ACTA DE INVESTIGACIÓN PSICOLÓGICA, 2012, 2 (3), 899 - 909

Context-switch effect produced by the ambiguity of the meaning of a cue

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Abstract

One experiment analyzed whether context dependency of a flavor-illness association depends on the extinction of a different flavor-illness association in rats. There were two sessions per day, one in context A and the other session in context B. A half of the rats were allowed to drink distilled water within context B, while the other half of the group spent the same amount of time in context B without access to water. In context A, half of the subjects received conditioning and extinction of flavor X, while the other half did not received extinction. Then conditioning of flavor Y was conducted for all rats in context A. Finally, testing of Y was conducted in context A for half of the rats, while the other half received the test in context B. Results shown that extinction of flavor X affected the recovery of subsequently acquired information about flavor Y regardless the treatment received in context B. This data is consistent with Attentional Theory of Context Processing.

KeyWords: Rats, Extinction, Context, Taste Aversion Learning.

Efecto de cambio de contexto producido por la ambiguedad del significado de la clave

Resumen

Un experimento analizó si la dependencia contextual de una asociación sabor – enfermedad depende de la extinción de una asociación sabor – enfermedad distinta en ratas. Se realizaron dos sesiones diariamente, una en el contexto A y la otra en el contexto B. Una mitad del grupo ratas bebieron agua destilada en el contexto B, mientras que la otra mitad del grupo se colocó por el mismo tiempo en el contexto A sin beber nada. La mitad de las ratas recibieron condicionamiento y extinción de un sabor X en el contexto A, mientras que la otra mitad no recibió extinción. Luego todas las ratas fueron condicionadas con el sabor Y en el contexto A. Por ultimo, se hizo la prueba de Y en el contexto A para la mitad del grupo, y en el contexto B para la otra mitad. Los resultados mostraron que la extinción del sabor X afectó la recuperación del favor Y sin importer si el tratamiento se hizo en el contexto B. Estos datos son consistentes con la Teoría Atencional de Procesamiento del Contexto.

Palabras Clave: Ratas, extinción, contexto, aversión condicionada a sabores

Original recibido / Original received: 03/04/2012 Aceptado / Accepted: 30/10/2012

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Contemporary learning theorists agree on that on extinction the reduction of the conditioned response (CR) when the conditioned stimulus (CS) is no longer followed by the unconditioned stimulus (US) doesn't implies erasure of the original learned information (e. g., Delamater, 2004; Rescorla, 2001; see also, Pavlov, 1927). The renewal effect is consistent with this idea because a change of context between extinction and test results in a partial restoration of the CR. For instance, when a CS is paired with an US within a specific background cues (context A), and then extinction is conducted in a second set of cues (context B), presentation of the CS in the context A during test produces the renewal of the CR. This class of renewal is the so-called ABA renewal (e. g., Bouton & Peck, 1989; Bouton & King, 1983; Rosas, Vila, Lugo, & López, 2001). A second class of renewal is AAB where conditioning and extinction are both conducted in the same background (context A) and then the CS is tested in a novel context B (e.g., Bouton & Ricker, 1994; Rosas, García-Gutiérrez & Callejas-Aguilera, 2007; Tamai & Nakajima, 2000). A third class is the ABC renewal where conditioning, extinction and testing are conducted in a different context (e. g., Bernal-Gamboa et al., 2012; Bouton, Todd, Vurbic, & Winterbauer, 2011; Thomas, Larsen & Ayres, 2003).

