e = 42.50$), but they did not differ in T2, $F < 1$. Consumption of group ABA on the first test day was lower than in groups AAA, and AAB, $Fs(1, 10) = 6.35$, and 5.02, respectively ($MS_e = 22.17$, and 26.16, respectively). There were no differences on consumption between groups AAA and AAB, $F < 1$.

In summary, extinction proceeded similarly in the three groups, suggesting that context change did not affect conditioning. However, test data clearly differ from those obtained in Experiment 1. In this experiment, renewal was found only in group ABA, a result that has been reported in the literature with different conditioning procedures (e.g., Nakajima et al., 2000; Tamai & Nakajima, 2000; Thomas et al., 2003). This result begins to suggest that the mechanisms underlying AAB renewal and ABA renewal might be different. However, before accepting this assumption, renewal after different amounts of extinction should be compared within the same experiment. This was the goal of Experiment 3.

EXPERIMENT 3

Experiments 1 and 2 suggest that both AAB and ABA renewal can be found after 3 extinction trials, but AAB renewal disappears when the number of extinction trials is increased to 5. This idea is based on the comparison between the results of Experiments 1 and 2. The aim of Experiment 3 was to compare AAB and ABA renewal after 3 and 5 extinction trials within the same experiment.

The design of the experiment is presented at the bottom of Table 1. It was a factorial design with type of renewal design (AAB or ABA) and number of extinction trials (3 or 5) as factors. According to the results of Experiments 1 and 2, renewal of the extinguished taste aversion was expected in both types of renewal design after 3 extinction trials and only in ABA after 5 extinction trials.

METHOD

Animals and apparatus. Thirty-two female Wistar naïve rats with a mean weight of 256.3 grams were used in the experiment. They were maintained in the same conditions described in Experiment 1. Apparatus was the same used in Experiment 1.

Procedure. Procedure was identical to the one used in Experiment 1, except where noted. Rats in groups ABA5 and AAB5 received conditioning on day 6, and 5 extinction trials between days 8 and 12. Rats in groups ABA3 and AAB3 received conditioning on day 8, and 3 extinction trials between days 10 and 12. All rats were tested on days 13 and 14. The design ensured the days of testing and the level of deprivation at the moment of testing was identical for all the rats.

RESULTS

Mean water intake within the experimental contexts on the two days prior to the conditioning day was 4.0, 4.4, 6.1, and 8.3 in context A, and 3.5, 5.0, 6.5, and 6.4 in context B on the first day in the experimental contexts, and 5.1, 5.3, 7.1, and 7.0 in context A, and 5.0, 5.0, 7.1, and 7.3 in context B on the second day for groups AAB5, ABA5, AAB3, and ABA3, respectively. A 2 (renewal design) x 2 (extinction trials) x 2 (day) ANOVA found a significant main effect of day, $F(1, 28) = 6.51$ ($MS_e = 1.68$), and extinction trials, $F(1, 18) = 19.98$ ($MS_e = 7.42$). No other main effect or interaction was significant, largest $F(1, 28) = 3.28$ ($MS_e = 1.68$). Thus, consumption of water increased between the first and second day in the experimental contexts. Water intake in groups 3 was higher than water intake in groups 5. Most likely, this result reflects the difference on the time under the water deprivation schedule for groups 5 and 3 before receiving water in the experimental contexts –to equate the level of deprivation and the time of testing, rats in groups 3 received water in the experimental contexts in their 6th day of deprivation, while rats in groups 5 received it in their 4th day of deprivation.

Figure 3 presents the saccharine consumption on the conditioning trial, the extinction trials, and the two test trials for groups AAB5, ABA5, AAB3, and ABA3. Conditioning was evaluated by a 2 (renewal design) x 2 (extinction trials) x 2 (day) ANOVA conducted with the data from the conditioning day and the first extinction day. Only the main effect of day was significant, $F(1, 28) = 143.94$ ($MS_e = 2.71$). No other main effect or interaction were significant, $Fs < 1$. Aside the replication of the lack of context change effect upon conditioning found in Experiments 1 and 2, the most interesting result here is the lack of differences in consumption in the conditioning day between groups conditioned on day 6 (AAB5, and ABA5), and groups conditioned on day 8 (AAB3 and ABA3). Differences among groups in the last days of water deprivation disappeared when saccharine was administered.