The key factor of all three classes of renewal is switching context B during testing and not testing the CS in the original context. This strongly indicates that extinction information is more sensitive to contextual changes than information about conditioning. In order to explain this interesting asymmetry, Bouton (1993, 1994) suggested that both inhibitory and second-learned information, as in extinction, are more context-dependent than excitatory and first-learned information, as the initial conditioning. There are some data supporting this idea, Nelson (2002) has shown that information learned after an initial conditioning stage became context-specific regardless of whether conditioning was inhibitory or excitatory (see also, Bouton & Nelson, 1994; Nelson, 2009). As a possible solution of the asymmetry arising from first-learned and second-learned information on contextual conditioning, Bouton (1997) proposed that retrieval of second-learned information is impaired by a context change since the information it provides about the occurrence of the US is ambiguous (see also, Darby & Pearce, 1995). That is, the meaning of a CS is clear during the initial conditioning trials (e. g., tone□food), then when the CS undergoes extinction its first meaning is changed, it no longer predicts food arrival (e. g., tone□no food) thus becoming ambiguous. Bouton proposed that in order to solve this ambiguity produced during extinction, subject must pay attention to the context, making the retrieval of any ambiguous information context specific.

Although this explanation can explain a large group of data (e. g., Bouton, 2004), there are some results that show context-switch effects of unambiguous information (e. g., Bonardi, Honey & Hall, 1990; Rosas, García-Gutiérrez & Callejas-Aguilera, 2006). Rosas, Callejas-Aguilera, Rámos-Álvarez & Abad (2006) extended the role of ambiguity and proposed the Attentional Theory of Context Processing (ATCP). This theory proposes that contextual dependency of the information doesn't depend on specific sign of the information (i. e. excitatory, inhibitory), on its primacy of learning (i.e., first or second learned) or on whether it is ambiguous or not. Instead, they propose an attentional mechanism activated by various factors. ATCP suggests five factors that might modulate attention to the context: 1) the ambiguity of the meaning of the information could activate the attentional mechanism to the contextual cues making all the information context-specific (e. g., Callejas-Aguilera & Rosas, 2010; Rosas & Callejas-Aguilera, 2006; see also, Bouton, 1997). 2) the informative value of the context to resolve the task leads subjects to pay attention to the background (e. g., León, Abad & Rosas, 2010a; Preston, Dickinson & Mackintosh, 1986). 3) With human participants, Instructions that focus participant's attention to the contexts might affect context-switch effects (e. g., Callejas-Aguilera, Cubillas & Rosas, 2012). 4) Experience with the context and the task can modulate subject's attention to the context (e. g., León, Abad & Rosas, 2010b; Myers & Gluck, 1994). 5) Finally, the relative salience of the context with respect to other discrete stimuli could modulate the attention.

Rosas and Callejas-Aguilera (2007) conducted an experiment using a conditioned taste aversion paradigm (CTA) with rats to explore the role of ambiguity on context specificity. Two groups of rats (i. e., EA, EB) received free access to flavor X, drinking flavor X was paired with an injection of Lithium Chloride (LiCl) in context A. In the following phase, also conducted in context A, all rats received free access to flavor X without the injection (i. e., extinction trials). Then all rats drank flavor Y in context A, consumption of this flavor was paired with LiCl. Finally, on the test session all rats received free access to flavor Y without the injection. Rats in group EA received the test in the same context where conditioning of Y took place, while group EB was tested in a different but equally familiar context (context B). Results showed higher consumption of Y in group EB than in group EA, showing that retrieval of flavor Y-Illness association was impaired by changes in the context. Rosas and Callejas-Aguilera, suggested that the ambiguity in the meaning of flavor X (during extinction) led rats to pay attention to the context, making the retrieval of the information about flavor Y context specific, regardless of whether the information about Y was first-learned and unambiguous (see also, Rosas & Callejas-Aguilera, 2006).

Although Rosas and Callejas-Aguilera's findings (2007) are consistent with the attentional mechanism proposed by ATCP, a closer look at the design suggests an alternative explanation. It is important to note that throughout the experiment rats received free access to distilled water in context B, and because rats were maintained in a liquid deprivation schedule it is likely that this treatment produced a direct context B-water excitatory association (e. g., Archer, Sjöden & Nilsson, 1985; Loy, Álvarez, Rey & López, 1993; Nakajima, Kobayashi & Imada, 1995). Thus, the higher consumption of flavor Y in group EB during the test could be explained by assuming contextual control of context B, because this context was associated with an appetitive outcome and not because the ambiguity in the meaning of the flavor activates an attentional mechanism to the context.

Therefore, the main goal of the present experiment was to test whether Rosas and Callejas-Aguilera´s results (2007) could be replicated when controlling consumption of distilled water in context B is controlled, and a direct context B-water association is prevented. The design of the experiment is presented in Table 1. Four groups of rats received conditioning and extinction of flavor X in context A. Then, all rats received conditioning of flavor Y in context A. Later consumption of Y was tested. Half of the groups received the test in context A; whereas for the other half of rats, the test was conducted in a second but equally familiar context B. Throughout the experiment rats received an equal exposure to both contexts A and B. In order to test whether the context-switch effects could be due to direct Context—Outcome associations, half of the groups were allowed to drink distilled water in context B (i. e., Aw and Bw), while the other groups (i. e., Aw- and Bw-) were merely exposed to context B without any other event.

Table 1
Experimental Design

Group	Conditioning X	Extinction X	Conditioning Y	Test Y
Aw	A: 1X+ B: 1W	A: 3X- B: 3W	A: 1Y+ B: 1W	A: 3Y- B: 3W
Aw-	A: 1X+ B:	A: 3X- B:	A: 1Y+ B:	A: 3Y- B:
Bw	A: 1X+ B: 1W	A: 3X- B: 3W	A: 1Y+ B: 1W	A: 3W B: 3Y-
Bw-	A: 1X+ B:	A: 3X- B:	A: 1Y+ B:	A: B:

Note: A & B, were two different contexts, counterbalanced. X and Y were 15% sucrose and 0.5 salt solutions counterbalanced. W stands for distilled water. “+” was LiCl injection (0.3 molar, 0.5 % body weight). “-“ stands for no injection.

Method

Subjects

Thirty-two male Wistar rats (8 per group) weighing in average 317.3 g were used. One rat from group Aw- was excluded because aversion to X was never extinguished. The rats were about three months old and experimentally naïve at the beginning of the experiment. They were individually housed in standard Plexiglas cages inside a room maintained on a 12-12 hr light dark cycle. Rats were maintained with ad libitum access to food, but they were water deprived 24 hrs before the beginning of the experiment. Throughout the experiment rats were kept on a water-deprivation schedule that included two daily 15-min sessions of free access to fluids. The first session took place at 9am and the second session began at 7pm.

Apparatus

Eight Plexiglas cages measuring 22 x 20 x 43 cm were combined with the daily sessions (morning or evening) to be used as experimental context (A or B). The walls of four cages were covered with dark green sheets of paper and the floor was covered by recycled eggs cartons adapted to the floor of each cage; a cotton wool scented with 10 ml of white vinegar (Clemente Jaques, Sabormex S.A. de C.V., México) was placed under the each egg carton. The walls of the four remaining cages were covered with white paper with red squares of 7 mm in width, the floor of each cage was covered by perforated chipboard adapted to it, and a cotton wool scented with 10 ml of anise (McCormick & Company Inc., Maryland) was placed under the perforated chipboard. It is important to note that these contextual cues were counterbalanced between subjects. For half of the rats in each group, context A was made of by cages with green paper sheets on the morning sessions and cages with red squares in the evening were context B, while the opposite was true for the other half.

Two flavors (a solution of 15% sucrose and a solution of 0.5% salt, both diluted in distilled water) were counterbalanced as CSs X and Y. The US was a single intra-peritoneal injection of LiCl, at 0.3M, 0.5% of bodyweight. Fluids were administered in 50-ml bottles with a standard spout.

Procedure

Days 1-3. Rats received distilled water in the two daily sessions in their home cage. On Day 3, rats were assigned to four groups Aw, Bw, Aw- and Bw- matched on their water consumption during the 3 previous days.

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

Day 6 (Conditioning of X). All the rats received free access to flavor X in Context A. For all groups, consumption of X was followed by an injection of LiCl; rats were left in context A for 15 min, then they were taken to their home cages. During the other session on this day rats received a different treatment in context B. Groups Aw and Bw received 15 min of free access to distilled water in context B, while rats in groups Aw- and Bw- were only exposed to context B with no bottles during 15 min; then they were moved to their home cages, where given 15 min of free access to distilled water.