Saccharine intake during extinction was evaluated with three separate analyses. The first analysis included all groups and the first 3 days of extinction. A 2 (renewal design) x 2 (extinction trials) x 3 (day) ANOVA found a significant main effect of day, $F(2, 56) = 141.49$ ($MS_e = 1.35$). No other main effect or interaction was significant, largest $F(2, 56) = 1.01$ ($MS_e = 1.35$). The second analysis only included data of groups AAB5 and ABA5. A 2 (renewal design) x 5 (day) ANOVA found a significant main effect of day, $F(4, 56) = 65.63$ ($MS_e = 1.74$). Neither the main effect of renewal design, nor the renewal design x day interaction were significant, $Fs < 1$. Finally, the third analysis compared saccharine intake in the last

extinction trial for all groups. A 2 (renewal design) x 2 (extinction trials) ANOVA found a significant main effect of extinction trials, (1, 28) = 6.32 (MS_e= 2.85). Neither the main effect of renewal design, nor the renewal design x extinction trials interaction were significant, *Fs* < 1. Thus, no context switch effect was found during extinction, replicating the results of Experiments 1 and 2. By the end of extinction, saccharine intake was greater in groups AAB5, and ABA5 than in groups AAB3, and ABA3, showing that increasing the number of extinction trials led to an increase in saccharine consumption.

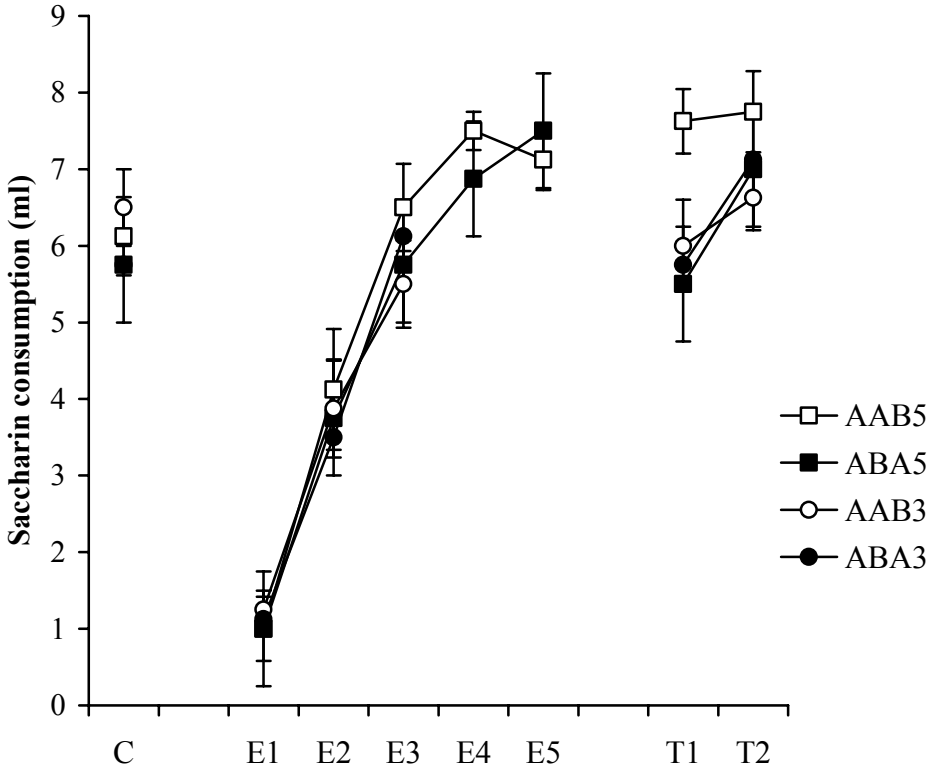

Figure 3. Mean saccharin consumption on the conditioning trial (C), during the days of extinction (three for groups 3, and five for groups 5), and during the 2 test trials in the four groups that participated in the experiment. Group names represent the contexts where conditioning, extinction and test took place. Error bars denote standard errors of the mean.