Day 7. All subjects received distilled water in their home cages.

Days 8-10 (Extinction of X). All groups were exposed to flavor X in context A without injection. Groups Aw and Bw received free access to distilled water in context B, while rats in groups Aw- and Bw- were exposed to context B without bottles.

Day 11 (Conditioning of Y). Rats in both groups had free access to flavor Y, and then each rat was given an injection of LiCl in context A. In alternate daily session in context B rats received the usual treatment according to the group they were assigned.

Day 12. Subjects received distilled water in their home cages.

Days 13-15 (Test of Y). All the rats received free access to flavor Y. Half of the rats in each group were exposure to flavor Y in context A, whereas the other half received access to flavor Y in context B.

Statistical analyses

Liquid consumption was recorded to the nearest milliliter throughout the experiment. Consumption was compared using analyses of variance (ANOVA). The rejection criterion was set at $p<0.05$.

Results

Conditioning and Extinction of X. The left panel of Figure 1 shows the mean consumption of flavor X during the conditioning trial, and the right panel of Figure 1 shows the mean consumption of flavor X during the 3 trials of extinction in Groups Aw, Aw-, Bw and Bw-.

Consumption was high in the conditioning day for all the groups. During the extinction trials, all groups showed lower consumption in trial 1, consumption increased as extinction progressed. A one-way ANOVA of these data showed consumption of X between the groups did not differ significantly, $F(3, 27) = 0.06$, $Mse = 18.11$. A 4 (Group) x 3 (Trials) ANOVA conducted on the extinction data found significant main effect of Trials, $F(2, 54) = 77.80$, $Mse= 5.27$. Neither the main effect of Group nor the interaction Group x Trials were significant, largest $F(6, 54) = 1.21$, $Mse= 5.27$.

In summary, during conditioning and extinction of flavor X, groups showed a similar performance. The lower consumption of X during the first extinction trial relative to the last extinction session, indicated a strong aversion to X as a consequence of being paired with an LiCl injection.

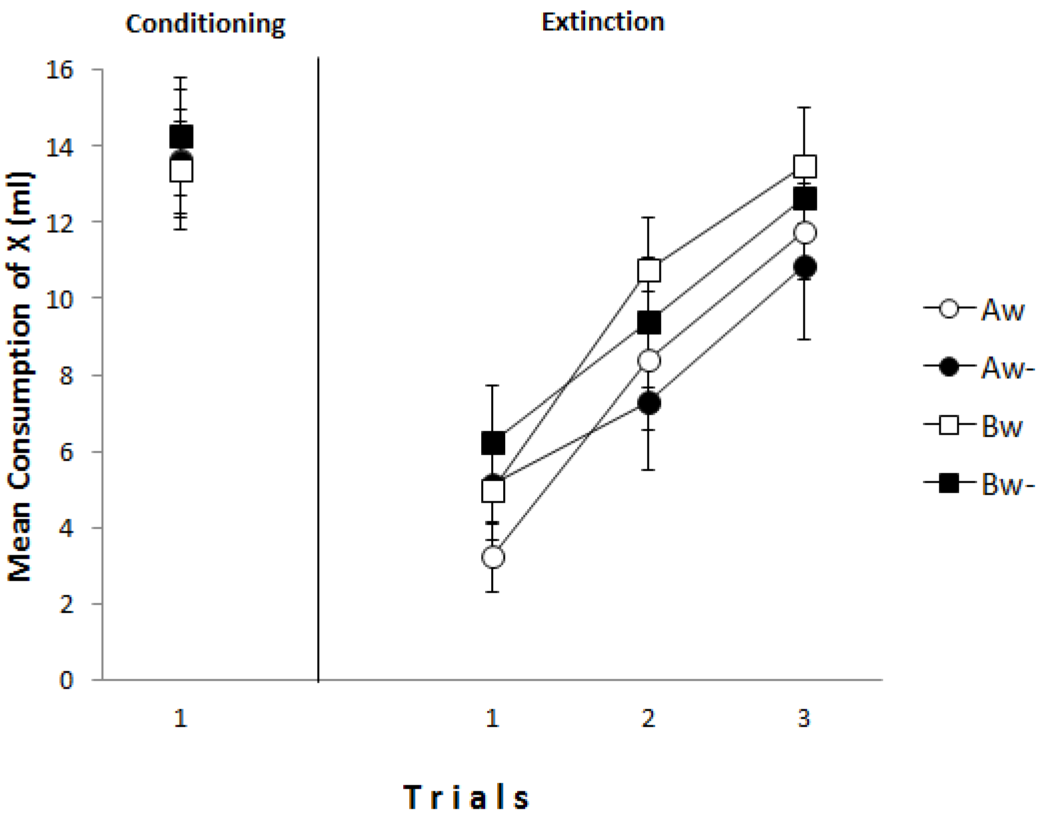

Figure 1. Mean consumption of flavor X in the conditioning day and in the 3 days of flavor exposure in context A for groups Aw, Bw, Aw- and Bw-. Error bars denote standard errors of the mean.

Conditioning and Test of Y. Left panel of Figure 2 shows the mean consumption of Y during the conditioning trial, while the right panel shows the mean consumption of flavor Y during the 3 test trials. A one-way ANOVA conducted on the data from the conditioning trial of Y found no significant between-group differences in the consumption of the flavor (3, 27) = 0.48, Mse = 8.81. A 4 (Group) x 3 (Trials) ANOVA conducted on the data from test trial found a significant main effect of Group F (3, 27) = 3.30, Mse= 22.74, also the main effect of Trials was significant, F (2, 54) = 58.50, Mse= 6.99. The interaction Group x Trials was not significant, F (6, 54) = 1.54, Mse= 6.99.

Planned comparisons found no significant differences on the consumption of flavor Y during the test for groups Bw and Bw-, the largest F (1, 27) = 0.28, Mse= 10.78. Finally, planned comparisons found that rats in groups Bw and Bw- consumed higher levels of Y than rats in groups Aw and Aw- in trial 1 and 2, smallest F (1, 27) = 4.26, Mse= 10.78, but not in trial 3, F (1, 27) = 1.33, Mse= 11.45.

In summary, when extinction of Y took place in context A after previous conditioning and extinction of flavor X, testing in context B impaired performance even when context B was associatively neutral.