A 2 (renewal design) x 2 (extinction trials) x 2 (test day) ANOVA conducted on the test trials only found a significant main effect of day, $F(1, 28) = 10.42$ ($MS_e = 1.26$). No other effect or interaction was significant, largest $F(1, 28) = 3.58$ ($MS_e = 1.26$).

Though the expected three-way interaction was not found in the overall analysis, planned comparisons were conducted to evaluate groups' intake in the first day of testing. The simple effect of extinction trials was significant only in AAB renewal design, $F(1, 14) = 4.95$ ($MS_e = 2.13$), but it was not significant in the ABA design, $F < 1$. Similarly, the simple effect of the renewal design was significant after 5 extinction trials, $F(1, 14) = 7.05$ ($MS_e = 2.56$), but not after 3 extinction trials, $F < 1$. These results replicate results obtained in Experiments 1 and 2 with respect to the lack of differences between AAB and ABA treatments after 3 trials of extinction, and a greater renewal effect on ABA than on AAB after 5 extinction trials.

Not including control groups without context switch after 3 or 5 extinction trials precludes any conclusion about whether AAB renewal was found after 5 extinction trials in this experiment. However, the 4th extinction trial of group AAB5 could be considered equivalent to a test trial on an AAA3 group, allowing for a comparison with the test data of groups AAB3 and ABA3. This comparison was significant in both groups, $Fs(1, 14) = 5.73$ and 11.07 ($MS_e = 1.57$ and 1.11) for comparisons with groups AAB3 and ABA3, respectively. Thus, this experiment replicated the AAB renewal result after three extinction trials found in Experiment 1.

In summary, the results of this experiment replicated the lack of effects of a context change upon conditioning regardless of the level of extinction. Increasing the number of extinction trials led to higher saccharin consumption that may be interpreted as a higher level of extinction. The context change at testing after three extinction trials produced the same renewal from extinction regardless of whether the test was conducted in the conditioning context (group ABA3) or in a different, but equally familiar context (group AAB3). This result replicated the results obtained in Experiment 1, showing that AAB renewal can be found in taste aversion when extinction is not asymptotic. However, the effect of context change disappeared after five extinction trials when the context change did not involve a return to the conditioning context. The results of this experiment show that AAB renewal design produces weaker CR recovery than ABA renewal design in conditioned taste aversion, extending similar results found with different procedures (e.g., Tamai & Nakajima, 2000).

GENERAL DISCUSSION

The three experiments reported in this study explored renewal in conditioned taste aversion as a function of the renewal design (AAB vs. ABA) and the number of extinction trials. After three extinction trials, a context change produced renewal from extinction regardless of the renewal design used (Experiment 1). After five extinction trials, the effect of context change during the test was found only when ABA renewal design was used (Experiment 2). Finally, both results were replicated within the same experiment (Experiment 3). AAB renewal was found in conditioned taste aversion in this experimental series. As far as we know, this is a unique result in the literature, and extends the range of phenomena found with this procedure.

AAB renewal cannot be easily explained by many learning theories regardless of whether it is obtained with taste aversion or with other learning techniques (e.g., Pearce, 1987; Rescorla & Wagner, 1972). On explaining disinhibition (recovery from extinction by presenting a new stimulus before the extinguished CS), Pavlov (1927, p. 99) suggested that inhibition processes are more labile than excitation processes, and more easily disrupted by the presence of new stimuli. From this perspective, AAB renewal could be considered a case of disinhibition where the CR is recovered because the CS is presented together with a new stimulus (Context B). Note that this interpretation could also explain why no effect of context change is found after simple conditioning while an equivalent change produces renewal after extinction, given that excitation processes are considered less labile than inhibition processes. However, the design of this experimental series took special care to equate familiarity with the different contexts throughout each experiment. At the time of testing, the context was far from being a new stimulus, and disinhibition was not expected. Additionally, Nelson (2002) found that conditioned excitation was also affected by the change in the context whenever it was learned second, after conditioned inhibition had been established.