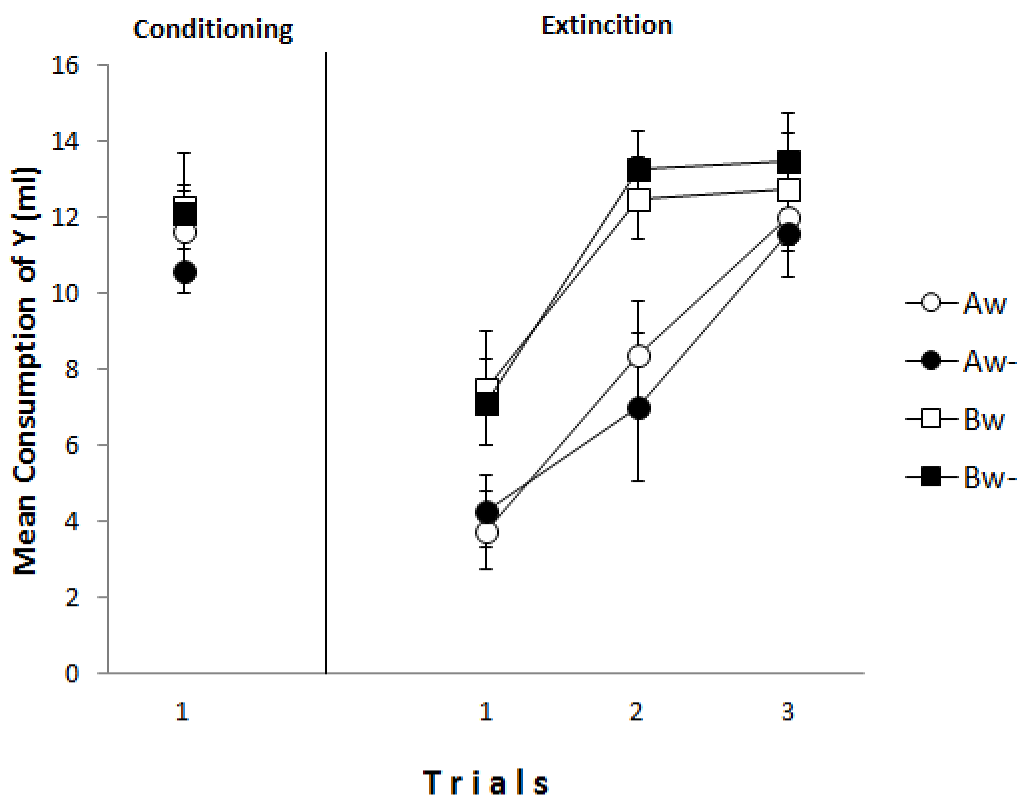

Figure 2. Mean consumption of flavor Y in the conditioning day and in the 3 days of testing for groups Aw, Bw, Aw- and Bw-. Error bars denote standard errors of the mean.

Discussion

The experiment reported here was designed to assess the role of ambiguity on context dependency in a taste aversion paradigm. More specifically, It assessed whether the context-switch effect reported by Rosas and Callejas-Aguilera (2007) could be found when controlling for an additional confounding effect, that of the excitatory associative strength of context B. During testing, group Bw drank more of Y than rats in group Aw, this results replicates the findings of Rosas and Callejas-Aguilera (2007). More interesting, a similar pattern of results was found when rats were merely exposed to context B during the alternative sessions (i. e., Groups Bw- and Aw-), thus preventing direct context B –water associations. Thus, the present results can't be explained by assuming that the mechanism through which the context exerted its control on behavior was a direct association with the outcome.

It is important to point out that the present data are inconsistent with Bouton's (1997) proposal that only the retrieval of ambiguous information should be sensitive to changes in the context. However, retrieval of information about flavor Y was context-dependent regardless the absence of ambiguity about Y. The overall pattern of our results could be explained by assuming the attentional mechanism proposed by ATCP. This theory assumed that extinction of X generates ambiguity that leads rats to pay attention to the context, the activation of the attentional mechanism produces that the recovery of information about Y becomes context specific.

The present data is consistent with several published data with both human and nonhuman subjects (e. g., Rosas et al., 2006, but see Nelson, Lombas & León, 2011). For example, Rosas and Callejas-Aguilera (2006) using a predictive learning task found that responding to a cue became context-dependent when it was learned within a context where another cue underwent extinction (see also, Callejas-Aguilera & Rosas, 2010). Recently, in a CTA preparation with rats, Bernal-Gamboa, Callejas-Aguilera, Nieto and Rosas (*Manuscript in revision*), replicated and extended the findings of Rosas and Callejas-Aguilera (2007) using changes in the temporal context.

Although the results mentioned above fit nicely to the ATCP, there are important aspects that need special attention. For example, ATCP suggest that the ambiguity on the meaning of the extinguished flavor X leads rats to pay attention to the context, making information about Y context dependent. However, neither the present experiment nor in other reports have a direct measure that demonstrates the involvement of attention in ambiguous situations.

In addition, there are two conditions that should be accomplished in order to test the general applicability of the role of ambiguity on context specificity. The first one is assessing the role of the attentional mechanism to the context using different preparations of pavlovian and instrumental conditioning. Most of the data consistent with ATCP has been found using predictive learning task with humans and CTA with rats (see Nelson et al., 2011, for inconsistent data using appetitive conditioning with rats).

The second aspect that needs more empirical work is to test whether the activation of the attentional mechanism could be found using other procedures that involves ambiguity of the meaning of a cue different to an extinction treatment (e. g., Rosas et al., 2006; but see Nelson & Callejas-Aguilera, 2007). In conclusion, although ATCP is still in development it seems to be a good start theory to the understanding of the mechanisms that underly the role of the contextual cues on recovery of the information by both humans and nonhumans animals.

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