Bouton (1997) suggests that the newly established ambiguity on the meaning of the CS during extinction would make the animal to pay attention to the context where it is learned, with the information becoming context specific (see also Darby & Pearce, 1995). Discounting the acquisition context, ABA and AAB renewal could be reinterpreted as BA and AB renewal and thus, being considered nominally identical designs from this perspective. Results of Experiment 1 are in agreement with this idea. AAB and ABA renewal were found to be identical after 3 extinction trials.

However, AAB renewal disappeared in Experiment 2 when the number of extinction trials was increased to 5. The same manipulation had no effect on ABA renewal suggesting that both forms of renewal cannot be considered identical. This result is new in conditioned taste aversion, but is not new in the literature. Tamai and Nakajima (2000) found a very similar result by using a conditioned fear preparation and continuing extinction after behavioural asymptote had been reached (see also, Nakajima et al. 2000; Thomas et al., 2003).

This result may be integrated in Bouton's (1993) theory if one would assume that an increase in extinction trials would increase the number of contextual cues that control the CS-NoUS association, so that massive extinction would have the same effect that conducting extinction in different contexts, attenuating renewal (Chelonis, Calton, Hart, & Schachtman, 1999; Gunther, Denniston, & Miller, 1998). However, according to Bouton's theory increasing the number of extinction trials should also increase the value of the context as an occasion setter. Accordingly, extinction should become more context specific when the number of extinction trials increases, a prediction that is in disagreement with the results of this experiment.

Denniston, Chang, and Miller (2003) used a procedure that discarded both of these interpretations. They conducted two experiments where ABC renewal (Experiment 1) and ABA renewal (Experiment 2) were tested after moderate (160 trials) and massive (800 trials) extinction training. The number and duration of extinction sessions was equated across groups, thus equating the number of contextual cues that might have control the CS-NoUS association. However, Denniston et al. (2003) found that renewal disappeared after massive extinction while it was evident after moderate extinction. This result is also contrary to the possibility of increasing extinction trials enhancing the value of the context as an occasion setter. Denniston et al. (2003) explained their results as an increase in the generalization gradient of the CS-NoUS association to contexts different from the extinction context when the extinction training increases. This could explain why AAB renewal disappears after 5 extinction trials in these experiments.

Alternatively, Brooks, Bowker, Anderson, and Palmatier (2003) suggest that learning in conditioned taste aversion may be different after 5 extinction trials than after 3 extinction trials. According to them, increasing the number of extinction trials in conditioned taste aversion might endow the extinguished CS with the same properties of a conditioned inhibitor (e.g., Calton, Mitchell, & Schachtman, 1996). This increase in the

inhibitory power of the CS as extinction increases may explain why the context switch effect disappears after longer extinction training.

Both of these proposals may be considered compatible to each other, as an increase in the inhibitory power of the CS (Brooks et al., 2003) may increase the generalization gradient of the CS-NoUS association (Denninston et al., 2003). However, none of them helps us to explain why the increase in extinction affected AAB renewal while it did not affect ABA renewal. Note that the results reported by Denniston et al., (2003) suggest that an additional increase in the number of extinction trials might ultimately attenuate ABA renewal as well as AAB renewal. Thus, in a conservative conclusion, AAB renewal should be considered more easily affected by the increase in the extinction trials than ABA renewal. This difference in the strength of AAB and ABA renewal suggests that the explanation of renewal in terms of leaving the extinction context needs to be qualified. AAB and ABA renewal designs differ at least in two respects and any of them might be relevant for explaining the differential strength of these two phenomena.

First, ABA renewal implies a return to the context where acquisition was established that is not included in the AAB renewal design. The acquisition context could have served as a retrieval cue that would facilitate recovery of the CS-US information. This interpretation is not without problems. In most of the ABA renewal experiments, included the ones reported here, there is no evidence of context switch affecting retrieval of CS-US information (for a review see Bouton, 1993). If the acquisition context would serve as a retrieval cue for CS-US information, the change of context should affect retrieval of such information. Additionally, if the return to the acquisition context was a relevant factor in the strength of ABA renewal, ABA renewal should be also stronger than ABC renewal. A direct comparison conducted by Thomas et al. (2003) has recently shown both effects to be of the same size and bigger than AAB renewal. However, one could argue that the role of the acquisition context as a retrieval cue in the absence of ambiguity is too weak as to be detected on changes in behaviour when they are directly evaluated, but it could be strong enough as to produce the difference between AAB and ABA renewal under some circumstances (5 extinction trials in the present experimental series). Alternatively, CS-US associations have shown to be context dependent after the CS undergoes extinction, suggesting that animals might use contextual information to retrieve a CS-US association only after the association has become ambiguous (Harris, Jones, Bailey, & Westbrook, 2000). In this line, recent research in humans suggest that participants may learn about ignored contexts (the acquisition context, in this case), but that those contexts are not used unless they latter become attended (Jiang & Leung, 2005). Applied

to the present situation, this could explain why context changes do not affect acquisition performance, but then a return to the acquisition context increases conditioned responding more than simply leaving the extinction context (see Larrauri & Schmajuk, submitted, for a complementary explanation where it is assumed that the context becomes directly associated to the US).

Second, the presence of context B during extinction in ABA renewal might have partially protected the CS from extinction as the Rescorla and Wagner's (1972) model would predict. Context B would acquire some inhibitory strength during extinction that would protect the CS from losing all of its excitatory associative strength (Thomas & Ayres, 2004; see also Rauhut, Thomas, & Ayres, 2001). Thomas and Ayres (2004) suggest that extinction leads to some loss of the excitatory strength of the CS combined with the establishment of the CS-No US association. When the extinction takes place in a context different from the acquisition context, this new context would make the CS to lose less associative strength than when extinction takes place in the acquisition context (AAB groups). That protection of the loss of associative strength in groups ABA would lead to stronger renewal in those groups than in groups AAB. This kind of interpretation is bound to assume that contexts acquire some excitatory strength during acquisition, and thus it will confront the same problems described above for the interpretation of ABA renewal as caused by a return to the acquisition context, and might have to accept the same tentative solutions.

At this point any of these possibilities is speculative. Discovering which of the factors proposed above is responsible for the differences between the results of different renewal designs, whether there are other factors involved, and how these factors might interact is an open challenge for retrieval theory as a renewal account.

RESUMEN

Renovación AAB y ABA en función del número de ensayos de extinción en aversión condicionada al sabor. Se realizaron tres experimentos en los que se exploró el efecto de renovación en aversión condicionada al sabor en función del número de ensayos de extinción. En el Experimento 1, tres grupos de ratas recibieron un ensayo de condicionamiento, donde una solución de sacarina se emparejó con LiCl, seguido por tres ensayos de extinción y dos ensayos de prueba. Los grupos difirieron en el contexto donde recibieron cada una de las fases (AAA, ABA y AAB). El cambio de contexto después de la extinción renovó la aversión condicionada al sabor, independientemente de si aquél implicó el regreso al contexto de condicionamiento (ABA) o el paso a un contexto diferente (AAB). En el

Experimento 2, aumentar el número de ensayos de extinción a 5 eliminó la renovación en el grupo AAB. El Experimento 3 replicó estos resultados dentro de un diseño factorial. Se discuten las implicaciones del efecto diferencial de la cantidad de extinción en la renovación AAB y ABA para la teoría de la recuperación de la información.

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